Taxonomic and Ecological Relations in Urban and Rural Children's Folk Biology[1]

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Taxonomic relations organize knowledge and guide induction in the domain of folk biology. However, potentially orthogonal ecological relations influence categorization and reasoning for adult experts, but not novices. The present study examines the potential role of direct experience in guiding folk biological conceptual development. 106 6-, 8- and 10-year-olds living in urban (high population density) and rural (low population density) communities in New England were given a triad induction task which examined whether taxonomic or ecological relations guided inferences about "insides," and a sorting task which examined their use of taxonomic and ecological relations to group pictures of plants and animals. As predicted, ecological relations were more evident in the sorting and justifications of rural children, although taxonomic relations were preferred for induction and sorting in both populations. Results suggest that ecological relations increase in salience with development and augment taxonomic relations for organizing folk biological knowledge to a greater degree in populations with relatively high opportunities for direct experience with plants and animals.

Taxonomic relations (e.g., relations based on overall similarity, shared features or common membership in superordinate classes) are extremely powerful for organizing young children's knowledge about the biological world and for guiding inferences that go beyond that knowledge (e.g., Carey, 1999; Coley, 1995; Coley, Solomon & Shafto, 2002; Keil, 1989). Parental input to children about living things stresses the importance of taxonomic relations among objects (Gelman, Coley, Rosengren, Hartman & Pappas, 1998). Moreover, by 30 months children prefer to generalize a property on the basis of category membership–conveyed by labels–than appearance (Gelman & Coley, 1990). Likewise, models of inductive reasoning in adults (e.g., Osherson, Smith, Wilkie, López & Shafir, 1990; Sloman, 1993) also emphasize the importance of taxonomic relations.

However, studies of folk biological expertise in adults suggest that individuals with extensive experience utilize ecological relations (relations based on habitat, interaction, or shared niche) as well as taxonomic relations among species in both categorization and reasoning. For instance, Shafto and Coley (in press) found that novices sorted sea creatures on the basis of taxonomic relations (e.g., *whales, sharks, fish*) whereas commercial fishermen used ecological relations (e.g., subdividing *fish* on the basis of feeding habits and migratory patterns) in addition to taxonomic relations. Similar findings have been reported for Itza' Maya versus US undergraduates sorting mammals (López, Atran, Coley, Medin & Smith, 1997), sports fishermen versus US undergraduates (Boster & Johnson, 1989), and US tree experts (Medin, Lynch, Coley & Atran, 1997). With respect to induction, Shafto and Coley (in press) show that commercial fishermen made causal inferences based on ecological relations when asked to make generalizations about a novel disease, whereas novices relied on taxonomic relations. Likewise, the taxonomically-driven model developed by Osherson et al. (1990) does not predict the inferences of Guatemalan Itza' Maya

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with respect to mammals and palms (López et al., 1997), nor does it predict the inferences of Chicago-area tree experts with respect to trees (Proffitt, Coley & Medin, 2000). (See also Lin & Murphy, 2001; Medin, Coley, Storms & Hayes, in press; Ross & Murphy, 1999, for further discussion of non-taxonomic relations guiding induction).

In sum, research with adults suggests that experience may increase the salience of ecological relations relative to taxonomic relations in folk biology. Experts' categorization and reasoning seem to be driven as much by specific knowledge about categories and properties, as by general taxonomic relations between categories, suggesting a pervasive effect of domain-specific experience on folk biological thought. However, we know little about the developmental course of this shift in the relative salience of taxonomic versus ecological relations.

Several studies have looked at experience and development of folk biology. Inagaki (1990) found that direct experience raising goldfish impacted reasoning about similar species; children who raised goldfish were more likely than their counterparts who did not to reason about a novel aquatic animal (a frog) by analogy to goldfish. Children who differ in cultural beliefs about relations between humans and nature, and presumably in direct experience with nature, also differ in the centrality of humans (anthropocentrism) in folk biological reasoning. Ross, Medin, Coley and Atran (2003) examined inductive inferences among three populations–Native American and European American children in rural Wisconsin, and ethnically diverse urban children in Boston–by teaching them novel properties about certain species and querying patterns of projection to other species. Between the ages of 6 and 10, rural Native American children showed little evidence of anthropocentrism, whereas rural European American children showed decreasing anthropocentrism and urban children showed increasing anthropocentrism. Moreover, both rural groups exhibited systematic taxonomic reasoning earlier than the urban group. K. Johnson and colleagues (e.g., Johnson & Eilers, 1998) have shown that specific expertise leads to accelerated acquisition of subordinate-level categories. Perhaps most relevantly, child dinosaur experts studied by Gobbo and Chi (1986) showed use of causal/ecological as well as taxonomic relations in organizing knowledge of dinosaurs. Although these studies suggest that experience leads to increased differentiation and sophistication of taxonomic relations, they do not look at differences in the relative salience of ecological relations.

The research presented herein involves comparative studies of the acquisition of folk biological knowledge in rural and urban New England children. Context is a critical albeit often overlooked factor in conceptual development (e.g., Cole & Scribner, 1974; Coley, 2000; Greenfield & Lave, 1982). For instance, children in different contexts may participate in different activities, or in similar activities with different frequency (LCHC, 1983). The urban-rural comparison is especially germane for the development of folk biological thought because *prima facie*, these two populations differ greatly in terms of the potential for direct biological experience offered in their respective environments. Rural children–by definition living in much less densely populated areas– are more likely to have greater direct experience via exposure to plants and animals in relatively intact ecosystems. In contrast, urban children may have little opportunity for such direct experience. Experience may lead rural and urban children to differ with respect to the relative importance of taxonomic and ecological relations in organizing folk biological knowledge. Like adult experts, rural children–with more potential to garner direct experience with plants and animals–may find ecological relations relatively salient.

These questions were addressed using both targeted and open-ended procedures. A triad induction task was used to directly compare the salience of taxonomic versus ecological relations in guiding generalizations about "insides." Of interest are the relative frequency of biological versus ecological projections. If experience renders ecological relations more salient, rural children should be more likely to generalize based on ecological relations than urban children. A less constrained way to examine the relative salience of taxonomic versus ecological relations is to present a set of stimuli in which both kinds of relations are available, and note which relations children use to spontaneously sort the stimuli. In addition to the induction task, participants were asked to sort a set of 15 detailed color drawings of plants and animals falling into orthogonal taxonomic and ecological groups. Of interest are the relative frequency of taxonomic versus ecological groupings and justifications in each population. If experience leads to increased salience of ecological relations, then frequency of ecological groups and ecological justifications should be higher for rural than urban children. If any of these predictions are confirmed, the course of age-related changes in the relative salience of taxonomic versus ecological relations could be informative. If taxonomic relations predominate among younger children in both settings, and ecological relations increase in salience relatively late for rural children, it would suggest that knowledge of taxonomic relations among living kinds provides a foundation upon which ecological reasoning develops. Alternatively, if ecological relations are more salient among rural children from early in development, it would suggest that greater experience with plants and animals may give children more flexibility in organizing knowledge at initial stages of acquisition.

Method

Participants

"Urban" and "rural" populations were defined based on population-density data from the 2000 US Census. Urban participants were kindergartners, 2^{nd} graders, and 4^{th} graders from an school in East Boston, MA (population density 12,166 people per square mile). Densely populated urban environments are likely to offer little opportunity for direct experience with plants and animals because of the lack of access to habitats that have not been significantly impacted by human activity. Rural areas were defined as areas with less that 1% of the population density of the urban population. Specifically, rural participants were kindergartners, 2^{nd} graders, and 4^{th} graders from schools in North Berwick, ME (pop. density 112) and Plainfield, NH (pop. density 43). Total N=106 (Kindergarten N_{rural}=16, M_{Age}=6-2; N_{urban}=19, M_{Age}=6-0; 2^{nd} Grade N_{rural}=17, M_{Age}=8-0; N_{urban}=14, M_{Age}=8-2; 4^{th} Grade N_{rural}=16, M_{Age}=10-1; N_{urban}=24, M_{Age}=10-2). These age groups are interesting for several reasons. Kindergartners are just beginning formal education, and as such are unlikely to have had extended exposure to formal science curricula, so their responses are likely to represent informally acquired folk knowledge. Moreover, between the ages of 6 and 10, important developmental changes occur in biological reasoning (e.g. Carey, 1985), and some evidence also points to intriguing group differences in reasoning during this period (e.g., Ross et al., 2003; Hatano, Siegler, Richards, Inagaki, Stavy & Wax, 1993).

Materials, Design, and Procedure

Triad Induction Task. Stimuli consisted of 12 triads of full color detailed line drawings of plants, animals, and naturally occurring objects or substances. Each triad contained a target picture of a plant or animal, a *taxonomic match* belonging to the same superordinate category as the target picture, and an *ecological match* belonging to a different superordinate category, but which was related ecologically to the target picture. For example, in one triad, the target was *bee*, the taxonomic base was *fly* (both are insects) and the ecological base was *goldenrod* (a wildflower from which bees collect pollen). The ecological match was varied so that 4 triads involved predator/prey relations (e.g., trout-fly), 4 triads involved organisms and some aspect of their habitat (e.g., walleye-water) and 4 triads involved organisms that share ecological niche or some other indirect relation (e.g., eagle-wolf). All triads are presented in Table 1.

Children were tested individually away from their classroom. After a warm-up task, they were shown both matches for the first target, and told about contrasting internal properties for each item. Information was presented using generic sentence frames, to emphasize that the property should be taken as true of the kind generally, e.g., "See this fly? Flies have one kind of stuff inside. See this goldenrod? Goldenrod plants have another kind of stuff inside."

Table 1. Picture Triads used in Induction Experiment.

Target	***Taxonomic Match***	***Ecological Match***	***Ecological Relation***
Worm	Snake	Rock	Habitat
Walleye	Sparrow	Water	
Blue jay	Turtle	Maple	
Eagle	Raccoon	Cloud	
Bee	Fly	Goldenrod	Same ecological niche or other indirect interaction
Turtle	Snake	Walleye	
Bear	Raccoon	Bee	
Eagle	Blue jay	Wolf	
Bear	Wolf	Trout	Food chain
Milkweed	Goldenrod	Water	
Eagle	Sparrow	Trout	
Trout	Walleye	Fly	

Children were then shown the target picture, and asked which kind of stuff it would have inside, e.g., "See this bee? Do you think bees have the same kind of stuff inside as flies, or the same kind of stuff inside as goldenrod plants?" All 12 triads were presented in a different random order for each child.

Sorting Task. Participants were presented with 15 color drawings of organisms falling into orthogonal taxonomic and ecological groups. Taxonomic groups were *mammals*, *birds*, *insects*, *trees*, and *plants*. One member of each taxonomic group fell into each of the following ecological (habitat-based) groups: *forest species*, *meadow species*, *wetland species* (see Table 2). Pictures were arrayed on a table, and participants were asked to “Put together the things that go together,” and to explain why they formed each group. The sorting task was always administered first because it was less constrained and therefore deemed less likely to influence performance on the induction task.

Table 2. Stimulus Pictures Used in Sorting Experiment.

	Ecological (Habitat) Category		
Taxonomic Category	*Forest*	*Meadow*	*Wetland*
Mammal	Red Squirrel	Woodchuck	Beaver
Bird	Screech Owl	Meadowlark	Common Loon
Insect	Gypsy Moth	Firefly	Dragonfly
Tree	White Pine	Paper Birch	Black Willow
Plant	Common Fern	Milkweed	Cattails

Results

Triad Induction Task

Relative frequencies of taxonomic projections (i.e., responses where the child indicated that the target would have the same stuff inside as the taxonomic match) were computed for each child and analyzed using a 2 (Population: Urban, Rural) x 3 (Age Group: Kindergarten, 2nd Grade, 4th Grade) x 3 (Triad Type: Predator/Prey, Habitat, Ecological Niche) mixed ANOVA. All differences in cell means reported below are significant at $p<.05$ by Tukey HSD. It was predicted that rural children should find ecological relations more salient than urban children, and therefore should make fewer taxonomic projections.

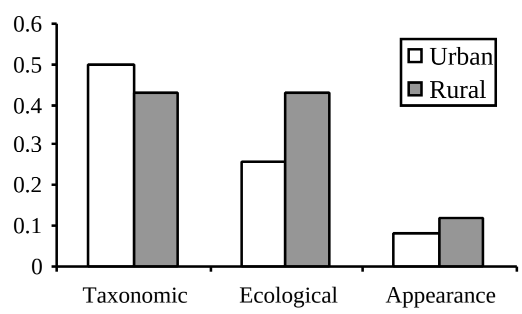
Overall, taxonomic projections were preferred at above-chance levels (*M*=.73, *t*(105)= 12.08, *p*<.0001). Contrary to the prediction, urban and rural children did not differ on frequency of taxonomic projections (M_{urban}=.72, M_{rural}=.75). However, taxonomic projections were more frequent for 2nd and 4th graders (*M*=.77 and .78, respectively) than for kindergartners (*M*=.64), *F*(2,100)=6.43, MS_E =.107, *p*<.003. Frequency of taxonomic responses also differed by triad type (*F*(2,200)=60.22, MS_E = .041, *p*<.0001). Specifically, taxonomic projections were most frequent for predator/prey triads (*M*=.90) followed by ecological niche triads (*M*=.73) and habitat triads (*M*=*.58*), suggesting that shared habitat in particular provided a compelling ecological alternative to taxonomic-based projection. No other effects reached significance.

Sorting Task

Sorting responses were scored based on which cards were grouped together, and also based on how the groupings were justified. The actual sorting was scored by noting which of the 105 possible item pairs were grouped together by each child. Then the relative frequency of grouping each pair was computed for each age group and location. Overall, urban and rural children showed extremely high agreement (*r*(105)=.96, *p*<.0001). Moreover, both urban and rural children sorted organisms into predominantly taxonomic groups. To test this, the mean relative frequency of grouping together the 15 pairs of taxonomically related organisms (e.g., *red squirrel* and *woodchuck*, *paper birch* and *black willow*) was compared to the relative frequency of grouping together a randomly-selected group of 15 pairs via Monte Carlo simulation. For each age group in both locations, taxonomically related pairs were much more likely to be sorting into the same pile than randomly chosen pairs, *z*= 6.94 - 8.56, *p*<.0001). A comparable analysis of ecological pairs revealed no tendency to group organisms on the basis of habitat. However, plant-animals pairs were grouped together more frequently by rural 2nd and 4th-graders than urban 2nd and 4th-graders (Paired Sign Test *p*<.0001), suggesting that relations between plants and animals were more salient to older rural children.

Justifications for each grouping were coded for content as *appearance* (i.e, based on color, size, shape, appendages, e.g. "these have two wings"), *taxonomic* (based on a shared name or being "the same kind"), *ecological* (based on interactions among organisms or between organisms and their environment, e.g., "these live in the water") or *other*. Except for *other*, categories were not mutually exclusive and responses could fall into more than one category. Coding was done independently by 2 coders blind to the hypotheses of the study, with a reliability of 91%. Disagreements were resolved by a 3rd coder. Each child was given 3 scores, corresponding to the proportion of groups justified as *appearance*, *taxonomic*, and *ecological*. These were analyzed using a 2 (Population: Urban, Rural) x 3 (Age Group: Kindergarten, 2nd Grade, 4th Grade) x 3 (Justification: Appearance, Taxonomic, Ecological) mixed ANOVA. In contrast to the sorting data reported above, urban and rural children showed clearly different patterns of justifications for their groupings, as evinced by a population x justification interaction, *F*(2,198)=3.52, MS_E=.111, *p*=.03. Means are shown in Figure 1.

Figure 1. Relative Frequency of Justifications by Population.



Simple effects analyses revealed that for urban children, taxonomic justifications (*M*=.50) were more frequent than ecological justifications (*M*=.26) which were more frequent that appearance justifications (*M*=.08). In contrast, for rural children, taxonomic and ecological justifications were equally frequent (*M*=.43), and more frequent than appearance justifications (*M*=.12). Finally, t-tests directly comparing relative frequencies of each justification in the two populations revealed no differences in appearance or taxonomic justifications, but a reliable difference in ecological justifications, ($t(103)=2.71$, $p=.008$). No age differences reached significance.

Discussion

These results suggest that taxonomic relations are equally salient to urban and rural children, and are important in organizing folk biological thought in both populations. Both groups relied on taxonomic over ecological relations to guide inferences about "stuff inside." The salience of taxonomic relations was underscored by results of the sorting task; both urban and rural children at all ages showed an overwhelming preference to group together species from the same taxonomic class (e.g., *mammals*, *trees*) rather than from the same ecological habitat (e.g., *wetlands species*). Taxonomic justifications were also relatively frequent in both groups at all ages; almost half of all groupings were explained on taxonomic grounds. Although there was an increase in taxonomic induction with development, the importance of taxonomic relations in sorting did not change with age. Thus, these results reinforce previous findings showing the importance of taxonomic relations in folk biological thought.

In addition to the clear importance of taxonomic relations, results of the sorting task show that, as predicted, ecological relations were more salient to rural than urban children. Rural children were more likely than urban children to cross taxonomic boundaries by including plants and animals together in the same grouping; this tendency was more pronounced in older rural children. Rural children were also more likely than urban children to justify a grouping on ecological grounds; indeed, for rural children, such justifications were as frequent as taxonomic justifications. These results are remarkably consistent with results of adult studies that link expertise with increased salience of ecological relations.

Taken together, these results suggest differences in folk biological conceptual development between rural and urban children. For both groups, taxonomic relations are salient early on and become more so; with development ecological relations become increasingly salient to rural children but not to urban children. Ecological relations do not eclipse, but rather augment taxonomic relations by potentially giving rural children multiple ways to organize and utilize folk biological knowledge. This pattern of augmentation rather than replacement is similar to that reported by Shafto & Coley (in press) for commercial fishermen.

Given the difficulty in making quasi-experimental comparisons and the many potential differences between the urban and rural sample beyond potential for direct biological experience, it is critical to emphasize that the differences between urban and rural children were not global. Urban and rural children did not differ with respect to patterns of induction, sorting, or frequency of taxonomic justifications. Rather, as predicted, differences were specific to the use of ecological relations in folk biological reasoning. Finally, although these results document a specific difference in folk biological thought between urban and rural children, they do not pinpoint the cause of that difference. Although consistent with the hypothesis that greater access to direct experience with relatively intact ecosystems increases the salience of ecological relations in folk biological thought, the present study does not measure experience per se. It remains for future research to explore specific links between experiences with nature and conceptual structure. Nevertheless, the present results provide clear evidence for different developmental trajectories for children in different contexts, and for parallels between conceptual development and studies of adult experts and novices.

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