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Cross-cultural variation in the development of folk ecological reasoning

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ABSTRACT

Two studies examined children's reasoning about biological kinds in populations that vary in formal education and direct experience with the natural world, a Western (urban U.S.) and a Non-Western population (Tanna, Vanuatu). Study 1 examined children's concepts of ecological relatedness between species ($N = 97$, 5–13-year-olds). U.S. children provided more taxonomic explanations than Ni-Vanuatu children, who provided more ecological, physiological, and utility explanations than U.S. children. Ecological explanations were most common overall and more common among older than younger children across cultures. In Study 2, children ($N = 106$, 6–11-year-olds) sorted pictures of natural kinds into groups. U.S. children were more likely than Ni-Vanuatu children to categorize a human as an animal and the tendency to group a human with other animals increased with age in the U.S. Despite substantial differences in cultural, educational, and ecological input, children in both populations privileged ecological reasoning. In contrast, taxonomic reasoning was more variable between populations, which may reflect differences in experience with formal education.

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Cross-cultural variation in the development of folk ecological reasoning

“Mechanized man, oblivious to floras, is proud of his progress in cleaning up the landscape on which, willy-nilly, he must live out his days. It might be wise to prohibit at once all teaching of real botany and real history, lest some future citizen suffer qualms about the floristic price of his good life” - Leopold (1949)

1. Introduction

In these lines, Aldo Leopold describes industrialization's impact upon human interaction with the environment. Leopold recognized that never before in history have the majority of humans been as isolated from the natural environment as they are today. This poses a major challenge for understanding reasoning about *folk ecology*, or interactions between plants, animals, and humans (Atran et al., 1999; Bang, Medin, & Atran, 2007), given that much of the current human population has increasingly limited direct interaction with nature and learns about the natural world primarily through formal education (Wolff & Medin, 2001).

Previous cross-cultural research on folk ecological reasoning has been conducted predominantly with non-Native majority culture Americans and indigenous American populations, such as the Menominee, the Wichi, and the Itza (Atran, 1994; Bang et al., 2007; Taverna,

Medin, & Waxman, 2016). This research has shown cultural variation in anthropocentrism on category based induction tasks (Atran, Medin, & Ross, 2004) and mental models and organization of biological kinds (Medin et al., 2006). There is also cultural variation in the learning goals parents have for their children regarding the natural world (Bang et al., 2007), and how children view predator-prey relationships (ojalehto, Medin, Horton, Garcia, & Kays, 2015). In a study of non-Native U.S. and Menominee fish experts, non-Native fish experts were more likely to sort fish based on taxonomic, morphological, or goal-related categories, whereas Menominee fish experts were more likely to sort fish on the basis of their ecological relationships, such as grouping fish by their habitat (Medin et al., 2006; Medin & Atran, 2004). In another study, 5–7-year-old children were shown pictures of two biological organisms, and asked to explain why the two organisms might be paired together. Menominee children were more likely to reason ecologically about biological kinds than were non-Native U.S. children (Unsworth et al., 2012).

This variation in folk ecological knowledge between indigenous and non-native U.S. populations has primarily been attributed to cultural differences in epistemological orientations, or beliefs about the nature and acquisition of knowledge (McGinnis, 2016; Medin & Atran, 2004; Medin, Waxman, Woodring, & Washinawatok, 2010; Unsworth et al., 2012). From a Western scientific perspective, the world operates on a linear basis of cause and effect, whereas indigenous knowledge is more likely to construe the world as consisting of a complex web of interactions (Freeman, 1992). These different epistemological orientations are influenced by formal education, which is an important conduit for the intergenerational transmission of cultural knowledge (Chavajay & Rogoff, 2002; Rogoff, 2003). For children living in urban

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industrialized populations, formal education is the primary source of information about how biological kinds relate to one another and how humans fit within the ecological system (Wolff & Medin, 2001). In contrast, children from rural areas also often learn about ecology through direct interaction with the environment, which has been shown to impact reasoning about biological kinds. Children living in rural areas are more likely to make inductive inferences based on ecological relationships than children from urban environments (Coley, 2012; Herrmann, Waxman, & Medin, 2010; Ross, Medin, Coley, & Atran, 2003). Children's experience with the natural world, along with the epistemological orientation of their community, shapes the development of ecological reasoning (Medin et al., 2010).

The increased attention to ecological relationships documented among indigenous populations and non-Native, rural U.S. populations may be a result of how humans attain ecological knowledge. *ojalehto, Waxman, and Medin (2013)* argue that ecological knowledge is constructed through the human ability for perspective taking, which allows us to perceive the interdependent relationships between species. Knowledge of ecology is accumulated across generations through observation and experiences with nature (Turner & Berkes, 2006). Over time, events of resources scarcity, the migration of human populations, trial and error, experimentation, and incremental modifications of ecological knowledge enter the oral history of a population leading to the emergence of rules, taboos, and cultural institutions, which work to conserve resources (Johannes, 2002; Turner & Berkes, 2006). This knowledge of ecological relationships is essential for the survival of populations who are reliant on subsistence agriculture, foraging, and hunting. It is also possible that intuitive folk theories for reasoning about the natural world in terms of ecological relationships represent a more salient framework for understanding nature than a taxonomic framework, which has historically been assumed as the default in much of the research on folk biological knowledge. If folk ecology is an intuitive theory for reasoning about relationships in the natural world, there should be evidence for both similarities and variation in reasoning about the natural world between highly diverse populations (*ojalehto & Medin, 2015*).

The objective of the current studies was to examine variation in how children reason about the relationships between natural kinds in an urban U.S. population in Austin, Texas and a non-industrialized, indigenous population in Tanna, Vanuatu. In two studies, we examined the development of U.S. and Ni-Vanuatu children's understanding of species' ecological relatedness and interdependence (Study 1), as well as their understanding of the relationship of humans to other plants and animals in the environment (Study 2). Children in the U.S. and Vanuatu differ in their level of interaction with the natural world and in their level of participation in formal education, which may influence the way children construct knowledge of ecological concepts (Taverna, Waxman, Medin, & Peralta, 2012; Wolff & Medin, 2001).

First, we examined variation in folk ecological reasoning between populations. We predicted that children in Vanuatu, who have more direct interaction with the natural world and less formal schooling, would engage in more ecological reasoning than children in the U.S. In contrast, we predicted that U.S. children, who have less direct interaction with the natural world and more formal schooling, would engage in more taxonomic reasoning than children in Vanuatu.

Next, we examined the development of folk ecological reasoning across childhood. Reasoning about biological kinds is a developmentally privileged, core domain of thought (Inagaki & Hatano, 2002; Legare, Wellman, & Gelman, 2009; Wellman & Gelman, 1992). Eight-month old infants are sensitive to cues that a novel object is an animal as opposed to a non-living object, which suggests that the process of forming a conceptual understanding of nature begins in infancy (Setoh, Wu, Baillargeon, & Gelman, 2013). Infants will avoid potentially noxious plants (Wertz & Wynn, 2014), dangerous snakes and spiders (DeLoache & LoBue, 2009; Hoehl & Pauen, 2017; Rakison & Derringer, 2008), and rapidly acquire information from conspecifics about other

dangerous animals (Barrett & Broesch, 2012). Across cultures, children reliably categorize living organisms at the same, generic-species level (Medin & Atran, 2004). These biases are early developing and elaborated through cultural, educational, and ecological experiences (Raman & Gelman, 2004; Rhodes & Gelman, 2009). Despite this research on children's early-developing biases for reasoning about biological kinds, little work has been done to examine how children's knowledge of relationships between natural kinds develops. We predicted that older children would be more likely to engage in both ecological and taxonomic reasoning than younger children due to increased knowledge about the natural world with age. We predicted that younger children would rely more heavily on morphological similarities between kinds.

2. Study 1

In Study 1 we examined how children reason about the relations between plants and animals using a species relations task (Unsworth et al., 2012). This task presented children with picture pairs of non-human animals and plants and asked children to articulate how or why the two organisms might go together. The open-ended nature of the task allowed children to generate responses ranging from perceptual similarities between biological kinds to ecological relationships. We predicted that ecological explanations would be the more common in Vanuatu than the U.S. Second, we predicted that explanations referring to taxonomic relationships would be more common among our U.S. sample than our Ni-Vanuatu sample.

2.1. Methods

2.1.1. Participants Austin, Texas, U.S.A.

The U.S. sample (fifty-eight 5–13-year-olds, average age 8.66, $SD = 2.60$, 30 female) was recruited through birth records maintained at a research university, and at a local children's museum in Austin, Texas. Depending on the recruitment method, children participated in the study on the university campus or in a quiet room at the museum. Sixty-nine percent of parents reported their child's ethnicity as Caucasian/European American, 12.1% reported Latinx, 3.4% reported African/African-American, 3.4% reported Asian/Asian-American, 1.7% reported other, and 10.3% chose not to report their child's ethnicity.

The city of Austin, Texas, has a population of nearly 1 million people. Austin is one of the most highly educated metropolitan areas in the nation with 39% of the population over 25-years-old holding a Bachelor's degree. Children in our U.S. sample attended school in the Austin Independent School District (AISD) where they begin learning about the relationships between animals in kindergarten. The science curriculum requires that the youngest children in our studies (5-years-old/ kindergarten) should understand "that plants and animals have basic needs and depend on the living and non-living things around them for survival." Children of this age also practice sorting "plants and animals into groups based on physical characteristics." By the upper age range of our studies (13-years-old/7th grade), students are expected to have learned to "identify... changes in genetic traits that have occurred... through natural selection and selective breeding" and to be able to utilize a dichotomous key to identify insects and plants.

2.1.2. Participants Tanna, Vanuatu

The Ni-Vanuatu sample (thirty-nine 5–13-year-olds, average age 9.10, $SD = 2.64$, 16 female) was collected at schools in the town of Lenakel, or in the nearby village of Ikunala on the island of Tanna. A local research assistant conducted all interviews in one of the local languages, Bislama. The people of Tanna engage almost exclusively in subsistence agriculture (Cox et al., 2007). Tanna operates on a semi-cash economy where the majority of resources are raised or harvested and not purchased at shops. Cash tends to be viewed as a community resource, not private capital, and functions more to ensure social conformity and solidarity within the group (Peck & Gregory, 2005). Reliance

on industrial resources is minimal, amounting to approximately \$300 million per year nationwide, about 20% of which are petroleum products, and about 18% are foodstuffs (Hausmann et al., 2011; Simoes & Hidalgo, 2011). The majority of these imports are sent to Port Vila and Luganville, making subsistence living even more common on Tanna. Because of their limited access to industrial commodities Ni-Vanuatu children participate in planting, caring for, and harvesting crops, as well as raising several types of domesticated animals (i.e., pigs, cows, chickens, dogs) (Busch, Watson-Jones, & Legare, 2017; Watson-Jones, Busch, Harris, & Legare, 2017; Watson-Jones, Busch, & Legare, 2015).

Schools with formal curricula have only been present in Vanuatu for the last thirty years (Peck & Gregory, 2005). The percentage of children completing primary school between 2008 and 2012 was around 72% (UNICEF, 2013). According to the Vanuatu Ministry of Education, children in the youngest age group examined in these studies should learn to sort animals into groups and generate justifications for their groups such as, “fly or not; swim or not; lay eggs or not; etc.” Children are also expected to learn ecological characteristics of animals such as, which animals eat meat and which eat plants as well as construct food chains. Children learn about which animals are helpful to people and which are harmful. By 6th grade children learn practical knowledge about how to plan and care for gardens, including crop rotation and composting.

Five to thirteen-year-old children were chosen to participate in this study because past research has documented developmental differences with 6–10-year-olds in biological reasoning between non-Native urban, non-Native rural, and Native U.S. populations (Ross et al., 2003). Our intention was to examine how cultural variation would influence the developmental of folk ecological reasoning, so we selected the age at which past research suggested there would be the greatest conceptual change. No research of this kind has previously been conducted in Tanna, thus, we decided to broaden the age range slightly to include children 5–13-year-old.

2.1.3. Materials

Children were shown twenty-five pairs of pictures depicting various plants and animals. Included in the experiment were six plant/plant pairs, seven plant/animal pairs, and twelve animal/animal pairs. One of the plant/plant pairs was used as a practice trial, thereby bringing the total number of test trials to twenty-four. The plants and animals used in the study were chosen to afford the same types of relationships as the biological kinds used by Unsworth et al. (2012), and on the basis that they would be familiar to children in both the U.S. and Vanuatu (see Table 1 for full list). All pairs could be related to one another on the basis of their taxonomic relationship (e.g., a horse and a mouse are both mammals), or ecological relationship (e.g., a spider eats a fly). Many pairs also depicted morphological similarities (e.g., a dog and a pig both have four legs) and all pairs related to one another in more than one way (e.g., a dog and a pig are also both mammals). The pairs were each presented on an 8.5" × 11" sheet of paper with the pictures oriented on the page vertically. The pictures themselves measured approximately 6.5" × 4.5" and the position of the pictures (top vs. bottom) was counterbalanced across participants.

2.1.4. Procedure

A speaker of the participants' native language told the participant “I am going to show you some pictures of plants and animals and then ask you some questions about them. Do you want to play?” Once children felt comfortable with the experimenter, they completed one training trial and twenty-four test trials. For use in Vanuatu, the protocol was translated from English to Bislama by a local bilingual schoolteacher and then back translated to English to ensure accuracy. Research assistants were identified and recruited with the aid of local schoolteachers and representatives from the Vanuatu Cultural Center. Research assistants were required to be fluent in both English and Bislama.

Table 1
Species pairs used in Study 1.

Organism 1	Organism 2
Orchid	Hibiscus
Tree Fern	Palm Tree
Kauri Tree	Moss
Papaya	Mango
Fig Tree	Banyan Tree
Pandanus Tree	Coconut Tree
Gecko	Skink
Snake	Frog
Dog	Pig
Bee	Butterfly
Ant	Beetle
Swallow	Mosquito
Fly	Spider
Petrel	Fish
Sailfish	Marlin
Rat	Harrier Hawk
Horse	Mouse
Duck	Sandpiper
Fruit Dove	Mangrove
Dugong	Sea Grass
Cow	Grass
Snail	Noni Tree
Owl	Sandalwood Tree
Coconut Crab	Coconut Tree
Fruit Bat	Bread Fruit

2.1.4.1. Training trial. The training trial began with the experimenter turning over the training trial picture pair, pointing to each picture one at a time, and stating the species name of the plant or animal (i.e., “This is an orchid, and this is a hibiscus”). The experimenter then asked, “How or why do you think these two could go together?” All children in the U. S. received one practice trial, which depicted an orchid and a hibiscus. After giving their response to the practice trial, the experimenter provided several other explanations for how the orchid and hibiscus might go together, for example, “they are both plants” (taxonomic), “they both have petals” (morphological), “they both attract insects to eat their nectar” (ecological), or “they can both be planted in the garden for decoration” (utility). Twenty-eight of the children in Vanuatu did not receive a practice trial, however, a Chi-square on response type showed no difference in the number of participants providing the various explanation types between those who received the practice and those who did not, $\chi^2(4, N = 39) = 4.67, p = 0.32$.

2.1.4.2. Experimental trials. The experimental trials continued for twenty-four additional picture pairs. The procedure was the same as the training trial in which the pair of pictures was presented to the child, the experimenter stated the species name of each picture in the pair, and then asked how the two organisms might go together. The order in which the species were named was counterbalanced and the order in which each pair was presented to the children was random. The only difference from the training trial was that after the child gave their response the experimenter did not offer any additional explanations.

2.1.5. Coding

Responses to each of the 24 experimental pairs were video recorded and then coded into six categories based on the coding categories used by Unsworth et al. (2012). Responses were coded as ecological relationships, taxonomic relationships, utility relationships, morphological relationships, physiological relationships, or non-explanatory (see Table 2). Responses were coded by undergraduate research assistants, blind to the hypotheses of the study. Responses were coded as *ecological* if they referred to interdependent relationships between the species. Ecological relationships could refer to shared habitat relations or food chain interactions. *Taxonomic* relationships were any explanations that referred to category membership. Explanations that referenced how humans could use both organisms, or other ways the picture pair was

Table 2
Coding categories for explanations from Study 1.

Explanation type	Definition	Examples
Ecological	Refers to relationships between species, which could include habitat, food chain, or other biological needs	“The petrel eats the fish” “They can both live in the same place” “Snail can climb on the tree” “The bird can sit on top of the mangrove branches”
Taxonomic	Refers to category membership of the species	“Because they're both trees” “Both insects” “They're both plants” “Both types of birds” “Both types of lizards”
Utility	Refers to any utility function the species could provide for human use	“People eat both of them” “We weave baskets and mats” “Some people have pigs and dogs as pets” “Both are fruit and can be food” “Found where the chiefs and the fathers go”
Morphological	Refers to perceptual features of the species	“They have big leaves” “Both have feathers and look similar” “The tree fern is long and the palm is short” “Both have rough teeth” “They both have antennae”
Physiological	Refers to any behavioral similarities made possible the organism's physiology	“They both fly” “They both swim”
Non-explanatory	Any response which does not clearly indicate how the two species relate	“I don't know” “They're the same”

related to humans were coded as *utility* relationships. Responses were coded as *morphological* if they referenced the perceptual features of the organisms in the photos. Responses that highlighted a behavioral similarity were coded as *physiological*. Any explanation that did not fit into one of these coding categories was coded as *non-explanatory*.

If an explanation contained elements from more than one type of relationship (i.e., taxonomic, and ecological), that explanation was double coded. Therefore, with 24 test pairs the maximum number of explanations children could give of any one type was 24, but it was possible for children's explanations to be coded with >24 codes if a single response contained information that was relevant to more than one coding category. For example, a response of “they both have spikey noses and they both eat fish” would be double coded as morphological (spikey noses) and ecological (eat fish).

To ensure accurate translation of Ni-Vanuatu children's responses, their explanations were translated twice. First, during the experiment, the local research assistant would translate the child's responses for the experimenter, one at a time, who made note of each response. All experimental sessions were videotaped and an independent native Bislama speaker, blind to the initial translation, then reviewed these videotapes and translated the children's responses a second time. The experimenter then compared these two independent translations, and discussed any discrepancies with the translator to reach a consensus.

2.2. Results

The interrater reliability of the raters was $Kappa = 0.72$. The overall frequency of children's responses of each type were analyzed using a

multilevel linear model with random intercepts to control for non-independence of data points using category of explanation as the within subjects independent variable, and age and culture as the between subjects independent variables. The same model was used to examine differences across age and country by releveling the within subjects variable so each category of explanation type served as the reference group once.

The frequency of children's responses was standardized into z-scores and explanation type was dummy coded. Explanation type was included as a within-subjects independent variable while also controlling for participant country (U.S. or Vanuatu), and age (continuous), which was centered around the mean. Results of the multilevel linear model show that overall, ecological explanations were the most common for the U.S. sample. Children in the U.S. provided significantly more ecological responses than taxonomic responses $b = 1.41$ ($SEM = 0.093$), $p < 0.0001$. Taxonomic responses were the second most common explanation type for children in the U.S. Taxonomic responses were significantly more frequent than utility responses $b = 0.98$ ($SEM = 0.093$), $p < 0.0001$, as well as non-explanatory responses, $b = 0.88$ ($SEM = 0.093$), $p < 0.0001$, and physiological responses, $b = 0.83$ ($SEM = 0.093$), $p < 0.0001$. There was no difference in the U.S. between the number of taxonomic responses and the number of morphological responses, $b = 0.02$ ($SEM = 0.093$), $p = 0.80$ (Table 3).

In Vanuatu, as in the U.S., the most common explanation type was ecological. Ni-Vanuatu children provided significantly more ecological responses than taxonomic responses $b = 2.59$ ($SEM = 0.11$), $p < 0.0001$. Ni-Vanuatu children also provided significantly more non-explanatory responses than taxonomic responses $b = 0.57$ ($SEM = 0.11$), $p < 0.0001$, and more physiological responses than taxonomic responses $b = 0.39$ ($SEM = 0.11$), $p < 0.001$. There was no difference in the frequency of morphological responses and taxonomic responses from Ni-Vanuatu children, $b = 0.21$ ($SEM = 0.11$), $p = 0.07$, nor any difference in the frequency of taxonomic responses and utility responses, $b = 0.17$ ($SEM = 0.11$), $p = 0.13$ (Table 3).

Next we provide the results of the multilevel linear model in regards to differences between the U.S. and Vanuatu and across age for each of the five explanation categories. To do this, the within-subjects variable of explanation category was relevelled so each category served as the reference group once. We present the results for each category of explanation separately.

2.2.1. Ecological explanations

The multilevel linear model examining the total number of ecological responses reveals that children in Vanuatu ($M = 14.77$, $SD = 4.01$) provided more ecological explanations than U.S. children ($M = 13.21$, $SD = 4.40$), $b = 0.23$ ($SEM = 0.10$), $p = 0.03$. The data also show an effect of age $b = 0.14$ ($SEM = 0.02$), $p < 0.0001$, such that children provided more ecological responses as they got older across both cultures.

2.2.2. Taxonomic explanations

The multilevel linear model comparing the frequency of taxonomic responses across cultural contexts and age shows that Ni-Vanuatu children ($M = 0.64$, $SD = 0.96$) provided fewer taxonomic explanations than U.S. children ($M = 5.72$, $SD = 3.22$), $b = -0.95$ ($SEM = 0.10$), $p < 0.0001$.

Table 3

Mean number of responses across cultural communities from Study 1 (standard deviations).

Explanation type	U.S.	Vanuatu
Ecological	13.21 (4.40)	14.77 (4.01)
Taxonomic	5.72 (3.22)	0.64 (0.96)
Utility	0.47 (0.88)	1.56 (1.85)
Morphological	5.64 (4.16)	1.69 (2.84)
Physiological	1.29 (1.68)	2.69 (2.05)
Non-explanatory	1.00 (1.32)	3.67 (3.01)

Participant age did not predict differences in the number of taxonomic responses, $b = 0.005$ ($SEM = 0.02$), $p = 0.81$.

2.2.3. Utility explanations

The multilevel linear model comparing the frequency of utility responses across culture and age provides marginal support for the cross-cultural difference in children's likelihood to provide utility responses. Children in Vanuatu ($M = 1.56$, $SD = 1.85$) provided more responses of this type than children in the U.S. ($M = 0.47$, $SD = 0.88$), $b = 0.20$ ($SEM = 0.10$), $p = 0.054$. Participant age did not predict differences in the number of utility responses, $b = 0.006$ ($SEM = 0.02$), $p = 0.75$.

2.2.4. Morphological explanations

The results of the multilevel linear model reveal that children in Vanuatu ($M = 1.96$, $SD = 2.84$) provided fewer morphological responses than children in the U.S. ($M = 5.64$, $SD = 4.16$), $b = -0.71$ ($SEM = 0.10$), $p < 0.0001$. There was also a significant effect of age, $b = -0.04$ ($SEM = 0.02$), $p = 0.04$, such that age was negatively associated with providing morphological explanations.

2.2.5. Physiological explanations

The results of the multilevel linear model reveal that children in Vanuatu ($M = 2.69$, $SD = 2.05$) provided more physiological responses than children in the U.S. ($M = 1.29$, $SD = 1.68$), $b = 0.27$ ($SEM = 0.10$), $p < 0.01$. There was no significant effect of age on the frequency of physiological responses, $b = -0.03$ ($SEM = 0.02$), $p = 0.16$.

2.2.6. Non-explanatory responses

The multilevel linear model shows that that non-explanatory responses were more common in Vanuatu ($M = 3.67$, $SD = 3.01$) than they were in the U.S. ($M = 1$, $SD = 1.32$), $b = 0.43$ ($SEM = 0.10$), $p < 0.0001$. There was also a marginally significant effect of age, $b = -0.03$ ($SEM = 0.02$), $p < 0.073$, which revealed as age increased, the frequency of a non-explanatory responses decreased.

2.3. Discussion

As predicted, data from Study 1 show that the most common explanation type in Vanuatu was ecological and that ecological explanations were more common in Vanuatu than the U.S. This finding is consistent with previous research and supports the proposal that direct experience with the natural world supports ecological reasoning. Children living in urban and rural communities in the U.S., who have similar exposure to formal schooling yet differ in direct experience with the natural world, show differences in their ecological reasoning. U.S. children in rural areas privilege ecological explanations more than children living in urban areas (Coley, 2012).

Despite giving fewer ecological explanations than Ni-Vanuatu children, U.S. children provided more ecological explanations than any other explanation type. Furthermore, the data show ecological explanations become more common as children get older. This similarity between populations, with different cultural, educational, and ecological experiences, in privileging ecological explanations poses two interesting potential interpretations. One interpretation is that ecological reasoning is less dependent on particular input than other ways of thinking about the natural world, thus development of folk ecological reasoning proceeds similarly across populations regardless of input. An alternative interpretation is that the necessary input for developing folk ecological knowledge is present in both contexts, albeit from different sources and in differing amounts.

We predicted that children in the U.S. would provide a greater number of taxonomic responses than Ni-Vanuatu children due to lower levels of interaction with the natural world and higher engagement in formal education. The data support our prediction; children in the U.S. provided more taxonomic explanations than children in Vanuatu. This result is consistent with previous research demonstrating that formal

education emphasizes reasoning about taxonomic relationships (Coley, 2007; Coley, Arenson, Xu, & Tanner, 2017; Coley, Vitkin, Seaton, & Yopchick, 2005; Medin et al., 2006).

An alternative interpretation for the findings of Study 1 is that Ni-Vanuatu children could have been more familiar with some of the plants and animals used in the stimuli than U.S. children, however, supplementary analysis provides evidence that this was not the case¹. The data did not show any increase in taxonomic explanations with age. It is possible that even by 5-years-old, children in the U.S. have had enough experience with taxonomic categorizations through storybooks, educational media, and parental input that they had already attained a robust knowledge of taxonomic relationships in comparison to their Ni-Vanuatu counterparts.

In Study 2 we examined whether the same patterns of reasoning about non-human biological kinds would be reflected in the way children understand the human-environment interaction. Study 1 showed that Ni-Vanuatu children provided more ecological, physiological, and utility relationships than U.S. children and conversely, that U.S. children provided more taxonomic and morphological explanations than Ni-Vanuatu children. In both populations ecological explanations were the most common. Do children in the U.S. and Vanuatu also privilege reasoning about the human-environment interaction from an ecological perspective? Do U.S. children reason more taxonomically about the human-environment interaction than Ni-Vanuatu children?

3. Study 2

In Study 2 our aim was to examine how children reason about the place of humans within an ecological system across two distinct cultural contexts. Previous research has shown consistency across urban U.S., rural, U.S., and Native American cultures in the belief that humans are distinct from animals (Leddon, Waxman, Medin, Bang, & Washinawatok, 2012). The card-sorting task we used in Study 2 provided children with pictures of both living and non-living objects and asked them to sort them into groups (Levin & Unsworth, 2013). Based on the results of Study 1, we were interested in whether the preference for ecological relationships would extend into the categorization of humans within the natural world, or if the cultural differences in taxonomic reasoning would drive children's categorization of humans. We predicted that there would be variation in the way children think about the human-environment relationship between populations: Ni-Vanuatu children would be more likely to categorize the human on the basis of ecological or utility relationships, whereas U.S. children would be more likely to categorize the human on the basis of taxonomic relationships.

3.1. Method

3.1.1. Participants Austin, Texas, U.S.A.

U.S. participants (fifty-six 6–11-year-olds, average age = 7.18, female = 29) were recruited through the birth records to participate in the study on the campus of a large research university. U.S. children completed the study in a quiet room on campus and received a small toy as compensation for their participation.

¹ Picture pairs were split into those that were more familiar to U.S. children and those that were less familiar. Pairs coded as familiar included papaya/mango, snake/frog, dog/pig, bee/butterfly, ant/beetle, mosquito/swallow, fly/spider, rat/hawk, horse/mouse, duck/sandpiper, cow/grass, and owl/sandalwood tree. The remaining 12 pairs were coded as unfamiliar. A Pearson's Chi-square test on the frequency of each explanation type between familiar and unfamiliar items revealed no difference in the frequency of taxonomic, ecological, utility, or morphological explanations between familiar and unfamiliar items. U.S. children gave fewer physiological explanations for unfamiliar items, and more non-explanatory response for unfamiliar items, $\chi^2(5, N = 58) = 34.1$, $p < 0.001$ (standardized residuals = 4.61 and 3.48 respectively).

3.1.2. Participants Tanna, Vanuatu

Ni-Vanuatu participants (fifty 6–11-year-olds, average age = 8.72, female = 22) were recruited from two elementary schools in the town of Lenakel on the island of Tanna. Local research assistants collected all Ni-Vanuatu data in Bislama. None of the participants in Study 2 participated in Study 1.

3.1.3. Materials

To assess children's conceptual organization of the natural world, the experimenter presented the participants with twelve cards, each of which depicted either a plant, animal, non-living natural kind, or a human artifact. The cards were laminated, and all measured approximately 5.5" × 4.5". The items depicted on the cards were chosen based off of previous work by Levin and Unsworth (2013), but adapted to be familiar to children in both the U.S. and Vanuatu. The pictures used included a human, a dog, a horse, a fruit bat, a bird, a butterfly, a fish, a coconut tree, a palm tree, a stone, the sun, and a kayak. All participants were video recorded during the completion of the task.

3.1.4. Procedure

Once children felt comfortable conversing with the experimenter, they were told that they were going to play a game with pictures of plants and animals. The experimenter then showed the child the first picture, and asked, "Can you tell me what this is a picture of?" This process was repeated for all twelve picture cards, which were presented to the child in a random order. Once all the pictures had been presented to the child, the research assistant told the participant to "put these pictures into groups however you think they should go and remember there are no right or wrong answers" in the child's native language. For use in Vanuatu, this prompt was translated from English to Bislama by a local bilingual schoolteacher, and then back translated to English to ensure accuracy. Similar to Study 1, the prompt was intentionally open-ended to allow children an opportunity to group the cards in any way they wanted. Research assistants were identified and recruited with the aid of local schoolteachers and representatives from the Vanuatu Cultural Center. Research assistants were required to be fluent in both English and Bislama. Children were told that they could make as many or as few groups as they liked, and were reassured that there was no right or wrong way to group the pictures. Once the child finished making their groups, the experimenter went through each group the child made and asked, "why did you put these together?"

3.1.5. Coding

Children's explanations for the groups they made were coded into seven categories. Responses were coded as ecological relationships, taxonomic relationships, utility relationships, morphological relationships, physiological relationships, or non-explanatory, and these categories were the same as those used in Study 1. One additional code, a *uniqueness* code was added to Study 2. Instances where children stated that they left a particular picture on its own because it was different from the others were coded using a uniqueness code. If an explanation contained elements from more than one type of relationship (i.e., taxonomic and ecological), that explanation was double coded. Additionally, because children were allowed to make any number of groups they felt necessary, the total number of explanations children gave varied across participants. Undergraduate research assistants, blind to the hypotheses of the study, coded explanations from the videos.

3.2. Results

We present data on the frequency of each type of explanation in the U.S. and Vanuatu, and then we present data on the groups children made. The groups children created were analyzed in two ways. First, we discuss logistic regression analyses between the U.S. and Vanuatu. Four independent binomial logistic regression analyses were conducted to assess whether country or age significantly predicted the probability

that children grouped the human with a plant, a human artifact, a non-living natural kind, or an animal. Next, we discuss a cluster analysis of the data and provide a regional interpretation of the resulting dendrograms.

3.2.1. Explanations

For each group children made they provided an explanation of why they grouped the items together. The interrater reliability of the raters' explanation codes was Kappa = 0.83. A Pearson's Chi-square test was conducted on the overall frequency of each explanation type to examine whether the frequency of each explanation type was impacted by country. Results show that the frequency of explanation types differed across cultures, $\chi^2(6, N = 106) = 21.76, p = 0.001$. Examination of the standardized residuals reveals that children in the U.S. used more taxonomic explanations for their groups than Ni-Vanuatu children, whereas Ni-Vanuatu children used more morphological and utility explanations for their groups. The percentage of the total number of explanations accounted for by each explanation type by country with the standardized residuals is presented in Table 4.

3.2.2. Sorting

The data show that children in the U.S. sorted the twelve cards into 4.16 groups on average ($SD = 1.49$), while children in Vanuatu created, on average 4.88 groups ($SD = 1.69$). Children in Vanuatu created significantly more groups than children in the U.S., $t(104) = 2.33, p < 0.05, d = 0.45$.

To examine the groups participants made, we coded for whether participants put the human with any animal, with any plant, with any non-living natural kind, and with the human artifact. We then conducted four independent binomial logistic regression analyses using country (U.S., Vanuatu) and age as the independent variables to examine whether country or age significantly predicted how they sorted the human. Results showed similarities between the U.S. and Vanuatu and revealed one key difference.

Results showed that children in the U.S. ($M = 38\%$) categorized the human and plants into the same group at the same frequency as children in Vanuatu ($M = 32\%$), $b = 0.02, z(1) = 0.034, p = 0.97$. Children's likelihood to group the human with a plant was not predicted by age, $b = -0.17, z(1) = -1.08, p = 0.28$. The data also showed no difference in the likelihood of children grouping the human with the human artifact between the U.S. ($M = 18\%$) and Vanuatu ($M = 20\%$), $b = -1.06, z(1) = -1.69, p = 0.09$. Age however, was a significant predictor of children's likelihood to group the human with the human artifact across cultures, $b = -0.61, z(1) = -2.45, p = 0.01$ (Odds Ratio = 0.54, 95% CI = 0.34–0.89), such that younger children were more likely to group the human with the artifact than older children.

Children's likelihood to categorize the human with a non-living natural kind was significantly predicted by country. Children in the U.S. ($M = 25\%$) placed the human in a group with a non-living natural kind (sun or stone) less frequently than children in Vanuatu ($M = 42\%$), $b = -1.0, z(1) = -2.0, p = 0.045$ (Odds Ratio = 0.37, 95% CI = 0.14–0.98). Age did not significantly predict the likelihood that children would group the human with a non-living natural kind, $b = -0.13, z(1) = -0.87, p = 0.39$.

Table 4

Percentage of total number of responses from each coding category across cultures.

Explanation type	U.S.	Vanuatu	Standardized residual
Ecological	25%	23%	±0.39
Taxonomic	30%	16%	±3.67*
Utility	6%	11%	±2.27*
Morphological	7%	14%	±2.65*
Physiological	9%	10%	±0.17
Non-explanatory	10%	10%	±0.16
Unique	14%	15%	±0.52

Finally, the data show a significant interaction between country and age in the frequency with which participants in the U.S. and Vanuatu grouped the human with an animal. The results show that the odds of placing the human in a group with an animal increases with age for U.S. children, while the odds decreased for Ni-Vanuatu children, $b = 0.81$, $z(1) = -2.27$, $p = 0.024$ (Odds Ratio = 2.24, 95% CI = 1.11–4.49). (Fig. 1).

3.2.3. Cluster analyses

The groups that participants created were then used to conduct two independent cluster analyses. Using Euclidean distances between each of the twelve items a similarity matrix was constructed. The similarity matrix of Euclidean distances was then used to create two separate dendrograms, one for the U.S. and one for Vanuatu (Figs. 2 and 3). Consistent with research on folkbiology, these data show similarity across cultures in how plants and animals are sorted (Berlin, Breedlove, & Raven, 1973). A regional interpretation of the two dendrograms revealed that data from both the U.S. and Vanuatu cluster into two distinct branches, a branch dedicated to animals, which includes the dog, horse, bird, bat, and butterfly in both cultural communities. Finer-grained similarity between the U.S. and Vanuatu is revealed in distinct clusters for plants, quadrupedal mammals, and the three flying animals (bat, butterfly, bird).

There is variation between populations in how children categorize humans in relation to other natural kinds. In the U.S. the human is included on the branch with the rest of the animals, whereas in Vanuatu the human is more closely associated with the sun and the stone. One other difference is the association between the canoe and the fish in Vanuatu. The data from Vanuatu suggest that children associate the fish more closely with the canoe than children in the U.S., who were more likely to group the fish and the other animals.

3.3. Discussion

The data from Study 2 demonstrate that there is both cultural variation and similarity in the development of children’s knowledge about the human-environment interaction. Experience plays an

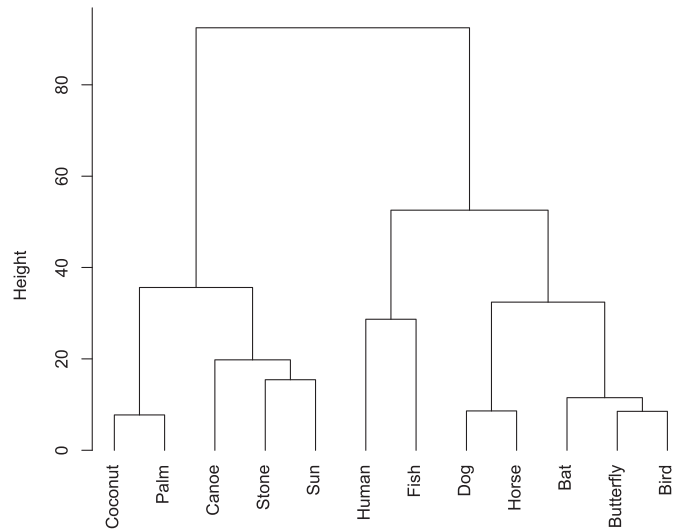


Fig. 2. United States dendrogram of similarity scores from Study 2.

integral role in shaping children’s conceptual understanding of the role of humans in the biological world. U.S. children were more likely to group the human with an animal as they got older, whereas children in Vanuatu were less likely to categorize the human with another animal as they got older. This finding provides more nuanced insight into previous research that shows across cultures, young children deny that humans are animals, but older children are willing to accept that humans are mammals (Leddon et al., 2012). Our findings suggest that the belief that humans are animals does not increase with age in all populations. In the U.S., where age and formal educational attainment are tightly linked, a folkecology which emphasizes the taxonomic relations between humans and the rest of the biological world may be more common. The categorization data also demonstrate that the U.S. participants placed the human with other animals, on the same branch as the fish, dog, horse, bat,

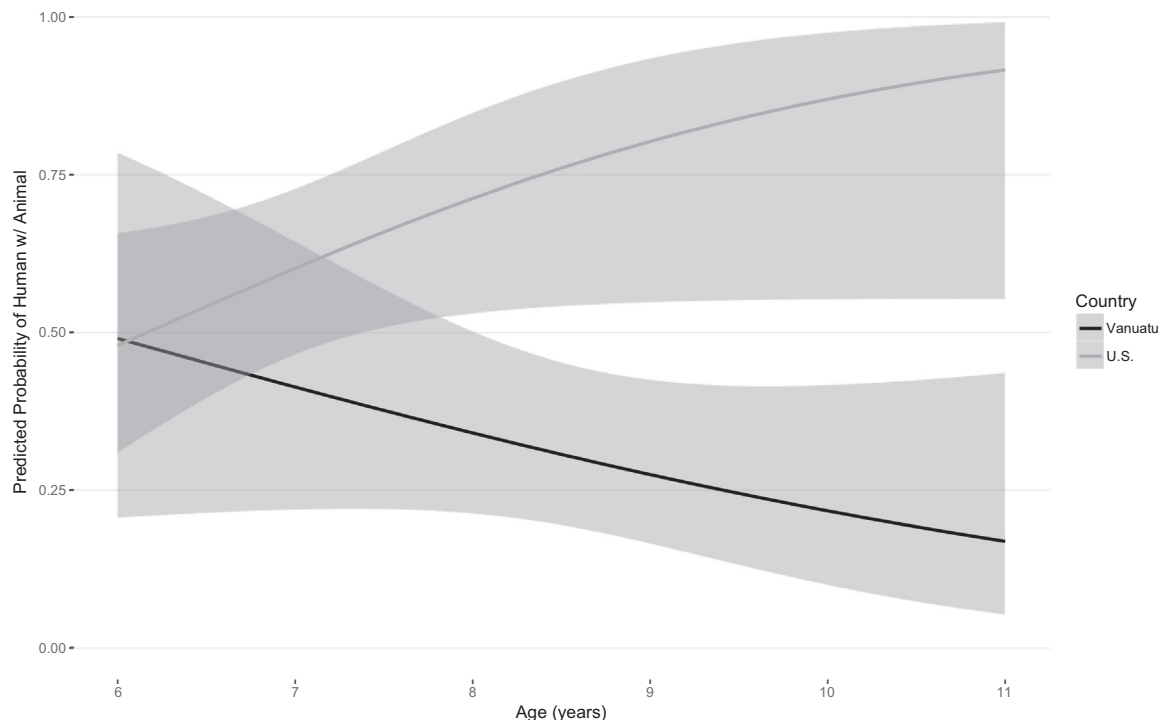


Fig. 1. Predicted probability of participants placing the human in a group with another animal across cultures in Study 2.

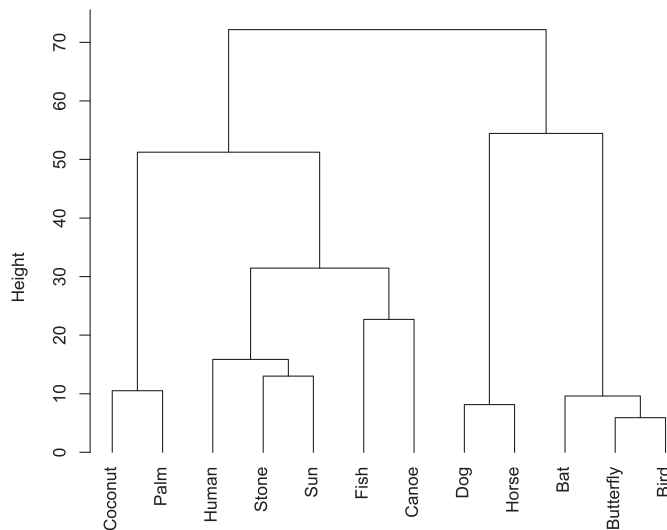


Fig. 3. Vanuatu dendrogram of similarity scores from Study 2.

butterfly, and bird, whereas the Ni-Vanuatu participants placed the human on a branch with all non-animals (except fish). Variation in how humans are categorized may arise from differences in input: In the U.S., less direct experience with the natural world and more experience with formal education increases taxonomic reasoning. In Tanna, the categorization of the human with non-living natural kinds may be related to Tannese origin beliefs where stones play a central role (Bonnemaison, 1994). In line with the finding that non-living natural kinds are closely related to humans, an analysis of children's storybooks shows that Native-American authors are more likely than non-Native American authors to provide greater depth of information about the natural world by including information about non-living natural kinds (Dehghani, et al., 2013). This suggests that cultural and ecological input may alter the development of children's concepts regarding the human-environment interaction.

The data on children's explanations provide insight into the motivations underlying the groups children constructed. In the U.S., the most common explanation type was taxonomic, whereas in Vanuatu, the most common explanation type was ecological. Notably, Ni-Vanuatu children also provided many taxonomic, uniqueness, and morphological explanations, while U.S. children also provided many ecological and uniqueness explanations. Unlike Study 1, in which there was a distinct preference for ecological explanations in both communities, Study 2 revealed no clear preference in children's explanations, highlighting the variability in children's understanding of the human-environment interaction.

Study 2 also revealed similarities across cultures, providing convergent evidence for the conclusions of previous research on folk biological knowledge (Berlin et al., 1973). Overall, children in both the U.S. and Vanuatu held similar conceptual categories for non-human biological kinds. Children in both Vanuatu and the U.S. reliably grouped quadrupedal mammals, apart from flying animals, apart from plants. Children's understanding of the human environment interaction exhibits striking variation over the course of development, and is influenced by cultural, educational, and ecological experience.

4. Conclusion

The aim of the current studies was to examine variation in children's reasoning about the ecological relationships between plants, animals, and humans in populations that differ based on relevant variables of interest. We conducted a cultural comparison between two populations of children who differ in their amount of direct experience with the

natural world and formal education. Our data support the proposal that reasoning about the natural world is early developing and responsive to cultural, educational, and ecological input.

When reasoning about the relations between plants and non-human animals, children in both populations privileged ecological reasoning. This finding is notable given the substantial differences between these two communities in the way children spend their time and attain knowledge about the natural world. Children in Vanuatu attend school irregularly, the curricula is informal and often at the discretion of the instructor, and a large portion of their time is spent outdoors engaging in subsistence agricultural and foraging activities. In the U.S., children spend the majority of their time in a highly standardized school environment, or indoors working on homework or engaged with technology.

The prevalence in the use of ecological reasoning in both populations to understand non-human biological kinds suggests less dependence on particular cultural input pointing to an early developing, core domain of thought (ojalehto & Medin, 2015). Conversely, other ways of thinking about the natural world, such as utility, taxonomic, morphological, and physiological, showed wider variation across cultures. For instance, utility explanations were given very infrequently in the U.S., possibly due to limited knowledge of how humans use natural kinds. In contrast, taxonomic explanations were given very infrequently in Vanuatu, possibly because knowledge of taxonomic relationships may be more reliant on particular educational input and less relevant to navigating the local ecology than ecological relationships. Study 2 provided convergent evidence to Study 1: U.S. children were more likely to sort humans and animals together with age whereas Ni-Vanuatu children were less likely to group human and animal together with age. Children in the U.S. were also more likely to generate taxonomic explanations for their groupings than Ni-Vanuatu children, providing further evidence that taxonomic reasoning is reliant on specific educational input.

What do these results mean for understanding folk ecology from an evolutionary perspective? Why do children with substantially different cultural and environmental input favor ecological explanations when reasoning about the connection between two non-human biological kinds? Two theories provide complementary cultural evolutionary explanations for the prevalence of ecological reasoning in the populations we studied (Berkes & Turner, 2006). The first theory is that ecological reasoning only emerges as a result of learning that resources are limited (Holt, 2005). After an event of resource scarcity, societies develop rules and taboos, such as closed fishing areas or bans on harvesting immature individuals to prevent future resource depletion (Johannes, 2002). This could explain the prevalence of ecological reasoning in Vanuatu, an island population with firsthand knowledge of the limitations of natural resources. The second theory is that there is a slow accumulation of ecological knowledge across generations as a result of observation and experiences in nature and a corresponding development of beliefs, as well as cultural and educational institutions that help to promote conservation (Turner & Berkes, 2006). This could explain the emphasis on ecological reasoning in biological science curriculum in schools in the U.S.

What is the function of an intuitive folk ecological theory? One possibility is that humans have evolved a specialized learning mechanism that prioritizes the learning of correlational structures between biological kinds. A mechanism of this kind might cause people to pay particular attention to the correlation between seasons and fruit ripening or animal migration. In a complex and dynamic environment, an intuitive theory that prioritizes rapid learning of relations between biological kinds (i.e., fruit bats eat breadfruit) would allow humans to more accurately predict the location of natural resources and thus, may confer a fitness advantage to individuals. Future research could examine whether learning about correlations between natural kinds occurs more quickly than learning about correlations between other, non-natural kinds. Learning correlations between natural kinds more quickly might suggest a specialized learning mechanism that prioritizes ecological relationships. Another possibility is that humans have innate

knowledge about ecological relationships. Previous research has shown that young children and adults exhibit increased attention to snakes and spiders (DeLoache & LoBue, 2009; New & German, 2015; Rakison & Derringer, 2008), preferentially associate them with fear stimuli (Hoehl & Pauen, 2017), exhibit prepared learning of danger information about animals (Barrett & Broesch, 2012) and show behavioral avoidance of potentially noxious plants (Wertz & Wynn, 2014). Furthermore, there is neurobiological evidence in monkeys for the rapid detection of snakes (Van Le et al., 2013). Additional data are needed to examine whether folk ecological reasoning is supported by specialized learning mechanisms or innate ecological knowledge.

The results from these studies provide new insight into how variation in cultural beliefs, experience in the natural world, and experience with formal education may shape the development of folk ecological reasoning. Data that can speak to the impact of these environmental inputs on children's beliefs about the environment, resource consumption, and conservation is critical as our species faces mounting environmental problems. Examining how diverse populations reason about ecology reveals flexibility in the development of folk ecological knowledge. Flexibility in reasoning about the natural world presents an opportunity for educational strategies to improve our ecological knowledge and environmental decision-making.

Data availability

The data associated with this research are available at: www.cristinelegare.com

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