Cogniţie, Creier, Comportament / Cognition, Brain, Behavior

ISSN: 1224-8398
Volume XI, No. 4 (December), 733-756

THE HUMAN ANIMAL: DEVELOPMENTAL CHANGES IN JUDGMENTS OF TAXONOMIC AND PSYCHOLOGICAL SIMILARITY AMONG HUMANS AND OTHER ANIMALS

John D. COLEY

Department of Psychology, Northeastern University, Boston, USA.

ABSTRACT

A triad oddity task was used to investigate developmental changes in perceived similarity among animals and humans. Four, five, seven, and eight year-old children and undergraduates were presented with triads consisting of a human, a non-human primate, and a non-primate animal, and asked about taxonomic similarity ("which two are the same kind of thing?") and psychological similarity ("which two think and feel the same way?"). At all age groups, humans were seen as taxonomically unique. Beliefs about psychological similarity underwent marked developmental change, from essentially random guessing to belief that humans were psychologically unique to beliefs that humans were psychologically similar to other primates. There was little evidence of differentiation between psychological and taxonomic similarity among children. Younger children's responses were apparently guided solely by the human-nonhuman dichotomy, whereas older children and undergraduates were also influenced by the category mammal. Results suggest interesting continuities and discontinuities in the development of folk biological thought, and between folk and scientific biology.

KEYWORDS: *similarity, folk biology, conceptual development.*

One important challenge in the development of any conceptual domain is establishing an ontology, or delineation of the basic entities that exist in that domain and the important relations that hold among those entities (Wellman & Gelman, 1992). In the domain of biology the ontology is particularly richly structured (e.g, Berlin, 1992); with development, understanding of relations among

[*] Corresponding author:
E-mail: j.coley@neu.edu

biological kinds becomes increasingly complex and multifaceted. For example, children become increasingly aware of plants' status as living things (Richards & Siegler, 1986), of taxonomic groupings of plants and animals at different levels of hierarchy (Carey, 1985; Coley, Hayes, Lawson, & Moloney, 2004; Coley, Solomon, & Shafto, 2002; Ross, Medin, Coley, & Atran, 2003), and of ecological and causal relations among species that are potentially orthogonal to taxonomic relations (Coley, Vitkin, Seaton, & Yopchick, 2005).

Another important development involves the way in which human beings are incorporated into the folk taxonomy of living things. Clearly, humans are unique among species in many ways; as such, are humans ever incorporated into the broader folk taxonomy? Are humans seen as similar to other species in some ways, and unique in other ways? How do these beliefs change over the course of development? In this paper I examine these questions by focusing on developmental changes in perceived similarity between humans and other animals. I also focus on two related questions: to what degree does the perceived similarity of humans to other animals depend on the nature of similarity being considered, and to what degree is perceived similarity modulated by sensitivity to intermediate-level animal categories?

Humans' place in folk biological taxonomy

According to geneticists, humans are African great apes. Our closest living relatives are chimpanzees and bonobos, with whom we share a common ancestor that lived c. 5-8 million years ago. Indeed, we are more closely related to chimpanzees and bonobos than either of those are to the gorilla, our next closest primate relative. However, folk biological taxonomies—particularly those found in industrialized western societies—tend to see humans as essentially separate from other species. Indeed, on some accounts, learning that humans are biologically "one animal among many" is a major developmental milestone in the acquisition of biological understanding.

For example, according to the "conceptual change" view first outlined by Susan Carey in her seminal 1985 book (see also Carey, 1995; Carey & Spelke, 1996; Johnson & Carey, 1998) children's understanding of animals is initially embedded in the core domain of intuitive psychology wherein behavior and intention rather than biological process are the central components. On this view, because behavior and intention are central and because people are the prototypical intentional behaving beings, children view humans as paragons of the animal world, and consequently children's understanding of and reasoning about other animals is largely anthropocentric, or framed in reference to, or by analogy to, human beings. Humans are used as the biological standard of comparison not because they are the most accessible animals, but because "these [biological processes] are fundamentally activities of people rather than of all animals." (Carey, 1985, p. 113). Put another way, "…animals for children of this age are fundamentally deficient variants of the prototypical behaving beings, people."

(Carey & Spelke, 1996, p. 525). This view suggests that young children possess an understanding of biological phenomena incommensurate with that of adults, and that pervasive conceptual change is necessary for children to acquire the adult model in which humans are seen as biologically one animal among many. This conceptual change takes place between the ages of 4 and 10, and involves (among other things) differentiating the biological and psychological construal of animals, and coming to see humans as biologically just another animal despite their unique behavioral and psychological repertoire.

One source of support for this view is the results of a property projection task where children were taught a new fact about a given biological kind (e.g., a dog "has an omentum") and asked whether other kinds (a bird, a fish, a plant) share that property (Carey, 1985). Results suggest that humans function as a prototypical yet distinct animal for young children, and are therefore consistent with the view that prior to age 10, children's conceptions of the natural world are indeed anthropocentric. First, on average projections from *human* were stronger than projections from other living things. Second, specific asymmetries in projection emerged, such that (for example) inferences from *human* to *dog* were stronger than from *dog* to *human*. Finally, children's reasoning followed striking violations of similarity, such that (for example) inferences from *human* to *bug* were stronger than from *bee* to *bug*. These patterns suggest that *human* is a privileged inferential base for the children Carey studied. “The prototypicality of people plays a much larger role in determining… projection of having a spleen than does similarity among animals” (p. 128). Although differing in their theoretical interpretation, Inagaki and Hatano (2002) also present evidence that children reason about nonhuman living things by analogy to humans. Together, these results suggest that for young children, in contrast to older children and adults, the category *human* is a privileged analogical base for the projection of biological properties, which is consistent with the conceptual change view.

However, some recent results challenge the universality of this characterization. Rather than being diagnostic of deep conceptual commitments, anthropocentrism may instead reflect a lack of knowledge about the biological world. Indeed, some evidence suggests that children who are more familiar with certain living kinds prefer to use knowledge of those kinds in reasoning. Specifically, Inagaki (1990) shows that children who raised goldfish tended to reason about a novel aquatic animal (a frog) by analogy to the goldfish, whereas children who did not raise a goldfish reasoned about the frog via analogy to humans. Likewise, Ross et al. (2003) show that anthropocentric reasoning, although pervasive and developmentally tenacious among urban majority culture children, was greatly mitigated among rural majority culture children and virtually absent among rural Native American children. Thus, it appears that early folk biology is neither universally nor inevitably anthropocentric.

In sum, the conceptual change view suggests that understanding of living things undergoes a developmental shift from a psycho-behavioral to a biological framework between the ages of 4 and 10. Because behavior and intention are central to children's conceptions of people and animals prior to this shift, humans should be viewed as both prototypical and as utterly unique. Although more recent findings have challenged the universality of this view, few studies have directly examined developmental changes in perceived similarity among humans and other animals. The predictions of the conceptual change view are clear; development should entail an increasing tendency to see humans as biologically one animal among many.

In one study that did directly address this question, Johnson, Mervis, and Boster (1992) found that while adults and children agreed on similarity relations among mammals in general, they differed in that adults perceived humans to be much more similar to nonhuman mammals, and to primates in particular, than children did. Seven-year-olds, 10-year-olds and undergraduates were shown sets of three pictures of mammals and asked to point to the two in each set that are "most like the same kind of thing". In general, children and adults perceived the same similarity relations among animals, and these relations corresponded to scientific classification equivalently.

However, children and adults differed regarding perceived similarity among humans, non-human primates (gorilla, monkey, chimpanzee), and non-primate mammals (e.g. tiger, dog, elephant). Most notably, for triads containing a human, a non-human primate, and a non-primate mammal, adults were more likely than children to pair the human with a non-human primate, and isolate a non-primate mammal (mean 68% of trials for adults versus 21% of trials for children) whereas children were more likely to pair the non-human primate with the non-primate, and isolate the human. Also, for triads containing two non-human primates and a non-primate animal, adults were more likely than children to pair the two non-human primates and isolate the non-primate animal (mean 95% of trials for adults versus 67% of trials for children). Finally, for triads containing a human and two non-primates, adults were more likely than children to pair a human with one non-primate, and isolate the other non-primate (mean 18% for adults versus about 6% for children).

Whereas in general, children and adults agreed on the similarity relations among mammals, adults considered humans to be more like the other mammals than children did. Adults also perceived more similarities between humans and non-human primates, and among non-human primates, than children did, indicating the primary developmental difference was the "emergence of a new category of primates." The authors imply that children must learn where humans fit in the animal world before incorporating them; after acquiring *primate* as a "salient intermediate-level category," they can learn that humans are primates, and therefore one animal among many.

In sum, the developmental differences documented by Johnson et al. (1992) are consistent with the conceptual change view in that humans are increasingly seen as one animal among many. However, one problem with these studies is that it isn't clear what kind of similarity participants used as the basis for their judgments. Given the conceptual change proposal about children's lack of differentiation between biological and psychological construals of living things, it is conceivable that Johnson et al.'s (1992) participants over the age of ten based their responses on what they saw as *biological* similarity of species, whereas younger subjects based responses on some sort of *psychological* similarity among the animals. In other words, the wording of the question "which of these is most like the same kind of thing" was not clear enough to allow the basis of subjects' judgments to be pinpointed, and moreover, there is reason to expect systematic differences therein.

Different kinds of similarity

As discussed above, the conceptual change view argues children's early conceptions of animals are imbedded in a psychological rather than a biological conceptual framework. This position would predict that prior to age 10 children's taxonomic judgments of what animal species were most similar would be heavily influenced by the degree to which such species were deemed psychologically similar.

Again, more recent evidence has qualified this position. By kindergarten and perhaps earlier, children are able to selectively utilize taxonomic similarity among species to guide inferences about novel physiological properties, and ecological similarity to guide inferences about disease (Coley et al., 2005; Vitkin, Vasilyeva, Coley, Baker, & Ciampanelli, 2007). This suggests that from relatively early in development, children are sensitive to potentially orthogonal relations among living things. More to the point, Coley (1995) showed that well before the age of 10, children showed different patterns of attribution for biological versus psychological properties across living things. For children as young as age 6, taxonomic groups (e.g., *mammal*, *bird*) predicted attribution of biological properties (e.g, "has blood") whereas behavioral groups (*wild predator*, *domestic pet*) predicted attribution of psychological properties (e.g., "is smart"). Likewise, Gutheil, Vera, & Keil (1998) showed that for preschoolers, attribution patterns for properties like "eats," "has a heart," and "thinks" differed markedly when the properties were presented in a biological versus a psychological context. Together, these patterns suggest a principled distinction between the psychological and biological construal of animals may be in place much earlier than predicted by the conceptual change account.

Although patterns of property attribution suggest that children may be capable of non-psychological construal of animals from relatively early in development, researchers to date have not directly compared different kinds of similarity judgments. If the conceptual change position is correct and folk biology and folk psychology coincide for young children, then judgments of folk biological taxonomic similarity among animals should show the same patterns as judgments of psychological similarity among animals. Alternatively, if children's taxonomic construal of biological ontology is not solely based on psychological properties, then judgments of taxonomic similarity might differ from judgments of psychological similarity. Distinct conceptual frameworks in these domains could support distinct biological and psychological similarity metrics for animals.

Emergence of intermediate-level animal categories

Johnson et al. (1992) argue that the integration of humans into the biological domain as "one animal among many" requires the emergence of an intermediate-level *primate* category. This highlights another important aspect of emerging folk biological ontology, which is the degree to which animals are subdivided into salient intermediate kinds. Both basic-level kinds (*dog, tree*) and higher-order global categories (*animal, plant*) emerge early in development (Booth & Waxman, 2003; Mandler & Bauer, 1988; Mandler & McDonough, 2000; Waxman, 1990). However, there are also salient intermediate-level biological categories (e.g., *mammal, bird, reptile, fish, bug*) that contribute to the rich taxonomic structure of the biological domain (e.g., Berlin, 1992). The emergence and use of these categories is an important milestone in the development of folk biological reasoning.

Ross et al. (2003) document developmental changes in the degree to which children's projection of novel properties among living things are sensitive to intermediate-level biological categories. They taught children novel properties (involving a hypothetical internal substance) said to be true of humans, wolves, bees, and plants (goldenrod), and asked whether the property was likely to also be true of a range of higher animals (mammals, birds, reptiles), lower animals (fish, invertebrates), plants, and inanimate objects. In general, results showed that these intermediate categories increasingly guided inferences as children got older. For example, for urban 6-year-olds, projections from *wolf* were equally high to other higher animals, lower animals, and plants, albeit higher to these groups than to inanimate objects, whereas for urban 8- and 10-year-olds, projections from wolf were strongest to higher animals, and then showed reliable decreases in strength to lower animals, plants, and inanimate objects, respectively. This suggests that the global category "living thing" was guiding 6-year-olds' inferences, whereas a more differentiated sense of phylogenic distance among living things was guiding inferences for older children. Likewise, Inagaki and Sugiyama (1988) show an increase in categorical attribution of human characteristics to other living things.

Thus, it appears that intermediate-level biological categories emerge between the ages of 6 and 8 among urban children (Ross et al., 2003 find that these distinctions are in place by age 6 among rural children.) Of present interest is the degree to which such intermediate distinctions may impact judgments of similarity of humans to non-human species. It has been well-documented that similarity judgments are context sensitive (see, for example, Tversky 1977, Medin, Goldstone, & Gentner, 1993). Of interest is whether children's judgments of taxonomic and psychological similarity among humans and animals are likewise sensitive to context, and in particular the degree to which such judgments are influenced by intermediate categories (in particular, *mammal* versus *non-mammal*).

If human/non-human is an absolutely ontological distinction, then humans should never be seen as similar to non-humans, regardless of the disparity between non-human species on a given trial. In contrast, if an intermediate-level concept like *mammal* that includes both humans and non-humans is informing similarity judgments, then a non-human mammal might be deemed more similar to a human than to a taxonomically distant creature, like an insect.

Specific Research Questions

The present experiment focused on the degree to which humans are seen to be taxonomically and psychologically unique, the degree to which such judgments are influenced by intermediate animal categories, and developmental changes in these processes. The experiment addresses these questions by comparing responses of preschoolers, elementary-school students, and adults on tasks requiring them to match two out of three animals on the basis of psychological and taxonomic similarity. The experiment uses the basic paradigm of Johnson et al. (1992), but focuses on the human/nonhuman primate/non-primate animal triads where they found clear developmental changes.

Previous work makes clear predictions about development changes in taxonomic similarity. The conceptual change view as developed by Carey and others (e.g., Carey, 1985; Carey & Spelke, 1996) as well as the empirical results of Johnson et al. (1992) suggest that younger children should see humans as taxonomically distinct from other animals (i.e., not at all the “same kind of thing”), whereas older children and adults should see humans as taxonomically one animal among many.

The investigation of psychological similarity is novel, and so it remains an open question how children (and adults) will construe psychological similarity among humans and other animals. However, Carey’s position makes the relatively clear prediction that among younger children responses to questions about taxonomic and psychological similarity should not differ. If children’s early ontology of living things is essentially psychological in nature, then asking children about taxonomic and psychological similarity should be tantamount to asking the same question twice. In contrast, consistently different responses on the two tasks would suggest the existence of a biological ontology that is not strictly psychological in nature.

With respect to the degree to which intermediate animal categories may impact similarity judgments, it’s important to note that Johnson et al. (1992) used only typical mammals. Therefore a strict interpretation of their results is that children tend to view *non-human mammals* as more similar to each other than to humans; what remains to be seen is whether children view *all animals* as more similar to each other than to humans. By employing a larger range of non-primate animals—including non-mammals like *centipede* as well as mammals like *jackal*—the current experiment presents a more rigorous test of the claim that young children see humans as different from all other animals, or whether their judgments are influenced by intermediate-level categories like *mammal*. If the human/non-human distinction is the major influence on perceived similarity, children should consistently isolate the human, and group together even taxonomically disparate nonhuman species (e.g., gorillas and centipedes). This would provide stronger evidence that children see humans as unique among animals. Alternatively, if *mammal* has emerged as a salient intermediate-level category, participants might judge humans and primates more similar when contrasted with a non-mammal (e.g., bird) than when contrasted with a third mammal. In other words, if humans and primates are judged more similar than either is to *bird*, this suggests the emergence of a mammal category thought to includes both humans and primates.

METHOD

Participants

A total of 90 participants were involved in this study. These fell into five age groups: 16 preschoolers (ages 3.95 to 5.07 years, mean age 4.49 years), 13 kindergartners (5.65 to 6.48, *M*=5.90), 26 2nd graders (7.49 to 8.46, *M*=7.96), 19 3rd-graders (8.50 to 9.71, *M*=8.90), and 16 undergraduate students (18.54 to 22.56, *M*=20.15). Participants were recruited from a university-run preschool, a parochial elementary school, and undergraduate psychology classes at two Midwestern universities in the USA.

Materials

Materials consisted of 24 pictures of animals and humans, each roughly 5.1 x 7.6 cm, mounted onto 10.2 x 15.2 cm index cards and laminated. The stimulus set consisted of eight pictures of humans, eight pictures of nonhuman primates, and eight pictures of non-primate animals. Hereafter for clarity (albeit not strict biological accuracy) these pictures will be referred to as “human”, “primate”, and “animal”, respectively. The humans were all shown from the head or shoulders up, and varied in apparent race, gender, and age. The primates were all monkeys or apes, and the non-primate animals represented various phylogenic classes from mammals through invertebrates. Specifically the non-primate animals included four mammals (*jackal, chinchilla, orca, bat*) and four non-mammals, including a bird (*sparrow*), a reptile (*collared lizard*) and two invertebrates (*bee, centipede*). Two sets of two training triads each were also used: boy/girl/shirt, lion/tiger/sunflower, and sow/piglet/lamp, polar bear/black bear/trout.

Design

The experiment consisted of a taxonomic similarity task and a psychological similarity task, presented in counterbalanced order. Pictures were presented as triads; each triad included one animal, one human, and one primate. The specific primate or human picture that accompanied each animal picture was determined randomly for each participant, as was the order of presentation. Triad order and composition were held constant across tasks for each participant.

Procedure

All subjects were tested individually. Children were tested during school hours, in a quiet room away from their classroom. Adults were tested by appointment. A training task immediately preceded each similarity task; each training task utilized one set of training triads, and pairing of training sets with tasks was counterbalanced.

Training for the taxonomic similarity task was carried out as follows. First, the subject was told, “OK, look at these pictures, and tell me which two are the same kind of thing.” They were shown the first training triad. Correct responses were encouraged with the words, “That’s right! These (indicating pigs or children) are both the same kind of thing and this (shirt or lamp) is a different kind of thing. Good job. Let’s try another one.” They were then shown the second triad, asked the same question, and responded to similarly. All subjects were correct on both taxonomic training trials. The taxonomic similarity task was presented immediately after the taxonomic training task. Subjects were shown each of the 8 triads, and asked for a judgment of taxonomic similarity (“Which two of these are the same kind of thing”). If reluctant, subjects were encouraged to make a choice.

In the training for the psychological similarity task, children were first encouraged to give separate examples of both thoughts and feelings. Then they were told, “I’m going to show you some pictures of some things, and I want you to tell me which two think and feel the same way.” They were then shown the first training triad. If they responded correctly, they were told. “That’s right, these two think and feel the same way, because they can both think about what they want to do tomorrow and this can’t, and they can both remember what they had for breakfast and this can’t, and they can both feel happy or sad and this can’t, right?” All but two subjects were correct on the first training trial. These subjects were shown the correct response and given the same justification for the response. Subjects were then shown the second triad, asked to make the same judgment, and given similar feedback. All subjects were correct on the second training trial. The psychological similarity task was presented immediately after the psychological training task. Each subject was shown the same 8 triads that were presented in the taxonomic similarity task, and asked for a judgment of psychological similarity (“Which two of these think and feel the same way”). Again, if reluctant, subjects were encouraged to make a choice.

RESULTS

Scoring

On each trial, subjects chose which 2 of the 3 pictures went together, yielding three possible responses: participants could group the human and primate as most similar, isolating the animal (an HP response) or group the primate and animal together, isolating the human (a PA response) or finally, they could group the animal and human together and isolate the primate (an AH response). Each subject was given a score reflecting the relative frequency of each response for both the psychological similarity trials and for the taxonomic similarity trials.

To assess individual response patterns, each participant was characterized as using a consistent response pattern if they made the same response on 6 or more out of their 8 responses (binominal p<.05 with probability 1/3). Thus, each subject was classified as consistently showing an HP, PA, or AH pattern, or showing no consistent pattern on each task. Frequencies of each pattern are summarized in Table 1.

Table 1.
Frequency of consistent response patterns for each age group on the taxonomic and psychological similarity tasks.

	Taxonomic Similarity	Psychological Similarity
4-year-olds (N=16)		
Primate + Animal	15 (94%)	6 (38%)
Human + Primate	1 (6%)	2 (13%)
Human + Animal	0	2 (13%)
Inconsistent	0	6 (38%)
5-year-olds (N=13)		
Primate + Animal	10 (77%)	7 (54%)
Human + Primate	0	0
Human + Animal	0	1 (8%)
Inconsistent	3 (23%)	5 (38%)
7-year-olds (N=26)		
Primate + Animal	18 (69%)	15 (58%)
Human + Primate	3 (12%)	1 (4%)
Human + Animal	0	0
Inconsistent	5 (19%)	10 (38%)
8-year-olds (N=19)		
Primate + Animal	8 (42%)	7 (37%)
Human + Primate	3 (16%)	6 (32%)
Human + Animal	0	0
Inconsistent	8 (42%)	6 (32%)
Undergraduates (N=16)		
Primate + Animal	10 (63%)	3 (19%)
Human + Primate	3 (19%)	10 (63%)
Human + Animal	0	0
Inconsistent	3 (19%)	3 (19%)

Taxonomic Similarity

By far the most common response choice on the taxonomic task (76% of responses across age groups) was to group the primate and animal together as the "same kind of thing," and isolate the human (see Figure 1). To examine whether responses differed from chance, one-way t-tests were conducted comparing each cell to a hypothesized mean of .333. Results confirmed that all age groups chose PA responses at above-chance levels, and AH responses at below-chance levels ($p<.005$). Four, 5- and 7-year-olds chose HP responses at below-chance levels ($p<.005$ for 4- and 5-year-olds, $p<.05$ for 7-year-olds), whereas HP response rates for 8-year-olds and undergraduates did not differ from chance.

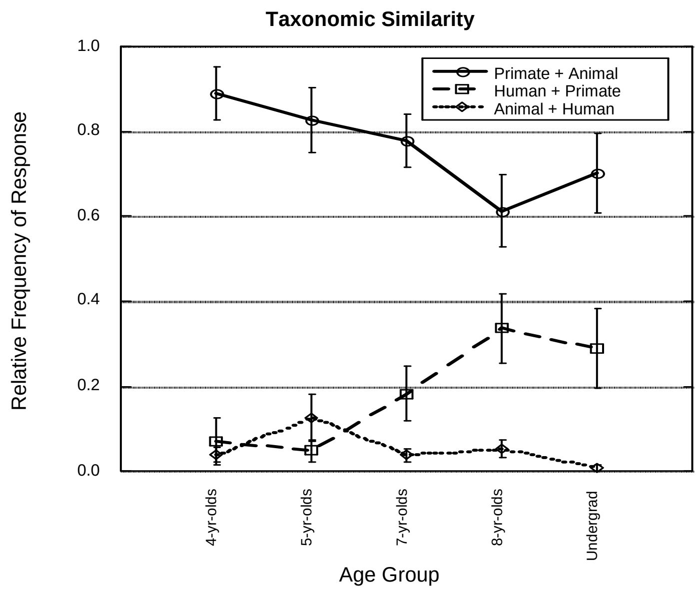

Figure 1.
Mean relative frequency of PA, HP and AH responses for each age group on the taxonomic similarity task.

One-way ANOVAs comparing the frequency of each response across age groups confirmed an age-related increase in HP responses ($F_{(4,85)}=2.92$, $MS_E=.090$, $p=.026$; 4- and 5-year-olds chose HP responses less frequently than 8-year-olds and Undergraduates, Fisher PLSD $p<.05$). They also confirmed an age-related decrease in AH responses ($F_{(4,85)}=2.67$, $MS_E=.010$, $p=.038$; although such responses were quite rare, they were chosen more often by 5-year-olds than any other age group, Fisher PLSD $p<.05$). PA responses did not differ reliably by age.

These developmental differences were corroborated by correlation analysis using Fisher's r; across all subjects, frequency of HP responses increased with age, $r_{(90)}=.216$, $p=.041$. Importantly, the correlation was not an artifact of differences between adults and children; with adults removed, the magnitude of the correlation increased ($r_{(74)}$=.337, p=.003); moreover, with adults removed the frequency of PA responses was negatively correlated with age, $r_{(74)}$=-.289, p=.012.

Analysis of consistent response patterns for the taxonomic task likewise confirmed the preference for PA responses (see Table 1); one-way Chi Square analyses revealed that consistent PA responses were more frequent than expected given a null hypothesis of equal probability of each possible response pattern for each age group ($X^2_{(3)} \geq 9.84$, $p<.02$); a 5 (Age) x 4 (Pattern) Chi Square analysis revealed only a marginal age difference in consistent response patterns ($X^2_{(8, N=90)}$=14.13 p=.078). Examination of post-hoc cell contributions showed that this effect was largely driven by higher than expected frequency of PA patterns by 4-year-olds and inconsistent patterns by 8-year-olds, and lower than expected frequency of inconsistent patterns by 4-year-olds and PA patterns by 8-year-olds.

Psychological Similarity

The most common response for younger children on the psychological task was to group the primate and animal together as "thinking and feeling the same way," and isolate the human, but this shifted markedly with development (see Figure 2). To examine whether responses differed from chance, one-way t-tests were again conducted comparing each cell to a hypothesized mean of .333. Results suggest pronounced developmental changes on this task (all $p<.0001$ unless otherwise noted). For 4-year-olds, no response differed from chance. For 5-year-olds, PA responses were above chance (p=.015), HP responses were below chance (p=.007), and AH responses did not differ from chance. For the remaining groups, AH choices were all below chance. Additionally, for 7-year-olds PA responses were above chance, and HP (p=.022) responses were below chance. For 8 year olds, PA and HP responses did not differ from chance, whereas for adults, HP responses were above chance (p=.002) and PA responses were at chance.

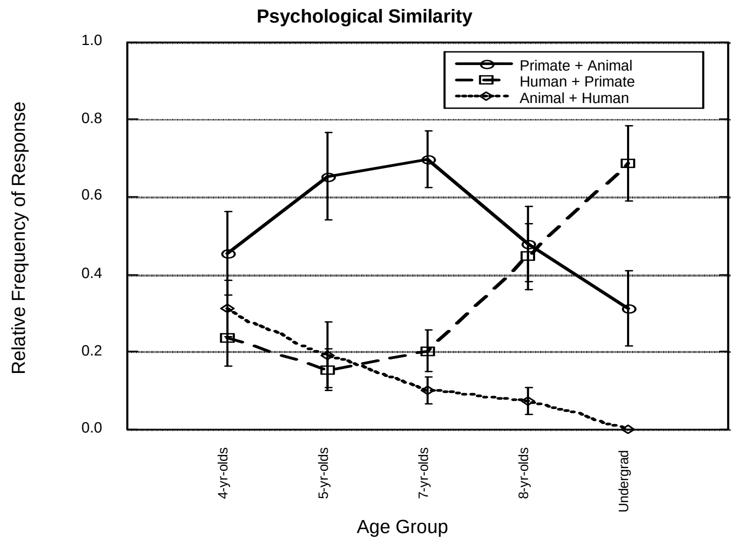

Figure 2.
Mean relative frequency of PA, HP and AH responses for each age group on the psychological similarity task.

One-way ANOVAs comparing the frequency of each response across age groups confirmed an age-related increase in HP responses ($F_{(4,85)}$=8.36, MS_E=.098, p<.0001; 4-, 5-, and 7-year-olds chose HP responses less frequently than 8-year-olds, who chose them less frequently than undergraduates, Fisher PLSD p<.05). They also confirmed an age-related decrease in AH responses ($F_{(4,85)}$=5.50, MS_E=.043, p<.001; such responses were chosen more often by 4-year-olds than by 7 or 8-year-olds or undergraduates (Fisher PLSD p<.002), and more often by 5-year-olds than by undergraduates, Fisher PLSD p<.02). Finally, they confirmed the curvilinear trend in PA responses seen in Figure 2 ($F_{(4,85)}$=2.80, MS_E=.163, p=.031; such responses were more common for 7-year-olds than for 4-year-olds, 8-year-olds or undergraduates, and more common for 5-year-olds than for undergraduates, Fisher PLSD p<.05).

These developmental differences were again corroborated by correlation analysis. Across all subjects, frequency of HP responses increased with age, $r_{(90)}$=.474, p<.0001, and frequency of AH and PA responses decreased with age, $r_{(90)}$=-.353, p<.001 and $r_{(90)}$=-.217, p=.039, respectively. With adults removed, the correlations for HP ($r_{(74)}$=.233, p=.046); and AH responses ($r_{(74)}$=-.363, p=.001) persisted.

Analysis of consistent response patterns for the psychological task reinforced the marked age differences reported above (see Table 1); one-way Chi Square analyses revealed that the observed pattern distribution for 4-year-olds did not differ from expectations generated from a null hypothesis of equal probability of each possible response pattern ($X^2_{(3,\ N=16)}$=4.00, *p*=.261). For 5- and 7-year-olds, consistent PA and inconsistent patterns were relatively frequent, and consistent AP and AH patterns were rare ($X^2_{(3)}$≥10.08, *p*<.02). For 8-year-olds, HP, PA and inconsistent patterns were equally frequent and no AH patterns were observed; this was marginally different from the expected distribution, $X^2_{(3,\ N=19)}$=6.47, *p*=.091. Finally, undergraduates strongly favored a consistent HP pattern, $X^2_{(3,\ N=16)}$=13.50, *p*<.004. A 5 (Age) x 4 (Pattern) Chi Square analysis confirmed these age effects ($X^2_{(12,N=90)}$=33.38, *p*<.001). Examination of post-hoc cell contributions showed that this effect was largely driven by higher than expected frequency of AH patterns by 4-year-olds and HP patterns by undergraduates, and lower than expected frequency of HP patterns by 5- and 7-year-olds, and of PA patterns by undergraduates.

Differentiation of Taxonomic and Psychological Similarity

The degree to which participants at different ages responded differently to the taxonomic and psychological tasks showed a striking curvilinear pattern; differentiation was strongest among youngest and oldest participants. To further examine these patterns, 2 (Task) x 5 (Age) mixed ANOVAs were conducted on the frequency of each type of response. These revealed Task x Age interactions for PA ($F_{(4,85)}$=2.78, MS_E=.085, *p*=.032), HP ($F_{(4,85)}$=3.17, MS_E=.059, *p*=.018) and AH ($F_{(4,85)}$=4.43, MS_E=.023, *p*=.003) responses. T-tests were used to compare response profiles on the taxonomic and psychological tasks for each age group; Figure 3 depicts difference scores computed by subtracting the relative frequencies of each type of response on the psychological task from the relative frequency of the same response on the taxonomic task.

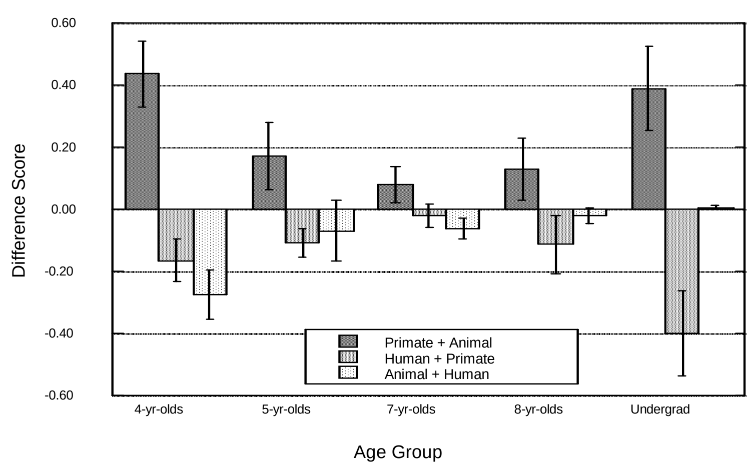

Figure 3. Mean difference between relative frequency of PA, HP and AH responses on the taxonomic task and on the psychological task for each age group. Positive scores represent

higher relative frequency on the taxonomic task; negative scores represent higher relative frequency on the psychological task.

Four-year-olds showed clearly differentiated responses to the two tasks. As reported above, this age group showed a strong preference for PA responses on the taxonomic task, and no modal response on the psychological task. Accordingly, t-tests revealed that PA responses were more frequent on the taxonomic task than on the psychological task ($t_{(15)}$=4.18, p<.001), and that HP and AH responses were more frequent on the psychological task than the taxonomic task ($t_{(15)}$=2.37, p=.032 and $t_{(15)}$=3.45, p=.004, respectively).

Older children showed markedly less differentiation. For 5-year-olds, HP responses were more common for the psychological task than for the taxonomic task ($t_{(12)}$=2.27, p=.042), but there were no task differences for PA or AH responses. For 7- and 8-year-olds, t-tests revealed no task differences on any measure.

Undergraduates, like 4-year-olds, showed clearly differentiated responses to the two tasks. For them, PA responses were more frequent on the taxonomic task than on the psychological task ($t_{(15)}$=2.86, p=.012), HP responses were more frequent on the psychological task than the taxonomic task ($t_{(15)}$=2.91, p=.011) and AH responses did not differ for the two tasks.

Emergence of Intermediate Categories

To examine the emergence of intermediate-level animal categories, scores were divided based on whether the animal in the triad was a mammal (*jackal, chinchilla, orca, and bat* items) or a non-mammal (*sparrow, lizard, bee,* and *centipede* items). These scores are presented in Figure 4. As described above, we hypothesized that human-primate-mammal triads might emphasize similarities between primates and other non-human mammals, whereas human-primate-non-mammal trials might emphasize similarities between humans and primates. If so, participants utilizing the intermediate category *mammal* should be more willing to group a primate with a human when the third animal is a non-mammal than when it is a mammal. Thus, HP responses should be more frequent for non-mammal items than for mammal items. This difference was reliable for adults ($t_{(15)}$=2.91, p=.011) and 8-year-olds ($t_{(18)}$=3.88, p=.001), but not for younger children.

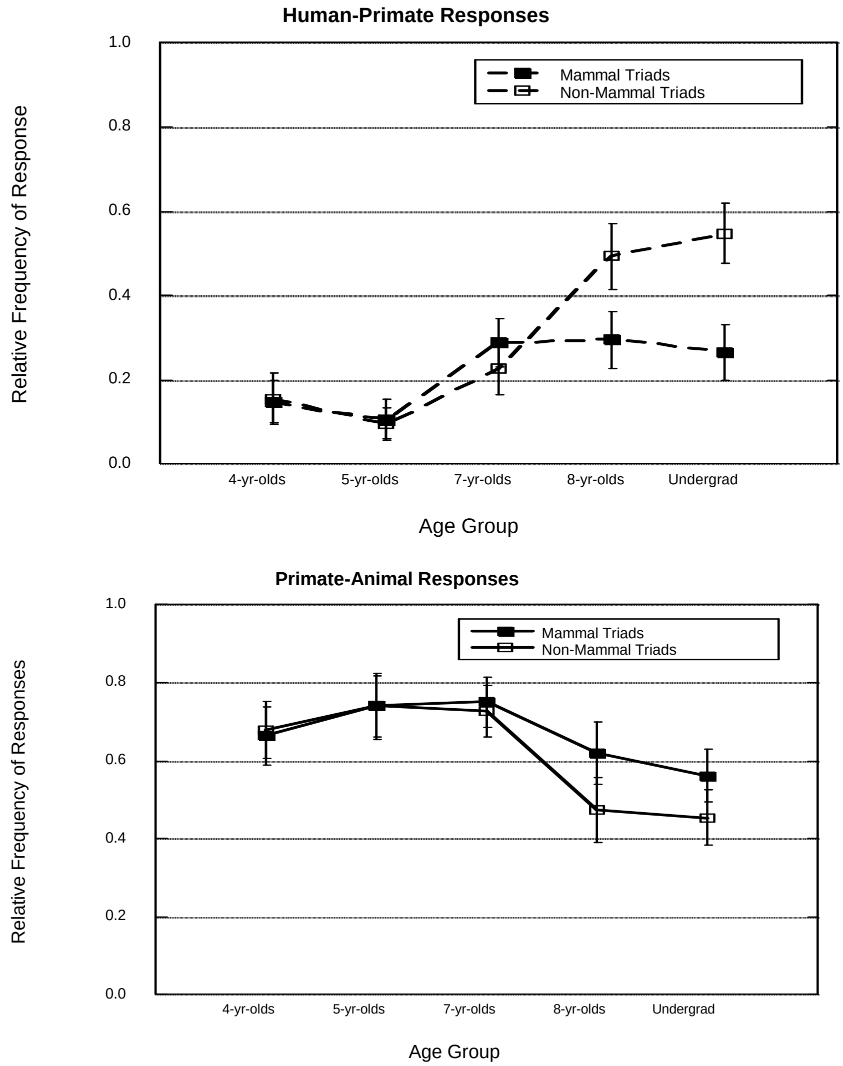

Figure 4.
Mean relative frequency of HP and PA responses for each age group on the mammal versus non-mammal triads.

Likewise, participants who are sensitive to phylogenic structure should be more willing to group a primate with another mammal than with a non-mammal. Thus, PA responses should be more frequent for mammal items than for non-mammal items. This difference was again reliable for adults ($t_{(15)}$=2.67, p=.017) and 8-year-olds ($t_{(18)}$=2.55, p=.020), but not for younger children.

DISCUSSION

These results show that between the ages of 4 and 20, humans are consistently seen as taxonomically unique, although the minority of participants who view humans as taxonomically one animal among many increases with development. During the same time period, confusion about psychological similarity among humans and other animals gives way to beliefs about human psychological uniqueness, which in turn give way to perceived psychological affinity between humans and other primates. Together, these two trajectories define a non-linear pattern of differentiation between perceived taxonomic and psychological similarity among humans and other animals. Finally, results document that humans may be integrated into biological ontology via the emergence of an intermediate-level *mammal* category around age 8.

Developmental Changes in Perceptions of Taxonomic Similarity

Responses to the taxonomic similarity task showed remarkable consistency across development. For all age groups, the preferred answer to "which two of these are the same kind of thing" was the animal and the primate. This clearly indicates that all participants—preschool through undergraduate—saw humans as taxonomically unique. Despite the near-unanimity of preference for this response, there was also a marked increase in the frequency of responses that grouped humans and primates together as the "same kind of thing," reflecting an increasing belief that humans are taxonomically one animal among many. These responses were more prevalent among 8-year-olds and undergraduates than among younger children. Interestingly, this remained a minority response even among undergraduates, and there was essentially no change in responses between ages 8 and 20.

This finding is consistent with the conceptual change position articulated by Carey (1985) and others that development of folk biological thought involves an emerging understanding that humans are biologically one animal among many, in that the major developmental trend is an increase in the frequency of responses that group humans and primates together. However, these results also suggest that, if anything, the conceptual change position might overestimate the degree to which spontaneous conceptual change regarding humans' privileged status in folk biological taxonomy ever takes place. Despite having received over a decade of additional science education, undergraduates were no more likely than 8-year-olds to judge humans as one animal among many. Indeed, these results suggest that the largest discontinuities in the nature of biological ontology might exist between adult lay people and adult scientists formally trained in modern genetics and evolutionary theory, rather than between adult lay people and children. In other words, changes in the position of humans relative to other animals may emerge not as a result of conceptual development per se, or even as a result of typical science education, but rather as a result of specialized training in evolutionary biology (cf Atran, 1998). As such, further explorations of linkages between formal science education in biology and beliefs about taxonomic similarity among humans and other species may be of particular interest. Another interesting avenue for further exploration is the potential impact of different cultural belief systems on folk biological ontology. Beliefs that emphasize humans' continuity (e.g., Ross et al., 2003) or discontinuity (e.g., Evans, 2001) with the biological world might lead to very different ideas about the rightful place of humans in (or outside of) the animal kingdom.

Developmental Changes in Perceptions of Psychological Similarity

In contrast to the continuity observed in beliefs about taxonomic similarity, responses to the psychological similarity task showed at least two different marked developmental changes between the ages of 4 and 20. Preschoolers' responses to the psychological task were essentially random; no response differed in frequency from chance, and though some individuals did show consistent response patterns, inconsistency was modal. This suggests a lack of consensus among 4-year-olds on humans' psychological similarity to other animals. Between the ages of 5 and 7, we observed a sharp increase in the frequency of PA responses—and in the number of children showing consistent PA patterns—and corresponding decreases in HP and AH responses, suggesting that the human versus animal dichotomy so clearly evident in the taxonomic task was also influential on the psychological task at this age.

By age 8, however, we see the beginning of a second developmental shift. This involves a sharp drop in the tendency to isolate the human, and a sharp increase in the tendency to see humans and primates as psychologically similar. This pattern seems to represent a transition from the pervasive human-animal dichotomy driving the responses of 5- and 7-year-olds. Moreover, it is important to distinguish this pattern from the seemingly random responses of the 4-year-olds. For the preschoolers, no choice differed from chance, all three responses were equally frequent, and as many children consistently grouped the human with the animal (a somewhat inexplicable choice) as consistently grouped the human with the primate. In contrast, for the 8-year-olds, HP and PA responses were equally frequent, there were virtually no AH responses, and consistent HP and PA patterns occurred with roughly equal frequency. Clearly, the 8-year-olds were divided as a group (and indeed, some were divided as individuals) as to whether the primate shared stronger psychological affinity with the human or with the animal, but their responses were more selective and systematic than those of the 4-year-olds. Finally, undergraduates' responses indicated a consensus that psychologically, humans are just another primate.

In sum, responses to the psychological similarity task reveal a very interesting and non-linear developmental trajectory. Between ages 4 and 8, children seem to go from having no consistent beliefs about psychological relations among species to having very clear beliefs that humans are psychologically unique to being somewhat unsure whether humans are unique or like other primates. Undergraduates, in contrast, seem to agree for the most part that humans are psychologically similar to other primates. These results seem to run somewhat counter to expectations of the conceptual change position, which would presumably predict that, if animal concepts are framed psychologically early in development, then children should show a stable psychological ontology from early on, and that humans should maintain a unique position in that psychological ontology. It would be interesting to extend this study to age groups between 8 and 20, to complete the mapping of this developmental trajectory.

Differentiation of Taxonomic and Psychological Similarity

Results revealed a markedly curvilinear trajectory for differential responding to the two tasks. Preschoolers clearly responded differently to the taxonomic and psychological similarity tasks, although these differences are somewhat hard to interpret. On the taxonomic task, their responses clearly demonstrated a belief that primates and animals are the "same kind of thing," and that humans are different. In contrast, preschoolers' responses on the psychological task, although clearly different from their responses on the taxonomic task, revealed no consensual beliefs. On the whole, preschoolers' responses reflect a belief in the taxonomic uniqueness of humans coupled with a lack of consensus on humans' psychological status vis-à-vis nonhuman animals. What remains unclear, however, is whether this pattern of results represents a principled distinction between two distinct ways to think about relations between humans and animals, or whether it represents clear beliefs about taxonomic similarity coupled with agnosticism or lack of understanding about psychological similarity.

Such questions of interpretation are moot for children between the ages of 5 and 7 who showed little systematic differentiation of their responses on the taxonomic and psychological similarity tasks. On both tasks, 5- and 7-year-olds showed a strong preference for PA responses, indicating a consistent belief that humans are unique both taxonomically and psychologically.

Arguably, 8-year-olds' responses show the beginnings of differentiation. On both tasks, 8-year-olds show evidence of an increasing awareness of the similarities between humans and primates, and this trend seems especially pronounced for psychological similarity. Although direct statistical comparisons revealed no differences in the two conditions, PA responses were more frequent than HP responses on the taxonomic task, but not for the psychological task.

Adults showed the clearest evidence of beliefs that humans' taxonomic relations with other species differ from their psychological relations. For the taxonomic similarity task, adults favored PA responses, indicating a belief that non-human primates and non-primate animals were the "same kind of thing," and that humans are taxonomically unique. In contrast, for the psychological similarity task, adults favored HP responses, indicating a belief that humans and non-human primates "think and feel the same way," and that non-primate animals were psychologically different. This clearly shows that adults perceive different patterns of relations among animals depending on whether those relations tie into a (presumably biological) taxonomy of species or into a system of psychological abilities.

Overall, then, there is clear evidence that adults differentiated between psychological and taxonomic similarity on this task, little evidence for such a differentiation among children between the ages of 5 and 8, and equivocal evidence of differentiation among 4-year-olds. If we interpret the 4-year-olds' performance conservatively, taking their lack of consistent responding to the psychological task as evidence for lack of understanding and therefore lack of differentiation, then results depict a relative smooth and late-emerging differentiation of biological and psychological construals of living things. At first glance this seems consistent with the conceptual change prediction that prior to age 10, children's understanding of animals conflates biological and psychological principles. However, a closer look reveals some discrepancies. First, extrapolating from the conceptual change view, at least as outlined by Carey (1985, 1995), young children should have clearer views about humans' psychological uniqueness, in so far as knowledge of animals is initially embedded in a psychological framework. However, results of this study reveal clear beliefs about human taxonomic uniqueness but somewhat muddled beliefs about psychological similarity among preschoolers. Second, although the finding of increased differentiation with development is consistent with the conceptual change view, the nature of that differentiation is not. Specifically, the conceptual change view suggests that development should entail changes in perceived taxonomic similarity, and specifically the emergence of a sense that humans are taxonomically one animal among many, whereas the present results suggest that beliefs about humans' taxonomic uniqueness are persistent, and the major developmental shift is in beliefs about the psychic unity of primates. Indeed, it is particularly interesting that for undergraduates, this differentiation takes the form of believing that humans are taxonomically unique yet psychologically like other primates, when arguably, the conceptual change position—as well as scientific biology—would seem to suggest the opposite; humans are biologically just another primate, but psychologically unique.

Alternatively, if we interpret the 4-year-olds' performance more generously, focusing instead on the fact that responses were very different on the two tasks, then a number of very different issues are raised. First, the early differentiation is clearly counter to the predictions of the conceptual change account. Second, we then have the puzzling finding that the early differentiation disappears among older children and then reemerges among undergraduates. It's not immediately clear what mechanism might be responsible for such a trajectory, although certainly such developmental patterns—from disorganization to rigidity to flexibility—are common in many areas of development (e.g., Coley & Gelman, 1989).

At first blush, the apparent lack of obvious differentiation of biological and psychological similarity among children in the present study appears to contradict previous findings suggesting an early differentiation of biological and psycho-behavioral understanding of living things (e.g., Coley, 1995; Gutheil et al., 1998; Inagaki & Hatano, 1993). However, it is important to point out that the methodology employed in the present study specifically addressed questions about how humans fit into a folk taxonomy, whereas previous studies differed in their focus. For instance, as described above, Coley (1995) focused on the degree that membership in orthogonal biological and psychological categories differentially predicted beliefs about the distribution of biological and psychological attributes among non-human animals. Thus, the strong belief in human psychological and taxonomic uniqueness in evidence among children in this study does not rule out an early differential understanding of biological and psychological relations among non-human animals. Rather, it suggests that such an early understanding is somewhat fragile, fragmentary, and undergoes elaboration with development.

Emergence of Intermediate Animal Categories

The results clearly show evidence for the emergence of an intermediate category of *mammal* around age 8. Specifically, children aged 7 and younger showed no sensitivity whatsoever to phylogenic class; whether the animal member of the triad was a mammal or not had no impact on their responses. The only taxonomic distinction they honored was the human-nonhuman distinction. It is striking that younger children were more likely to judge a chimpanzee to be the same king of thing as a centipede than to be the same kind of thing as a human being.

In contrast, 8-year-olds' responses were clearly influenced by the phylogenic class of the animal member of the triad, and moreover, provide evidence that the category *mammal* was guiding responses. Specifically—like undergraduates and unlike younger children—8-year-olds were more likely to group a primate with a human when the alternative was a non-mammal than when it was a mammal. Likewise, 8-year-olds—like undergraduates and unlike younger children—were more like to group a primate with another animal when the animal was mammal than when it was not.

These results qualify Johnson et. al.'s (1992) finding that, when given mammals only, 7- and 10-year-olds showed little evidence making taxonomic distinctions among mammals beyond that of human-nonhuman. By using a broader range of stimuli, the present study bolstered Johnson et al.'s claim about younger children; in the present study, children younger that age 8 not only saw humans as a unique *mammal*, but as a unique *animal*. In contrast, the present study also revealed among 8-year-olds a more sophisticated knowledge of taxonomic distinctions among animals than predicted by Johnson et al.'s results.

Moreover, results of the present study suggest that children may not initially fit humans into the animal kingdom via an emerging intermediate category of *primate*. If so, they should see humans and primates as similar as long as the third animal is not a primate. Rather, these results suggest that children first establish an intermediate—likely unnamed—category of *mammal*, of which humans and primates are both members, but within which humans occupy a unique position. This would explain why 8-year-olds believe primates are more like humans than like non-mammals, but more like non-primate mammals than like humans.

CONCLUSIONS

These results are generally compatible with views of development in the biological domain that emphasize increasing conceptual differentiation with age and experience (e.g., Carey, 1985; Coley, 1995; Coley, Vitkin, Seaton, & Yopchick, 2005). However, the specific nature of the documented changes run counter to predictions of the conceptual change view of development articulated by Carey (1985, 1995) and others, whereas the lack of clear differentiation among children emphasizes the relative fragility of early distinctions described by Coley (e.g., 1995, Coley, Solomon, & Shafto, 2002) and others. Indeed, one question raised by these results taken together is whether the largest discontinuities in the development of biological thought are between the folk belief systems of children and undergraduates, both of which see humans as unique, or between folk and scientific taxonomies, which differ pointedly on the proper place of humans in the animal kingdom. Another is the degree to which differences in cultural beliefs and direct informal experience with nature, which have been shown to have pervasive effects in other areas of folk biological thought, might also influence the degree to which humans are thought of as one animal among many.

ACKNOWLEDGEMENTS

This research was initiated as part of a doctoral dissertation submitted to the University of Michigan in 1993, and completed while the author was a Senior Visiting Fellow in the School of Psychology, University of New South Wales, Sydney, Australia in 2007. I'd like to thank Susan Gelman, Henry Wellman, Larry Hirschfeld, and Doug Medin for their guidance on this project way back when, and Marina Armendares Fontaine and Sarah Belfit for their tenacious typing skills.

REFERENCES

Atran, S. (1998). Folk biology and the anthropology of science: Cognitive universals and cultural particulars. *Behavioral and Brain Sciences, 21,* 547-609.

Berlin, B. (1992). *Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies.* Princeton, NJ: Princeton University Press.

Booth, A. E., & Waxman, S. R. (2003). Mapping words to the world in infancy: Infants' expectations for count nouns and adjectives. *Journal of Cognition and Development, 4*, 357-381.

Carey, S. (1985). *Conceptual Change in Childhood*. Cambridge, MA: Bradford Books, MIT Press.

Carey, S. (1995). On the origins of causal understanding. In D. Sperber, D. Premack, and A. J. Premack (Eds.), *Causal Cognition*. Oxford: Clarendon Press, 268-308.

Carey, S., & Spelke, E. (1996). Science and core knowledge. *Philosophy of Science, 63*, 515-533.

Coley, J. D. (1995). Emerging differentiation of folkbiology and folkpsychology: Attributions of biological and psychological properties to living things. *Child Development*, *66*, 1856-1874.

Coley, J. D., & Gelman, S. A. (1989). The effects of object orientation and object type on children's interpretation of the word “big.” *Child Development, 60,* 372-380.

Coley, J. D., Hayes, B., Lawson, C., & Moloney, M. (2004). Knowledge, expectations, and inductive inferences within conceptual hierarchies. *Cognition, 90*, 217-253.

Coley, J. D., Solomon, G. E. A., & Shafto, P. (2002). The development of folkbiology: A cognitive science perspective on children's understanding of the biological world. In P. Kahn & S. Kellert (Eds.), *Children and nature: Psychological, sociocultural and evolutionary investigations* (65-91). Cambridge, MA: MIT Press.

Coley, J. D., Vitkin, A. Z., Seaton, C. E. & Yopchick, J. E. (2005). Effects of Experience on Relational Inferences in Children: The Case of Folk Biology. In B.G. Bara, L. Barsalou & M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society* (471-475). Mahwah NJ: Lawrence Erlbaum Associates.

Evans, E. M. (2001). Cognitive and contextual factors in the emergence of diverse belief systems: Creation versus evolution. *Cognitive Psychology, 42,* 217-266.

Gutheil, G., Vera, A., & Keil, F. C. (1998). Do houseflies think? Patterns of induction and biological beliefs in development. *Cognition, 66,* 33-49.

Inagaki, K. (1990). The effects of raising animals on children’s biological knowledge. *British Journal of Developmental Psychology, 8,* 119-129.

Inagaki, K., Hatano, G. (1993). Young children’s understanding of the mind-body distinction. *Child Development 64,* 1534–1549.

Inagaki, K., & Hatano, G. (2002). *Young children's naive thinking about the biological world*. New York: Psychology Press.

Inagaki, K., & Sugiyama, K. (1988). Attributing human characteristics: Developmental changes in over and under-attribution. *Cognitive Development, 3,* 55-70.

Johnson, S., & Carey, S. (1998). Knowledge enrichment and conceptual change in folkbiology: Evidence from Williams Syndrome. *Cognitive Psychology, 37,* 156-200.

Johnson, K, Mervis, C., &, Boster, J., S. (1992). Developmental changes in the structure of the mammal domain. *Developmental Psychology, 28,* 74-83.

Mandler, J. M., & Bauer, P. J. (1988). The cradle of categorization: Is the basic level basic? *Cognitive Development, 3,* 247-264.

Mandler, J. M., & McDonough, L. (2000). Advancing Downward to the Basic Level. *Journal of Cognition and Development, 1,* 379-403.

Medin, D. L., Goldstone, R. L., & Gentner, D. (1993). Respects for similarity. *Psychological Review, 100,* 254-278.

Richards, D. D., & Siegler, R. S. (1986). Children's understanding of the attributes of life. *Journal of Experimental Child Psychology, 42,* 1 - 22.

Ross, N., Medin, D. L., Coley, J. D., & Atran, S. (2003). Cultural and experiential differences in the development of biological induction. *Cognitive Development, 18,* 25-47.

Tversky, A. (1977). Features of similarity. *Psychological Review, 84,* 327-352

Vitkin, A. Z., Vasilyeva, N. Y., Coley, J. D., Baker, A., & Ciampanelli, N. (2007). *Biological Reasoning in Preschool Children: The Roles of Knowledge and Experience.* Paper presented at the Biennial Meetings of the Society for Research in Child Development, Boston, MA.

Waxman, S. R. (1990). Linguistic biases and the establishment of conceptual hierarchies: Evidence from preschool children. *Cognitive Development, 5*, 123-150.

Wellman, H. M., & Gelman, S. A. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology*, *43*, 337– 375.