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One animal among many?

Children's understanding of the relation between humans and nonhuman animals

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Abstract

Children's understanding of the relationship between humans and nonhuman animals is an important component of their early understanding of biology. Yet it remains unclear whether children accept that humans are indeed part of the animal kingdom, or more precisely, whether humans are a part of a concept labeled 'animal.' In this study, we adopt a cross-cultural, developmental perspective to examine children's interpretation of fundamental biological terms like 'human,' 'mammal,' and 'animal', and the relations among them. We trace how children's understanding changes over time, examining 5- to 6-year-olds who have had relatively little formal science education, and 9- to 10-year-olds who are well into the science curriculum. We consider how children's understanding may be influenced by their surrounding environment, testing children from three US communities that vary in their habitual contact with the natural world and their cultural perspective on the human-nonhuman animal relation. One hundred and sixty children were tested using structured interviews, where we collected justifications to amplify our understanding of children's forced-choice responses. The results reveal a surprising consistency: children at both ages and in all communities largely deny that humans are animals. While the younger children strictly maintain the uniqueness of humans, the older children accept that humans are mammals (and that mammals are animals) but deny that humans are animals, thus violating a logical syllogism. This finding has implications not only for our understanding of children's development of biological concepts, but also for the design of science curricula.

Keywords: biology education, conceptual development, language, cross-cultural studies

One animal among many?

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Despite decades of research, questions remain concerning the way(s) in which young children understand the biological relation between human and nonhuman animals. On one hand, there is considerable evidence that even in the preschool years, children appreciate that humans and non-human animals alike share certain fundamental biological processes (including birth, growth and death) and biological requirements (including air, water and food) (Anggoro, Waxman, & Medin, 2008; Backscheider, Schatz, & Gelman, 1993; Hatano, Siegler, Richards, Inagaki, Stavy & Wax, 1993; Inagaki & Hatano, 1996; Leddon, Waxman, & Medin, 2008; Opfer & Siegler, 2004; Springer & Keil, 1989, 1991; Waxman, 2005). Indeed, even infants are sensitive to commonalities shared by humans and non-human animals (e.g., that they are agents, that they engage in biological motion) and distinguish animate objects (humans and non-human animals) from inanimates (Berthenthal, 1993; Carey, Diamond, & Woods, 1980; R. Gelman, 1990; R. Gelman, Durgin, & Kaufman, 1995; S. Gelman & Gottfried, 1996; Johnson, Slaughter, & Carey, 1998; Opfer, 2002, Opfer & S. Gelman, 2001; Poulin-Dubois & Shultz, 1990; Woodward, 1999; Woodward, Sommerville, & Guajardo, 2001).

At the same time, however, there is also strong evidence that most children have difficulty incorporating humans into the same category as non-human animals (e.g., Anggoro, Medin, & Waxman, 2010; Carey, 1985, 1995; Herrmann, Waxman, & Medin, 2010; Herrmann, Medin, & Waxman, 2011). In a striking demonstration of this phenomenon, researchers have presented children (from several different linguistic and cultural communities) with a picture of a human and asked 'Could this (the human) be called an animal?' English-speaking children,

ranging from 6 to 9 years of age, agreed that the human was an animal less than 30% of the time (Anggoro, Waxman, & Medin, 2008). Converging evidence reveals that children's failure to apply the word 'animal' to humans persists well beyond the elementary school years. Indeed, at 14 years of age, only 2 out of 3 children agreed that humans are animals (Bell & Barker, 1982). Clearly, then, the ability to incorporate humans into a category called 'animal' is far from universal, even at age 14.

This tension about the place of humans – as members of the animal kingdom, yet simultaneously set apart from it – is also reflected in our language. There are (at least) two senses of the word 'animal': one that encompasses both humans and nonhuman animals ($animal_{\text{inclusive}}$) and another that includes only nonhuman animals ($animal_{\text{contrastive}}$)[1]. See Figure 1.

[Insert Figure 1 about here]

The polysemy of 'animal', and the fact that its two meanings correspond to nested nodes in a conceptual hierarchy, has been proposed to present a distinct challenge to children developing fundamental biological concepts (Anggoro, Waxman, & Medin, 2008; Waxman, 2005). Yet while it is almost certainly the case that children understand 'animal' to refer to nonhuman animals (as a label for $animal_{\text{contrastive}}$), it remains an open question whether they can also map this term to a concept that includes humans (as a label for $animal_{\text{inclusive}}$). This is an important question, for a variety of reasons, but for our purposes because language is the primary conduit of information between students and teachers. Successful communication therefore relies on these two groups having common interpretations of key terms, and for teachers to recognize if children fail to understand a word like 'animal' in all of its senses. Moreover, developing a scientific understanding of humans as biological entities requires students to appreciate the commonalities that humans and nonhuman animals share as 'animals', or members of a category

with this label. Clarifying children's interpretation of this term will not only provide a window into their understanding of the relations between humans and nonhuman animals, but will also support our efforts to build on and respond to the meanings children bring with them to the classroom.

In the current study, we consider children's understanding of the relation between humans and nonhuman animals, focusing specifically on their interpretation of the word 'animal', and whether they map it to the concept $animal_{inclusive}$. We adopt a cross-cultural, developmental perspective to examine three potential influences on children's understanding. First, we trace how children's understanding changes over time, examining 5- to 6-year-olds who have had relatively little formal science education, and 9- to 10-year-olds, who are well into the science curriculum. Second, we consider children from three distinct US populations that vary in their habitual contact with the natural world and their cultural perspective on the human-nonhuman animal relation. Previous research suggests that these factors exert an important influence on the development of biological concepts (Astuti, Solomon, & Carey, 2004; Atran & Medin, 2008; Atran, Medin, Lynch, Vapnarsky, Ucan Ek', & Sousa, 2001; Bang, Medin, & Atran, 2007; Medin, Waxman, Woodring, & Washinawatok, 2010; Medin, Ross, Atran, Cox, Coley, Proffitt, & Blok, 2006; Proffitt, Coley, & Medin, 2000; Ross, Medin, Coley, & Atran, 2003; Waxman & Medin, 2007; Waxman, Medin, & Ross, 2007). Finally, we examine an intriguing possibility: that the concept *mammal* serves as an entry point toward discovering that humans are indeed animals (Coley, 2007; Johnson, Mervis, & Boster, 1992). On this view, by learning that humans are mammals, children can begin to understand that humans, too, are one species of animal amongst many, which therefore underscores the $animal_{inclusive}$ sense of

'animal'. If this account is correct, it would provide educators with a clear path for guiding children as they integrate humans and nonhuman animals into the concept $animal_{inclusive}$.

To address these questions, we develop a new task. Moving beyond the standard categorization tasks that have previously dominated research in this arena, we elicit children's reasoning about the concepts *human*, *mammal*, and *animal*, probing their interpretation of the words that describe these fundamental concepts, and examining their explanations of the relations among them. (See Wellman, 2011 for discussion about the importance of examining children's explanations). In doing so, we show how the justifications children provide amplify our understanding of their developing knowledge of these fundamental biological concepts.

Experiment

Our goal was to unveil whether young children in three distinct US communities extend the term 'animal' to include humans, how their understanding of this key term evolves over the primary school years, and how it is impacted by the acquisition of the related concept *mammal*. We developed a task, modeled after the Truth Value Judgment Task (Crain & McKee, 1985) and Piaget's structured interviews (e.g. Piaget, 1929). In this task, children are engaged in a series of probes, introduced within a playful context in which children were enlisted to help a puppet, who 'has a lot of questions'. This permitted us to gather both forced choice judgments as well as more extensive, explicit justifications from children.

Method

Participants. We recruited 5-year-old and 10-year-old participants (n = 160) from three distinct US communities: a rural European-American community (Shawano, WI); a rural Native American Community (the Menominee Indian Reservation adjacent to Shawano County); and an urban, racially diverse community (Chicago, IL). The contrast between the rural and urban

communities allowed us to consider the influence of direct experience with the natural world on children's reasoning; the contrast between the rural European American and rural Native American communities allowed us to consider the influence of cultural orientations towards the relationship between humans and nonhuman animals.

Rural European-American community. Shawano county is a predominantly rural area in northern Wisconsin encompassing farmland, small forest plots (typically 40-80 acres), and numerous lakes and rivers. It is common for residents of this community to spend quite a bit of time outdoors: hunting, fishing, water recreation in the summer, and snow-mobiling in the woods in the winter are popular activities for adults and children.

Children were recruited from public elementary schools in Shawano. Sixty children participated: 26 5-year-olds (M = 5.84, SD = .15; 13 female), and 34 9-year-olds (M = 10.05, SD = .41; 20 female).

Rural Native American community. The Menominee ('Wild Rice People') are the oldest continuous group of residents of Wisconsin. Four-thousand to 5,000 Menominee live on heavily forested tribal lands in Wisconsin. Members of this community tend to spend quite a bit of time outdoors: hunting and fishing are important activities for most adult males and for many females and children. In the Menominee creation story, humans come from certain nonhuman animals, which form the basis for 5 major clans (bear, thunder/eagle, wolf, moose, and crane). Even young children are familiar with the clan system.

Children were recruited through Keshena Primary School (KPS) on the Menominee reservation. At least 99% of children attending KPS are American Indian/Alaska Native, and the majority of these children are formally enrolled as Menominee Tribal members[2]. Children in this community are typically monolingual English speakers: although they have learned some of

the Menominee language (e.g., greetings, names for clan animals), they are not fluent. English is spoken in their homes. Fifty-four children participated: 31 5-year-olds (*M* = 6.31, *SD* = .31; 15 female), and 23 9-year-olds (*M* = 9.80, *SD* = .59; 16 female).

***Urban community*.** Urban participants were recruited from a large public magnet school in Chicago, IL. This school draws students from across the city to achieve a racial and ethnic diversity that goes beyond that typically found in neighborhood schools (it does not select for particular aptitudes (e.g. math, performance arts)). The student population in 2009 was roughly 41% African-American, 19% Hispanic, 17% White, 13% Asian, 9% Multi-Racial, and 1% Native American. There is considerably less participation in outdoor or nature-oriented activities in this urban sample as compared to the two rural samples. Forty-six children participated: 24 5-year-olds (*M* = 5.73, *SD* = .2; 14 female), and 22 9-year-olds (*M* = 9.89, *SD* = .26; 11 female).

Procedure. The task was administered in a quiet room on the child's school premises. To begin, a trained research assistant explained, 'I'd like to introduce you to my friend, Sara (a doll). Sara is really little, and is just learning about things. She needs your help to learn more! So I'll tell you what we're going to do. Sara is going to tell us some things that she thinks. Sometimes she'll be right, and sometimes she'll be wrong. It is your job to decide if she's right or if she's wrong, and to help her learn. Remember that she really wants to learn, so you'll have to be careful to teach her and explain to her why she is right or wrong!' Children then heard a series of 30 statements. For each, children were asked first whether Sara was right or wrong; they then were asked to provide justifications. We did not insist on justifications for every statement, but we did prompt children consistently for justifications on key statements, particularly the target items concerning the relation between humans and non-human animals.

Items. The task included three distinct types of items. See Appendix A[3].

(1) Filler items (e.g., 'Cows eat grass,' 'Trees can walk') were included to maintain children's interest and to mask the focus of our investigation. These were constructed in such a way as to elicit both 'yes' and 'no' responses. (2) Benchmark items (e.g., 'X's are alive'; X's are animals') were included to establish that performance in the current task converges with evidence from prior investigations. (3) Target items (e.g., 'Humans are mammals'; 'Mammals are animals'; and 'Humans are animals') were designed specifically to delve deeper into children's appreciation of the relation between humans, mammals and non-human animals.

Items were presented one at a time, in random order with one exception: because we were especially interested in children's responses to 'Humans are animals', we introduced this item before any other statements about humans or mammals. Sessions were audio taped. The experimenter recorded children's responses.

Coding and analysis. Acceptances, or 'yes' responses, were coded as 1, 'no' responses were coded as 0. Children's forced choice judgments were analysed using both standard parametric and non-parametric tests. We report the non-parametric analyses; in all cases, parametric tests yielded the same effects.

Justifications for children's forced choice judgments were transcribed and then assigned to a coding category:

(1) I don't know/no justification provided.

(2) Appeals to shared properties (e.g. 'Humans and animals both need water to live'), which reveals explicit knowledge in reasoning about the concepts in question and their relation.

(3) Appeals to distinct properties (e.g. 'Humans don't walk on 4 legs like animals do'), which reveal explicit knowledge in reasoning about the concepts in question and their relation.

(4) Tautologies (e.g. 'Humans are humans and animals are animals'), where children highlight the separation of the concepts mentioned, suggesting that they do not have any deeper explanations available to support their response.

(5) Appeals to an authority (e.g. 'I heard it from my mom,' 'My science teacher told us,' 'It says so in the Bible').

(6) Hedges (e.g. 'Some animals are mammals and some aren't'), revealing children's attempt to reconcile the concepts in question, but not to endorse the relation outright.

(7) Other, or all other responses (e.g. Comments involving concepts other than those in the question; comments whose relevance to the question was difficult to ascertain).

Results

The results reveal that while they are adept at this task, children in all three communities face similar difficulties extending the term 'animal' to humans, or mapping 'animal' to $animal_{\text{inclusive}}$. Moreover, an understanding of the concept *mammal* does not appear to influence children's ability to consider humans as animals. This difficulty persists throughout the elementary school years, highlighting the challenges facing children as they establish a relation between humans and nonhuman animals.

Filler and benchmark items. Children's uniformly accurate responses to the filler items accord well with previous work, and document that children were able to respond appropriately with either 'yes' (accepting the true fillers) or 'no' (rejecting the false fillers). See Table 1.

Table 1

Mean Proportion of 'Yes' Responses for Filler Items

		True Items			False Items	
		Cows eat grass	*Worms crawl in the mud*	*Pencils have erasers*	*Trees can walk*	*Humans have wings*
5-6-year-olds	**Rural European American**	.88*	.69	1.00*	.04*	0*
	Rural Native American	.90*	.73*	.97*	.03*	.07*
	Urban	.79*	.83*	.96*	.04*	.04*
9-10-year-olds	**Rural European American**	.97*	.94*	1.00*	0*	0*
	Rural Native American	.87*	.91*	1.00*	0*	0*
	Urban	1.00*	.95*	.95*	.05*	0*

Note. Asterisks indicate that the proportion of 'yes' responses differs from the rate expected by chance (.5) by a binomial test, $p < .05$.

Responses to the benchmark items also provide strong assurances that children responded appropriately[4]. Echoing prior reports, on questions concerning the biological predicate 'alive', children agreed that both humans and a range of nonhuman animals are alive, but that artifacts are not (e.g., Anggoro, Waxman, & Medin, 2008; Carey, 1985; Leddon, Waxman, & Medin, 2008; Opfer & Siegler, 2004; Piaget, 1929). See Table 2.

Table 2

Mean Proportion of 'Yes' Responses for Items Invoking the Concept Alive

		Human	Cow	Bird	Worm	Bike
5-6-year-olds	**Rural European American**	1.00*	1.00*	.96*	.92*	.19*
	Rural Native American	.97*	.97*	1.00*	.93*	.10*
	Urban	.96*	1.00*	1.00*	1.00*	.21*
9-10-year-olds	**Rural European American**	1.00*	1.00*	1.00*	.97*	0*
	Rural Native American	1.00*	1.00*	1.00*	.96*	0*
	Urban	.95*	1.00*	1.00*	1.00*	.09*

Note. All statements are of the form 'X's are alive'. Asterisks indicate that the proportion of 'yes' responses differs from the rate expected by chance (.5) by a binomial test, $p < .05$.Children were just as likely to accept that 'Humans are alive', 'Cows are alive,' 'Birds are alive,' or 'Worms are alive,' all *p*'s > .15. On questions concerning the concept *animal*, children's responses also converged well with prior work, asserting that nonhuman animals—but not artifacts – are animals. Interestingly, although children readily accepted that cows, birds, and fish are animals (and largely excluded bikes or pencils), they were more equivocal about the status of worms and bees. See Table 3. This converges with prior evidence (Coley, Shafto, Stepanova, & Barraff, 2005; Inagaki & Sugiyama, 1988), and underscores the challenge of with establishing the scope of the concept animal.

Table 3

Mean Proportion of 'Yes' Responses for Items Invoking the Concept Animal

		Human	Cow	Bird	Fish	Worm	Bee	Bike	Pencil
5- 6-year-olds	**Rural European American**	.04*	.96*	.81*	.69	.64	.65	.04*	0*
	Rural Native American	.03*	.90*	.80*	.80*	.50	.63	.03*	.03*
	Urban	.13*	.96*	.79*	.88*	.54	.63	0*	.04*
9- 10-year-olds	**Rural European American**	.42	.97*	.97*	.76*	.53	.36	0*	0*
	Rural Native American	.17*	.96*	.91*	.78*	.50	.48	0*	0*
	Urban	.27*	.91*	.91*	.82*	.68	.55	.05*	0*

Note. All statements are of the form 'X's are animals' Asterisks indicate that the proportion of 'yes' responses differs from the rate expected by chance (.5) by a binomial test, $p < .05$.

Target items. Children's responses to the filler and benchmark items provide strong assurances that they understand the task and responded appropriately. This set the foundation for going on to examine their responses to the target items, which were specifically designed to probe children's understanding of the relation between humans, mammals, and animals, and gauge whether children would extend the term 'animal' to include humans. Following recent analyses by Rhodes and colleagues (Rhodes & Gelman, 2009; Rhodes, Gelman, & Brickman, 2010), children's forced-choice responses were analysed with generalized linear models (SPSS 19) to assess main effects and interactions. The results demonstrate that children's responses are largely consistent across communities. See Figures 2 and 3. At both ages and in each community children rejected the statement 'Humans are animals,' despite the fact that the older children largely accepted the statements 'Humans are mammals' and 'Mammals are animals'. This suggests that an appreciation of humans as mammals does not necessarily provide a stepping

stone for extending 'animal' to humans, or for coordinating humans, (non-human) mammals, and other animals into a systematic hierarchical system. In what follows, we consider responses to each target item in turn.

[Figure 2 about here]

[Figure 3 about here]

Humans are mammals.

Forced choice responses. Children's responses to 'Humans are mammals' revealed a main effect of Age, $\chi^2(1) = 52.13$, $p < .001$, and a main effect of Community, $\chi^2(2) = 7.09$, $p = .029$; urban children were more likely than those two rural populations to respond in the affirmative. See Figure 2. The interaction between Age and Community was not significant, $\chi 2(2) = 2.67$, $p = .264$. In essence, then, 9- to 10-year-olds in all three communities largely affirmed that 'humans are mammals', but 5- to 6-year-olds did not.

Justifications. Children's justifications amplified their interpretation of this target item. See Appendix B. In all three communities, the 9- to 10-year-olds (who largely agreed that humans are mammals in their forced-choice responses) offered justifications that appealed primarily to attributes that are shared by humans and other mammals (e.g., giving birth to live young, having hair/fur, etc.). In contrast, the 5- to 6-year-olds (who did not agree that humans are mammals in their forced-choice responses) offered justifications of a very different flavor. Consider first the 5- and 6-year-olds from the two rural communities. These children, who systematically denied that humans are mammals in the forced choice task, tended to mention attributes that distinguish humans from non-human animals (e.g., not having 4 legs, not eating grass, etc.). Yet they also tended to offer tautological justifications (e.g., humans are humans, and therefore not mammals), or to offer no justification at all. The high number of responses in

these categories underscores young children's difficulty with this question, and suggests an underlying uncertainty about the relation between these concepts.

Consider next the 5- to 6-year-old urban children, whose forced-choice responses were at the chance level. Here, we were able to ask whether the kinds of justifications children provide varies as a function of their forced-choice response. An examination of Appendix B reveals that they did. Children who agreed with the statement 'Humans are mammals' tended to appeal to shared attributes of humans and mammals[5]. In contrast, those who rejected the statement appealed more to the attributes that distinguish humans from (other) mammals.

Mammals are animals.

Forced choice responses. Children at both ages in all communities tended to agree that *mammals are animals*. There was no main effect for Age, $\chi^2(1) = 2.37$, $p = .124$, or Community, $\chi^2(2) = .036$, $p = .982$, and no interaction, $\chi^2(2) = 1.67$, $p = .435$.

Justifications. See Appendix C. In all three communities, the older children, and many of the younger children as well, mentioned shared attributes of animals and mammals. However, many in the younger group appealed to tautologies, offered 'hedges', or failed to provide justifications at all. Once again, this pattern of justifications suggests that despite their consistent forced-choice responses, the younger children may not yet have a clear understanding of the relation between these concepts.

Humans are animals.

Forced choice responses. Children's difficulty accepting that humans are animals was evident at both ages and in all three communities. See Figure 4. The main effect of Age, $\chi^2(1) = 10.53$, $p = .001$, reveals that 10-year-olds were more likely than 5-year-olds to respond in the

affirmative. There was no effect of Community, $\chi^2(2) = 2.12$, $p = .346$, and no interaction, $\chi^2(2) = 2.17$, $p = .339$.

We next asked whether children are less likely to accept that 'Humans are animals' than that nonhuman animals (e.g., cows, birds, fish) are animals. See Table 3. At both ages in all 3 communities, children were significantly less likely to endorse 'Humans are animals' than either 'Cows are animals', 'Birds are animals', or 'Fish are animals', all *p's* < .007. In other words, children systematically excluded humans from the concept that they name *animal,* rejecting $animal_{inclusive}$, and endorsing an $animal_{contrastive}$ interpretation.

In a final analysis, we directly considered whether knowledge of *mammal* serves as a gateway to integrating humans into the concept $animal_{inclusive}$. Focusing on the few children who did accept the statement 'Humans are animals,' we asked whether these children also agreed that 'Humans are mammals.' As can be seen in Table 4, this was not the case, casting doubt on the suggestions that *mammal* plays a facilitative role in the acquisition of $animal_{inclusive}$.

Table 4

Mean Proportion of 'Yes' Responses to 'Humans are mammals', for Children Who Also Affirmed that Humans are Animals

		Humans are mammals
5-6-year-olds	**Rural European American**	.33
	Rural Native American	.33
	Urban	.10
9-10-year-olds	**Rural European American**	.24
	Rural Native	.45

American	
Urban	.30

Justifications. Children articulated strong opinions in response to this item, appealing overwhelmingly to distinctions between human and nonhuman animals (e.g., walking on 4 legs, living in the wild, eating grass or hay, making animals sounds like 'moo' or 'oink,' etc.). See Appendix D. At the younger ages, tautologies were also prevalent, suggesting some difficulty judging the relation between these concepts. Note that among the 9- to 10-year-olds, only the rural European-American group was even at chance in their forced-choice responses. Breaking down their justifications according to forced-choice response reveals that those who accepted it overwhelmingly offer shared attributes justifications, while those who rejected it cited distinct attributes. See Appendix D.

General Discussion

The goal of the current experiment was to consider whether young children from three distinct communities map the term 'animal' to the concept $animal_{\text{inclusive}}$, and in doing so, to gain a richer understanding of how they interpret the relation between humans and nonhuman animals. The results reveal that even 9- and 10-year-old children still encounter obstacles in integrating humans into a concept named 'animal', and this difficulty persists despite their apparent mastery of related concepts like *mammal*. Children's forced-choice responses, considered in conjunction with their explicit justifications, underscore that throughout the primary school years, children are in the process of working out the conceptual hierarchy encompassing humans, mammals and animals. This is an important finding that has implications not only for our understanding of cognitive development, and the development of biological concepts, but also for the design of science curricula.

Interestingly, children's understanding of these conceptual relationships was revealed to be largely the same across communities: neither habitual contact with the natural world (as in both rural communities), nor cultural belief systems that privilege the human-nonhuman animal relationship (as in the Native American community) appeared to influence children's responses. While the communities in our task did not differ, in other tasks, important differences have been revealed (e.g., Astuti, Solomon, & Carey, 2004; Atran & Medin, 2008; Atran, et al, 2001; Bang, Medin, & Atran, 2007; Medin, Waxman, Woodring, & Washinawatok, 2010; Medin, Ross, Atran, Cox, Coley, Proffitt, & Blok, 2006; Proffitt, Coley, & Medin, 2000; Ross, Medin, Coley, & Atran, 2003; Waxman & Medin, 2007; Waxman, Medin, & Ross, 2007). Future research should therefore continue to extend to diverse populations (Medin, et al, 2010), to pinpoint where these differences occur, and how they may be best addressed in science curricula. This process has already begun with an intriguing study that examines children acquiring Indonesian, where the conventions for naming biological concepts differ markedly from English (Anggoro, 2011).

While the current study found few differences across communities, it did reveal differences across age groups. Children were more likely to agree with the statement 'Humans are mammals' as they got older, perhaps reflecting increased knowledge of *mammal*, which is likely to be more aligned with formal education. Children in the older group were also more likely to agree to agree with the statement 'Humans are animals,' although they remained at or below chance in doing so. Clearly, even after considerable formal science education, children continue to reject the $animal_{\text{inclusive}}$ interpretation of 'animal'. Future research might consider at what point children, or even adults, come to endorse this sense of the term.

Taking a broader view of children's responses, an interesting pattern emerges when considering all 3 target statements together. Note that if children agree that 'Humans are mammals', and 'Mammals are animals,' it should logically follow that 'Humans are animals.' While we did not explicitly elicit children's judgments about the relation between these statements, we did examine children's responses for evidence of this logical reasoning. Interestingly, the younger children, while perhaps not fully understanding the concept *mammal*, at least demonstrate a consistent logic: they accept the statement 'Mammals are animals,' but maintain a clear distinction for humans, rejecting the statements 'Humans are mammals' and 'Humans are animals'. In contrast, the older children actually violate a logical syllogism: they accept the statements 'Humans are mammals' and 'Mammals are animals', but reject 'Humans are animals.' This finding casts doubt on the proposal that *mammal* serves as a gateway for considering humans as one animal amongst many, as the logical inference underlying the human – mammal – animal relationship is apparently absent. It therefore suggests there must be an alternative path to the successful integration of humans with nonhuman animals into the concept $animal_{\text{inclusive}}$. Future work might explicitly elicit children's reasoning about this logical syllogism, and consider whether pointing out these relationships to students increases their tendency to agree that 'Humans are animals.'

Despite these challenges, children in this task echo previous work by demonstrating knowledge of at least one similarity between humans and nonhuman animals: in particular, that both are alive. What this study reveals, however, is that even within the confines of a single task, children can simultaneously endorse such similarities (e.g., when it comes to the concept *alive*), while also maintaining a clear separation between these two groups (e.g., when it comes to the concept *animal*). As shown in previous work, children seem to understand many of the

biological commonalities between humans and animals, yet they still deny that both can be labeled ‘animals’. In future work, it will be interesting to explicitly probe whether and when appreciating these commonalities leads to integrating humans and nonhuman animals into a single concept labeled ‘animal’.

Finally, future research may also examine other potential influences on children’s understanding. We saw a hint of the influence of various authority figures in the justifications children provided in this study: parents, teachers, and religious influences were all mentioned at least once. It will be important to study more carefully the types of information children receive about the relation between humans and nonhuman animals, both at home, before formal science education begins, and in the classroom. It will also be interesting to examine how religion bears on this understanding, and if children from different religious backgrounds reveal distinct understandings of the relation between humans and nonhuman animals.

This study represents an important first step in considering the meanings children ascribe to terms for fundamental biological concepts. By understanding the meanings children bring with them to the classroom, we have the opportunity to design curricula that build on students’ existing knowledge, and effectively communicate new information.

References

Anggoro, F. (2011, March). *A Mammal That Is Not an Animal? Naming and the ANIMAL Concept in Indonesian-Speaking Children and Adults.* Poster presented at Biennial Meeting of the Society for Research in Child Development, Montreal, Canada.

Anggoro, F., Medin, D. & Waxman, S. (2010). Language and Experience Influence Children's Biological Induction. *Journal of Cognition and Culture, 10,* 171-187.

Anggoro, F. K., Waxman, S.R. & Medin, D.L. (2008). Naming Practices and the Acquisition of Key Biological Concepts: Evidence from English and Indonesian. *Psychological Science, 19(4),* 314-319.

Astuti, R., Solomon, G.E.A., Carey, S. (2004). *Constraints on conceptual development: a case study of the acquisition of folkbiological and folksociological knowledge in Madagascar*. Monographs of the Society for Research in Child Development. Boston: Blackwell.

Atran, S. & Medin, D.L. (2008). *The Native Mind and the Cultural Construction of Nature.* Boston, MA: MIT Press.

Atran, S., Medin, D., Lynch, E., Vapnarsky, V., Ucan Ek', E., & Sousa, P. (2001). Folkbiology doesn't come from folkpsychology: Evidence from Yukatek Maya in cross-cultural perspective. *Journal of Cognition and Culture, 1,* 3–42.

Backsheider, A., Shatz, M., & Gelman, S. (1993). Preschoolers' ability to distinguish living kinds as a function of regrowth. *Child Development, 64,* 1242–1257.

Bang, M., Medin, D., & Atran, S. (2007). Cultural mosaics and mental models of nature. *Proceedings of the National Academy of Sciences, 104,* 13868-13874. doi:10.1073/pnas.0706627104

Bell, B., & Barker, M. (1982). Towards a scientific concept of 'animal.' *Journal of Biological Education, 16,* 197-200.

Berthenthal, B. I. (1993). Infants' perception of biomechanical motions: Intrinsic image and knowledge-based constraints. In C. Granrud (Ed.). *Visual Perception and Cognition in Infancy*. Carnegie Mellon symposia on cognition (pp. 175-214). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: Bradford Books.

Carey, S. (1995). On the origin of causal understanding. In D. Sperber, D. Premack & A. J. Premack (Eds.), *Causal cognition: A multidisciplinary debate* (268-308). New York: Oxford University Press.

Carey, S., Diamond, R., & Woods, B. V. (1980). Development of face recognition: A maturational component? *Developmental Psychology, 16***,** 257–269. doi:10.1037/0012-1649.16.4.257

Coley, J.D. (2007). The human animal: Developmental changes in judgments of taxonomic and psychological similarity among humans and other animals. *Cognition, Brain, Behavior, 11*, 733-756.

Coley, J.D., Shafto, P., Stepanova, O., & Baraff, E. (2005). Knowledge and category-based induction. In Ahn, W., Goldstone, R.L., Love, B.C., Markman, A.B. & Wolff, P. (Eds.), *Categorization inside and outside the laboratory: Essays in honor of Douglas L. Medin*. Washington, DC: American Psychological Association.

Crain, S. & McKee, C. (1985). The acquisition of structural restrictions on anaphora. In S. Berman, J.-W. Choe, and J. McDonough (Eds.) *Proceedings of NELS 15*, 94-110. Amherst, MA: GLSA.

Gelman, R. (1990). First principles organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples. *Cognitive Science, 14*, 79-106. doi:10.1016/0364-0213(90)90027-T

Gelman, R., Durgin, F. and Kaufman, L. (1995). Distinguishing between animates and inanimates: Not by motion alone. In D. Sperber, D. Premack, and A. Premack, (Eds.), *Causality and culture*. Oxford: Plenum Press.

Gelman, S. A., & Gottfried, G. M. (1996). Children's causal explanations for animate and inanimate motion. *Child Development, 67*, 1970-1987. doi:10.2307/1131604

Hatano, G., Siegler, R.S., Richards, D.D., Inagaki, K., Stavy, R., & Wax, N. (1993). The development of biological knowledge: A multi-national study. *Cognitive Development, 8*, 47-62. doi:10.1016/0885-2014(93)90004-O

Herrmann, P., Medin, D.L., & Waxman, S.R. (2011). *When humans become animals: Development of the animal category in early childhood.* Manuscript submitted for publication.

Herrmann, P., Waxman, S.R., & Medin, D.L. (2010). Anthropocentrism is not the first step in children's reasoning about the natural world. *Proceedings of the National Academy of Sciences, 107(22)*, 9979-9984.

Inagaki, K., & Hatano, G. (1996). Young children's recognition of commonalities between animals and plants. *Child Development, 67*, 2823-2840. doi:10.2307/1131754

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

Johnson, K., Mervis, C., & Boster, J. (1992). Developmental changes within the structure of the mammal domain. *Developmental Psychology, 28(1)*, 74-83.

Johnson, S. C., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? Features that elicit gaze-following in 12-month-olds. *Developmental Science, 1*, 233-238. doi:10.1111/1467-7687.00036

Leddon, E. M., Waxman, S.R. & Medin, D.L. (2008). Unmasking 'alive:' Children's appreciation of a concept linking all living things. *Journal of Cognition and Development, 9(4)*, 461-473.

Medin, D.L., Ross, N., Atran, S., Cox, D., Coley, J., Proffitt, J., & Blok, S. (2006). Folkbiology of Freshwater Fish. *Cognition, 99*(3), 237-273. doi:10.1016/j.cognition.2003.12.005

Medin, D.L., Waxman, S.R., Woodring, J., & Washinawatok, K. (2010). Human-centeredness is not a universal feature of young children's reasoning: Culture and experience matter when reasoning about biological entities. *Cognitive Development, 25*(3), 197-207.

Medin, D., Waxman S., et al., (2010). *Diversity in the social, behavioral and economic sciences.* White paper for the Directorate for the Social, Behavioral, and Economic Sciences of the National Science Foundation (NSF/SBE).

Menominee Indian Tribe of Wisconsin. (2004). *Facts and figures reference book.* Keshena, WI: Menominee Indian Tribe of Wisconsin, Department of Administration.

Opfer, J. E. (2002). Identifying living and sentient kinds from dynamic information: The case of goal-directed versus aimless autonomous movement in conceptual change. *Cognition, 86*, 97-122. doi:10.1016/S0010-0277(02)00171-3

Opfer, J. E. & Gelman, S. A. (2001). Children's and adult's models for predicting teleological action: The development of a biology-based model. *Child Development, 72*, 1367-1381.doi:10.1111/1467-8624.00353

Opfer, J. E., & Siegler, R. S. (2004). Revisiting the living things concept: A microgenetic study of conceptual change in basic biology. *Cognitive Psychology, 49*, 301-332. doi:10.1016/j.cogpsych.2004.01.002

Piaget, J. (1929). *The child's conception of the world* (J. & A. Tomlinson, Trans.). New York: Harcourt Brace.

Poulin-Dubois, D., & Shultz, T. R. (1990). The infant's concept of agency: The distinction between social and nonsocial objects. *Journal of Genetic Psychology, 151*, 77-90.

Proffitt, J. B., Coley, J. D., & Medin, D. L. (2000). Expertise and category-based induction. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(4), 811-828.

Rhodes, M., & Gelman, S. A. (2009). A developmental examination of the conceptual structure of animal, artifact, and human social categories across two cultural contexts. *Cognitive Psychology, 59*, 244-274.

Rhodes, M., Gelman, S. A., & Brickman, D. (2010). Children's attention to sample composition in learning, teaching, and discovery. *Developmental Science, 13*, 421-429.

Ross, N., Medin, D.L., Coley, J.D. & Atran, S. (2003). Cultural and Experiential Differences in the Development of Folkbiological Induction. *Cognitive Development, 18*, 25-47. doi:10.1016/S0885-2014(02)00142-9

Springer, K. & Keil, F. (1989). On the development of biologically specific beliefs: The case of inheritance. *Child Development, 60*, 637-648. doi:10.2307/1130729

Springer, K. & Keil, F. (1991). Early differentiation of causal mechanisms appropriate to biological and nonbiological kinds. *Child Development, 62*, 767-781. doi:10.2307/1131176

Waxman, S.R. (2005). Why is the concept 'Living Thing' so elusive? Concepts, languages, and the development of folkbiology. In W. Ahn, R.L. Goldstone, B.C. Love, A.B. Markman, & P. Wolff (Eds.), *Categorization Inside and Outside the Laboratory: Essays in Honor of Douglas L. Medin.* Washington, DC: American Psychological Association.

Waxman, S., & Medin, D. (2007). Experience and cultural models matter: Placing firm limits on anthropocentrism. *Human Development, 50*, 23-30. doi:10.1159/000097681

Waxman, S.R., Medin, D.L., & Ross, N. (2007). Folkbiological reasoning from a cross-cultural developmental perspective: Early essentialist notions are shaped by cultural beliefs. *Developmental Psychology, 43*(2), 294-308. doi:10.1037/0012-1649.43.2.294

Wellman, H.M. (2011). Reinvigorating explanations for the study of early cognitive development. *Child Development Perspectives, 5*(1), 33-38.

Woodward, A. L. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior and Development, 22*, 145-160. doi:10.1016/S0163-6383(99)00007-7

Woodward, A. L., Sommerville, J. A., & Guajardo, J. J. (2001). How infants make sense of intentional action. In B. F. Malle & L. J. Moses (Eds.), *Intentions and intentionality: Foundations in social cognition*. Cambridge, MA: MIT Press.

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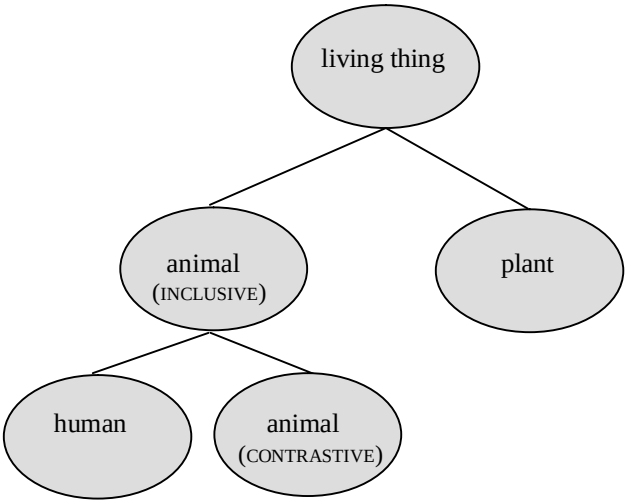
Figure 1.


living thing
animal
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human
animal
(CONTRASTIVE)

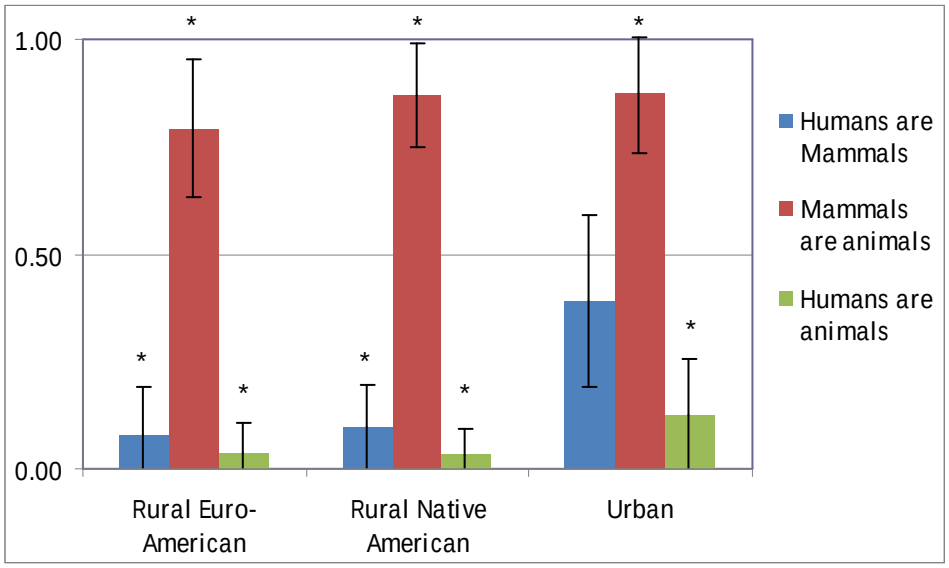

Figure 2.

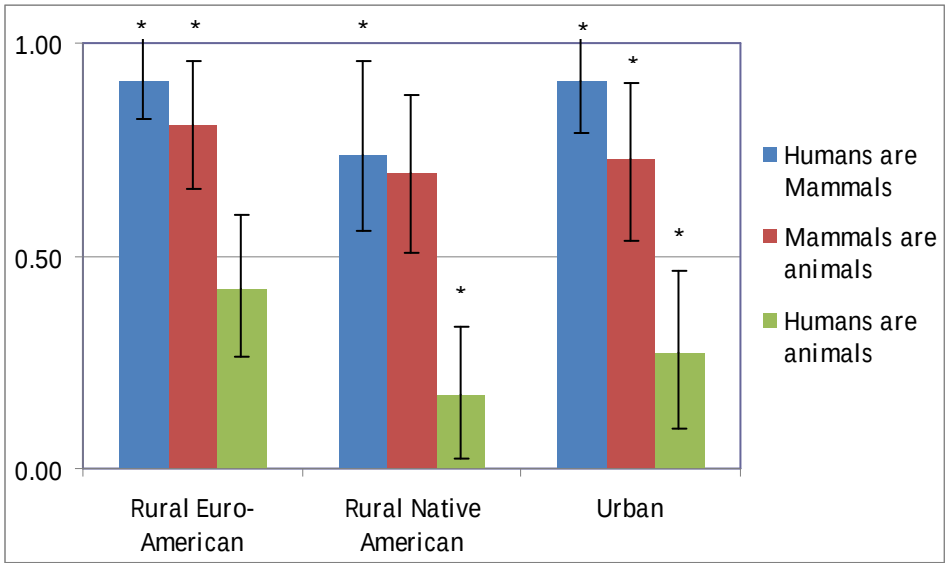

Figure 3.

Figure Captions

Figure 1. Schematic of the conceptual hierarchy containing living things. Note that the concept *mammal* intervenes between $animal_{\text{inclusive}}$ and $animal_{\text{contrastive}}$, encompassing humans and a subset of $animal_{\text{contrastsive}}$ (namely, nonhuman mammals).

Figure 2. The proportion of 'yes' responses to all target items, for 5- to 6-year-olds in each community. Error bars represent 95% Wald confidence intervals. Asterisks indicate a statistically significant difference between the proportion of 'yes' responses and the proportion expected by chance (.5), $p < .05$.

Figure 3. The proportion of 'yes' responses to all target items, for 9- to 10-year-olds in each community. Error bars represent 95% Wald confidence intervals. Asterisks indicate a statistically significant difference between the proportion of 'yes' responses and the proportion expected by chance (.5), $p < .05$.

Appendix A

Full list of items

Filler items

1. Cows eat grass
2. Worms crawl in the mud
3. Pencils have erasers
4. Trees can walk
5. Humans have wings

Benchmark items

6. Humans are alive
7. Cows are alive
8. Birds are alive
9. Worms are alive
10. Bikes are alive
11. Cows are animals
12. Birds are animals
13. Fish are animals
14. Worms are animals
15. Bees are animals
16. Bikes are animals
17. Pencils are animals

Target Items

18. Humans are mammals
19. Mammals are animals
20. Humans are animals

Other items, involving plants and nonliving natural kinds

21. Cows are plants
22. Birds are plants
23. Trees are plants
24. Flowers are plants
25. Trees are animals
26. Trees are alive
27. Plants are alive
28. Flowers are alive
29. Clouds are alive
30. Water is alive

Appendix B

Justifications for 'Humans are mammals'

Table B1

The Proportion of Children Giving Each Type of Justification for 'Humans are Mammals'

		No justification/ Don't know	Shared Properties	Distinct Properties	Tautology	Authority	Hedge	Other
5-6-year-olds	**Rural European American**	.47	.03	.13	.17	0	0	.20
	Rural Native American	.31	.09	.38	.06	0	0	.16
	Urban	.08	.29	.25	.13	.04	0	.21
9-10-year-olds	**Rural European American**	.33	.50	0	0	.05	0	.13
	Rural Native American	.09	.65	.13	0	.04	0	.09
	Urban	0	.59	.05	.05	.09	.05	.18

Table B2

Proportion of Justification Types Broken Down by 'Yes/No' Response for 5-to 6-year-old Urban Children

Forced Choice Judgment	No justification/ Don't know	Shared Properties	Distinct Properties	Tautology	Authority	Hedge	Other
Yes	0.10	0.70	0.00	0.10	0.10	0.00	0.00
No	0.07	0.00	0.43	0.14	0.00	0.00	0.36

Appendix C

Justifications for 'Mammals are animals'

Table C1

The Proportion of Children Giving Each Type of Justification for 'Mammals are Animals'

		No justification/ Don't know	Shared Properties	Distinct Properties	Tautology	Authority	Hedge	Other
5-6-year-olds	**Rural European American**	0.43	0.27	0.03	0.07	0.03	0.00	0.17
	Rural Native American	0.28	0.41	0.00	0.13	0.06	0.06	0.06
	Urban	0.13	0.33	0.00	0.04	0.08	0.21	0.21
9-10-year-olds	**Rural European American**	0.10	0.48	0.08	0.03	0.00	0.25	0.08
	Rural Native American	0.17	0.43	0.04	0.04	0.00	0.13	0.17
	Urban	0.00	0.59	0.05	0.00	0.00	0.23	0.14

Appendix D

Justifications for 'Humans are animals'

Table D1

The Proportion of Children Giving Each Type of Justification for 'Humans are Animals'

		No justification/ Don't know	Shared Properties	Distinct Properties	Tautology	Authority	Hedge	Other
5-6-year-olds	**Rural European American**	0.23	0.00	0.50	0.23	0.03	0.00	0.00
	Rural Native American	0.03	0.03	0.56	0.19	0.03	0.00	0.16
	Urban	0.00	0.04	0.83	0.13	0.00	0.00	0.00
9-10-year-olds	**Rural European American**	0.05	0.33	0.45	0.05	0.00	0.10	0.03
	Rural Native American	0.13	0.00	0.65	0.04	0.17	0.00	0.00
	Urban	0.05	0.14	0.41	0.09	0.09	0.09	0.14

Table D2

Proportion of Justification Types Broken Down by 'Yes/No' Response for 9-to 10-year-old Rural European American Children

Forced Choice Judgment	No justification/ Don't know	Shared Properties	Distinct Properties	Tautology	Authority	Hedge	Other
Yes	0.00	0.69	0.00	0.00	0.00	0.25	0.06
No	0.08	0.08	0.75	0.08	0.00	0.00	0.00

Footnotes

1 Throughout, we will distinguish words from the concepts they refer to by putting words in quotes, and concepts in italics.

2 To enroll as a Menominee Tribal member, one must be able to establish at least 25% Menominee lineage. In 2004, 77% of children aged 5-9 living on the Menominee reservation were enrolled Menominee (Menominee Indian Tribe of Wisconsin, 2004).

3 To maintain a focus on the relation between humans and nonhuman animals, we did not analyse items pertaining to plants or nonliving natural kinds here.

4 Because we did not require children to justify each of these items, and because their forced-choice responses were so straightforward, we do not include an analysis of the justification data here.

5 Interestingly, the justifications citing shared attributes, largely absent in the other two groups of 5- to 6-year-olds, may reflect a recent lesson on mammals in this particular school. One child mentioned that his class had recently read a book about humans and mammals. While investigating classroom activities is the scope of this particular study, it does underscore one possible explanation for the Community difference in the forced choice responses, which was driven by the younger urban group.