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Social-ecological relations among animals serve as a conceptual framework among the Wichi

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ABSTRACT

Although there is now wide agreement that across diverse cultures, taxonomic systems of organization are not necessarily the only prevailing framework for the animal kingdom, evidence concerning alternative frameworks, including ecological frameworks, remains sparse. Here, we begin to fill this gap by examining children and adults from an indigenous Wichi community in the Chaco forest of Argentina. We ask which organizing principles the Wichi invoke when organizing animals native to their forest (*tshotoy*). The results reveal that Wichi adults and children represent *tshotoy* primarily on the basis of ecological relations that become increasingly specified from with development. Moreover, the results reveal a pervasive import of social relations. Responses unveil a social-ecological framework that is well aligned with Wichi native epistemology. This new evidence, which underscores the potency of social relations within an ecological framework, also begins to map out a developmental path along which cultural knowledge grows.

1. Introduction

Jorge Luis Borges, one of the greatest Argentine writers in recent time, divided the animals into "…(a) those that belong to the Emperor, (b) those that are embalmed, (c) those that are trained, (d) suckling pigs, (e) mermaids, (f) fabulous ones, (g) stray dogs, (h) those that are included in the present classification, (i) those that tremble as if they are mad, (*j*) innumerable ones, (k) those drawn with a very fine camel hair brush, (l) others, (m) those that have just broken a flower vase, (n) those that look like flies from a long way off…" (Borges, 1952). In this passage, Borges underscores the arbitrariness, rather than the universality, of our classification of animals (Eco, 1994).

Questions concerning the organization of human concepts and categories have been pervasive in the cognitive sciences, with decades of work dedicated to identifying the conceptual frameworks that we use to organize and reason about the natural world (Margolis & Laurence, 2015; Murphy, 2002; Smith & Medin, 1981). Evidence from psychology, ethno-biology and anthropology suggests that across cultures, people use universal principles of lexical and conceptual organization to organize the natural world (Berlin, Breedlove, & Raven, 1974; Atran & Medin, 2008; Backscheider, Schatz, & Gelman, 1993; Berlin, Breedlove, & Raven, 1973; Brown, 1984; Medin, Ojalehto, Waxman, & Bang, 2015; Waxman, 2004). For decades, researchers tended to focus on the power of

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taxonomic systems of organization to conceptualize entities in the natural world (Hirschfeld & Gelman, 1994; Wellman & Gelman, 1992).

However, there is now broad agreement that taxonomic systems are not the sole organizational framework that we invoke when reasoning about the natural world. Instead, there is considerable evidence that adults and children use more than a single conceptual framework, calling upon different frameworks flexibly depending on the task at hand (e.g., Herrmann, Waxman, & Medin, 2010; Luria, 1976; Smiley & Brown, 1979; Waxman & Namy, 1997; Waxman, Herrmann, Woodring, & Medin, 2016). Moreover, the conceptual frameworks we impose are shaped powerfully by our interactions with the natural world. When asked to sort living things 'that go together by nature', urban, Western-educated people rarely invoke ecological systems, focusing instead primarily on taxonomic relations. Yet people with intimate and extensive experience in the natural world (e.g., indigenous people, people living in rural areas, experts in fishery, forestry) impose not only taxonomic systems, but also systems that highlight ecological relations among the entities (e.g., Bailenson, Shum, Atran, Medin, & Coley, 2002; López, Atran, Coley, Medin, & Smith, 1997; Medin et al., 2006; Ojalehto & Medin, 2015).

Moreover, in view of increasing evidence that we invoke conceptual frameworks flexibly, both within and across cultural groups, there is growing consensus that knowledge and culture, are best considered not as homogeneous, but as dynamic, causally distributional patterns of representations within a given community (Herrmann et al., 2010; Medin, Ojalehto, Marin, & Bang, 2013, 2015; Roberts, 1964; Sperber, 1996; Wallace, 1961; Wilensky & Resnick, 1999). From this perspective, the most compelling issue is not to identify a homogenous pattern displayed within a given cultural group, but to identify the distribution of ideas, often fragmentary and unstable, within a cultural community. In this framework, less than perfect consensus even within a given cultural group, is considered not as noise but as a sign of the more broadly distributed knowledge (Atran & Medin, 2008; Medin et al., 2013, 2015).

In the current research, we focus on the Wichi, an Argentinean Amerindian indigenous for whom ecological relations among living things take a center stage. In contrast to most cultural groups in which conceptual development has been studied, the Wichi people offer an opportunity to learn from a cohesive indigenous community with a strong native language, a constellation of experiences and a rich belief system about a cohesive and constant natural environment (for more details about the Wichi population, see Suárez & Montani, 2010; Taverna, Medin, & Waxman, 2016; Taverna, Medin, & Waxman, 2018). For example, in contrast to several other indigenous groups, the Wichi included in our investigation have remained in the same areas inhabited by their ancestors centuries ago (Braunstein, 1993; Montani, 2015). Indeed, their current cultural practices related to the natural world (gathering, collecting fruits, fishing, hunting) continue to be the same practices in the same environment that centuries ago and their ancestral native language and the cultural knowledge expressed by it remain well-preserved even today (Nercesian, 2014).

Our goal is to identify with greater precision the ecological frameworks of children and adults, and to examine how these frameworks develop. To do so, we employ a well-documented sequential sorting paradigm that has been used productively across diverse communities, including indigenous people, urban communities of university students and experts (Atran et al., 2002; Bailenson et al., 2002; Coley, Medin, & Atran, 1997; López et al., 1997; Lynch, Coley, & Medin, 2000; Medin, Lynch, Coley, & Atran, 1997; Medin, Ross, Atran, Burnett, & Blok, 2002; Medin et al., 2006).

1.1. *Understanding the natural world from an indigenous perspective*

There is now strong evidence that in contrast to the Western way of seeing the world, indigenous people tend to view themselves as ‘a part of’ (rather than ‘apart from’) the natural world (Bang, Medin, & Atran, 2007; Medin & Bang, 2014; Palmer, 2005; Pierotti, 2011; Wilbert & Simoneau, 1982). Certainly, indigenous participants invoke taxonomic relations, as do Western participants (Anderson, 1996; Berkes, 1999; Hughes, 1996; Huntington, 1992; Krech, 1999; Leddon, Waxman, & Medin, 2011; Pierotti & Wildcat, 2000; Tanner, 1979), but they also reveal powerful ecological frameworks or ‘ways of knowing’ (Barsh, 2000; Henriksen, 2009; Howitt, 2001; Mailhot, 1993). For instance, when classifying animals, the Itzaj Maya and other indigenous groups take into account not only taxonomic relations, but also the behaviors (e.g., habits, ecological proximity, domesticity), habitats, life cycles of animals, and their utility to humans (e.g., whether they are poisonous or edible) (Atran, 1998, 1999; López et al., 1997; Medin et al., 2006). Moreover, many indigenous groups endorse a pervasive belief in “spirits” and in their agency in the community and the surrounding ecosystem (Marshall, 2005; Taverna, Waxman, Medin, & Peralta, 2012). Crucially, these spirits are not seen as supernatural, but as integral agents in the natural order (Brody, 1982; Henriksen, 2009).

These organizational frameworks are typically grounded in sustained, first-hand observation of natural phenomena and encompass empirical and ideological knowledge. These frameworks are shaped by the epistemologies of the cultural community and serve as a strong guiding force for reasoning about the natural world (Medin et al., 2013).

1.2. *The natural world from a Wichi perspective*

Ecological relations among biological species, biological environments (such as the forest, rivers and lagoons), and spiritual beings are central to the Wichi (Palmer, 2005). This ecology is well captured by an overarching category, - *hunhat lheley* (inhabitants of the earth). This includes humans, spiritual inhabitants (*ahot*), and four distinct animal categories, each representing a distinct environment: *tshotoy* (animals of the forest), *tshotoy inot lheley* (animals of the water), *tshotoy fwiy’ohen* (animals of the air), *laloy* (domestic animals), and several categories of plant (see Suárez & Montani, 2010; Taverna et al., 2012; Taverna, Waxman, Medin, Moscoloni, & Peralta, 2014).

The concept of *husek* (goodwill) serves as an overarching organizing principle for *hunhat lhelhey* (inhabitants of the earth). *Husek* is aligned roughly with what Westerners describe as spirit or soul (Palmer, 2005). Within this broad concept, one type of *husek* (social goodwill) is attributed to humans, non-human animals and spiritual entities, but not to members of the plant kingdom (Palmer, 2005; Taverna et al., 2012). Social goodwill is seen as responsible for socialization (Palmer, 2005). In the Wichi epistemology, becoming socialized requires a transition from a natural, pre-social aggressive state to a more mature pro-social peaceful one, and making this transition requires *husek* (social goodwill), which provides the goodwill required to foster social cooperation and pro-social behaviors within the ecosystem (Palmer, 2005). The Wichi concept of *husek*, and social *husek* in particular, is evident in children and adult's understanding of animacy, living thing concepts and in reasoning about the *hunhat lheley* (inhabitants of the earth) (Taverna et al., 2012, 2016, 2018). In sum, a belief in goodwill as a mechanism for socialization and the close alignment among humans, nonhuman animals, and spiritual entities, constitutes a relational or ecological framework in which the social, spiritual and biological are fully intertwined (Taverna et al., 2012, 2014, 2016, 2018, Taverna, Waxman, & Medin, under review).

1.3. Overview of the current investigation

Our goal here is to illuminate further the frameworks invoked by the Wichi, focusing especially on the organizing principles invoked when considering animals native to their ecosystem. Building upon prior evidence, we go on to clarify (1) how Wichi ecological frameworks align with their native epistemologies about the *hunhat lheley* (inhabitants of the earth), and (2) how these frameworks emerge over development.

We focus on *tshotoy* (animals of the forest), a category that is imbued with powerful cultural significance because the Wichi identify themselves as descendants of *tshotoy* (Palmer, 2005; Taverna et al., 2012; Wilbert & Simoneau, 1982). Moreover, because *tshotoy* includes diverse life forms (predominantly mammals and reptiles, among others), it provides an opportunity to examine the salience of taxonomic (e.g., morphological or other perceptual commonalities among *tshotoy* like species, kind, size) and ecological relations (e.g., food chain, habitat, social relations, utility to humans).

Adopting a distinctly developmental perspective, we examine adults (Study 1) and children (Study 2). In both studies, we adapted a sorting task from previous studies (Bailenson et al., 2002; López et al., 1997; Medin et al., 2006) to assess the organizational structure (which animals cluster together in peoples' mental models) and underlying conceptual frameworks (including taxonomic and ecological frameworks, among others) when participants are asked to put together the animals they think 'go together in nature'. This instruction has been used successfully in many different cultures (Bailenson et al., 2002; López et al., 1997; Medin et al., 2006).

Within each experiment, we adopted a multifaceted analytic approach. First, we measured agreement among all participants' responses, using the 'cultural consensus model' (Romney, Weller, & Batchelder, 1986) to identify whether there was a single overarching model with broad agreement throughout the entire group. But in addition, we examined an alternative view of cultural knowledge. According to the 'culture as ecosystem' perspective (Atran & Medin, 2008; Medin et al., 2013, 2015), cultural knowledge is dynamic and variable, rather than static and homogenous. On this view, even in the absence of a single overarching model, two or more models may be expressed within a given cultural community. Outcomes like these are taken as an index that knowledge is not shared identically by all participants, but is instead distributed variably among individuals from the same cultural group. To test this alternative, we also analyzed the structure and content of each participant's responses, including any verbal explanations they may have provided. Throughout this project, we worked closely and collaboratively with native research consultants on experimental design, procedure, data collection and interpretation.

2. Study 1: Wichi adults

2.1. Method

2.1.1. Participants

Fifteen Wichi adults (9 female) ranging from 17 to 44 years of age (M_{age} = 26.3, SD = 8.5) participated. Wichi women are responsible for domestic work and are therefore more available to participate than men, whose work often takes them away from the home. In both Studies 1 and 2, all participants were native Wichi speakers living in the *Wichí Lawet* community located in the Chaco forest in the town of Laguna Yema, in Formosa, Argentina. All use exclusively Wichi at home. Regarding educational background, 2 participants completed only elementary school; 11 began, but did not complete, high school; 2 completed high school. For more details about cultural practices in this community, see Taverna et al. (2016, 2018). Individual one-one interviews, which took place in a community center, were conducted exclusively in Wichi by E.M.P. working in collaboration with the first author (M.C.B.). No others were present. E.M.P. translated Wichi to Spanish and vice-versa.

2.1.2. Design and materials

The sorting task included 41 colored photographs, each presented on a 7.5 × 5" laminated card (see Fig. 1). The animals were selected from a list of *tshotoy* that had been produced in a prior name generation task with a different group of adults from the same community (Baiocchi & Taverna, in prep.). We took care to select a representative set of *tshotoy*. Notice, however, that our set included only a single bird; this is because Wichi do not name birds as frequently as reptiles and mammals (Baiocchi & Taverna, in prep.). Nevertheless, because the set did include several members of two taxonomic life forms (reptiles; mammals), and several members of different species within these life forms (e.g., serpents, rodents, etc.) participants had an opportunity to form taxonomic groupings if they were inclined to do so.

We interviewed several members of the Wichi community, asking Wichi participants "…to make groups of animals of the forest

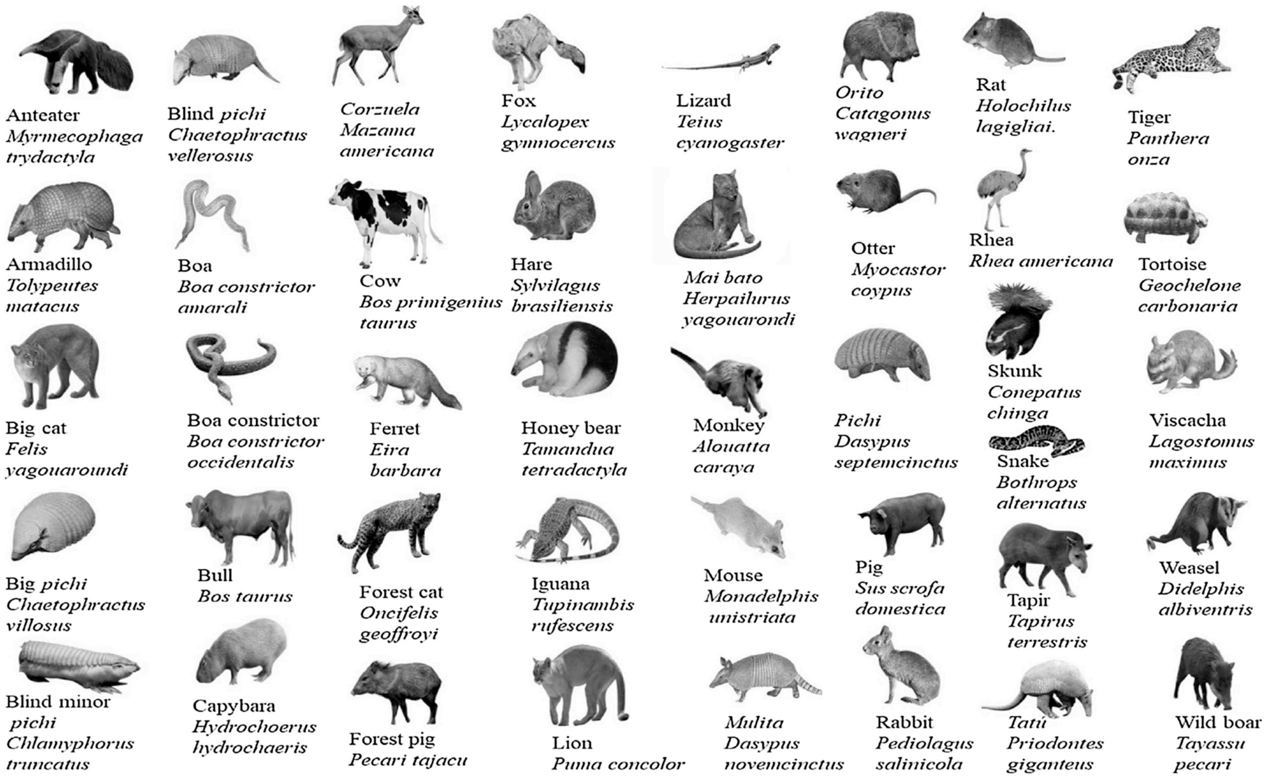

Fig. 1. Study 1. Complete set of photographs, in alphabetical order with each animal labeled with its scientific name.

(tshotoy) as you think they go together by nature".

2.1.3. Procedure

First, a native experimenter (E.M.P.) explained that we were interested in learning about the *tshotoy* of Laguna Yema. She then presented all 41 cards, in random order, asking participants to identify the depicted animal. Participants identified 95% of the photos correctly. On the rare occasion that a participant failed to identify a photo, it was excluded from that participant's subsequent sorting. Next, the photos identified by that participant were displayed randomly on a blanket on the floor in front of him/her. Each participant was asked to "make groups of these animals of the forest *(tshotoy)* as you think they are in nature". Next, the native experimenter (E.M.P.) asked (a) "Does this group have a name?" and (b) "Why did you group them in this way?". After recording their responses, participants were asked to "put these groups of animals of the forest *(tshotoy)* into larger groups as you think they are in nature". Again, for each group, she asked questions (a) and (b), above. Finally, the experimenter restored the participant's initial grouping, this time asking them to "separate these animals of the forest *(tshotoy)* as you think they are closer in nature". Again, for each grouping, participants answered questions (a) and (b), above. On every round of sorting, participants were free to form as many groups as they wished.

2.1.4. Analysis and results

2.1.4.1. Cultural consensus model (CCM). Following Romney et al. (1986), we derived, for each participant, a matrix in which rows and columns correspond to the sorted *tshotoy* and the cells correspond to the distances the participant imposed among them in their sorting. We then correlated all individual participant matrices, yielding a participant-by-participant matrix that represents the degree to which each participant's sorting converged with each other participants. This was submitted to a factor analysis to identify the degree to which there is cultural consensus concerning the composition and structure of *tshotoy*. The assumption of the cultural consensus model (CCM) is that if knowledge is widely shared within a community, the models will yield high agreement among individuals. Moreover, the CCM is sufficiently robust that consensus can be identified 'with a half-dozen or so informants' (Romney et al., 1986, p. 333). Agreement on the CCM is indicated by a strong single factor solution in which the first latent root (eigenvalue) is large compared to the rest; all scores on the first factor are positive; and the first factor accounts for most of the variance. Each participant's first factor score gives an estimate of the strength of the consensus between that participant and the cultural consensus. When this factor is high, it indicates that individual is especially 'culturally competent' in representing the cultural knowledge under investigation (Atran, 1999; Romney et al., 1986; Weller, 1987).

The CCM factor analysis revealed that no single model captured the responses of the full sample. There was not sufficient agreement within the whole sample because: i) the first latent root (eigenvalue) was not large compared to the others (6.4, 3.3 and 1.5); ii) scores on the first factor were not uniformly positive, ranging from -.600 to .931, with a mean score of .464; iii) the first factor did not account for most of the variance (42.4%). As a result, three factors were required to account for 74.5% of the variance.

We next asked whether despite the absence of a single overarching model, alternative models were expressed within this Wichi adult community. To do so, we analyzed participants' responses without an 'a priori' assumption of cultural homogeneity. Using each participant's factor loadings on the CCM factor analysis, we identified two subgroups. Participants in Model 1 exhibited high loadings on the first factor scores and low loadings on the second factor scores ($n = 8$, 5 female; age range = 18–40, $M_{Age} = 23.9$, $SD = 6.7$). Participants in Model 2 exhibited the opposite pattern of factor loadings ($n = 3$, 2 female; age range = 25–39, $M_{Age} = 31$, $SD = 7.2$). A CCM analysis conducted over participants in each subgroup yielded two consensual models, both of which highlighted ecological principles of organizations.

For participants in Model 1, the first latent root (eigenvalue) was 5.9; this is 6.5 times larger than the second (0.9). Within this group of participants, all scores on the first factor were positive, ranging from .477 to .938, with a mean score of .844. The first factor accounted for 73.5% of the variance. For participants in Model 2, the first latent root (eigenvalue) was 2.3; this is 4.5 times larger than the second (0.5); all scores on the first factor were positive, ranging from .798 to .919, with a mean score of .873. This first factor accounted for 76.5% of the variance. The remaining participants ($n = 4$, 3 females; age range = 17–44, $M_{Age} = 27.5$, $SD = 12.4$) did not fall into any apparent subgroup; their scores on the first and the second factors were either very low or negative.

2.1.4.2. Cluster analysis and justifications. To further specify the dimensions underlying Models 1 and 2, we conducted cluster analyses for each model, supplemented by participants' justifications. For the cluster analyses, we created a matrix in which columns represent each individual *tshotoy* and rows represent the average sorting distance that each animal assumed in combination with the rest of *tshotoy* in each sorting (Atran, 1998; Medin et al., 2006). This analysis provides a representation, depicted in Figs. 2 and 4, of the consensus generated by participants' responses to the sorting task.

We then calculated, for each participant contributing to each model, that individual participant's percent agreement with the model itself. This yielded a set of consensual groupings, depicted in Figs. 3 and 5. Finally, we considered participants' justifications, coding them as taxonomic (if they invoked morphological or other perceptual commonalities, e.g., species, kind, size) or ecological (if they invoked relations or interactions). See Table 1. All participants generated justifications (Model 1: range = 4–38, $M_{justifications} = 13.5$, $SD = 10.4$; Model 2: range = 8–40, $M_{justifications} = 27.3$, $SD = 17$; 5-year-olds: range = 5–9, $M_{justifications} = 7$, $SD = 1.9$; 10-year-olds: range = 7–13, $M_{justifications} = 8.4$, $SD = 1.9$). We double-coded half of the justifications; inter-rater agreement was 85%.

2.1.4.3. Model 1. As can be seen in Fig. 2, the cluster analysis for Model 1 yielded 32 clusters (CL) distributed among 16 levels. Within this, four major clusters yielded significant consensual agreement: a) 97.1%; b) 76.7%; c) 74.6% and d) 98.4%. These clusters, depicted in Fig. 3, include (a) a set including small mammals (e.g., rodents, fox and weasel), (b) a set including a mix of other mammals (e.g., armadillos, cows, pigs), reptiles (turtle, lizard) and a bird, (c) a set including mammals (cats and bears) and reptiles (snakes), and finally a higher-order 'parent' category (d) encompassing all of the items in (a) and (b). Note that in three of these four categories, reptiles and mammals were sorted into the same groupings; they were not separated into distinct groupings (as they would in a taxonomic system).

Delving deeper, we found that overall, adults whose responses were well-captured by Model 1 provided some taxonomic justifications mentioning species or kind, size and physical features (13.9%), but focused primarily on ecological relations (86.1%), X^2 (1) = 56.3, $p < .001$. See Table 1. A closer examination of the ecological justifications revealed a primary focus on ecological-social relations (38.7%) combined with utility relations (29%). Indeed, social relational and utility justifications (67.7%) exceeded the remaining ecological relations combined (32.3%), X^2 (1) = 11.7, $p < .005$.

Next, we considered the justifications provided for each of the four major categories of Model 1 (Figs. 2 and 3). Because the number of justification types is relatively small, we adopted a descriptive approach. For cluster (a), participants primarily emphasized utility to humans (7/12 or 58.3%) (e.g., 'we cannot eat them'). For (b), they primarily emphasized positive utility value (14/19 or 73.6%) (e.g., 'the iguana's tail can be used to make rings'). For (c), they primarily described aggressive social relations (21/36 or 58.3%) (e.g., 'they can attack people'). Finally, for the more inclusive cluster (d), peaceful social relations were highlighted (9/26 or 34.6%) (e.g., 'they are defenseless *tshotoy*').

Thus, adults adopting Model 1 joined individual mammals and reptiles together in the same clusters. Moreover, their justifications focused on ecological-social relations, and especially peaceful versus aggressive behaviors. These four clusters are covert categories (Berlin, 1992); the Wichi did not label any grouping in their classifications

2.1.4.4. Model 2. For Model 2, the cluster analysis yielded 16 clusters (CL) distributed among 8 levels. See Fig. 4. This organization, depicted in Fig. 5, revealed three main clusters, each including both mammals and reptiles: (a) rodents, rabbits, armadillos, tortoise, among others (100% agreement over co-ocurrences of grouping patterns); (b) cows, pigs, bears, lizard, iguana and others (84.6%); (c) cats and snakes (87.5%).

As in Model 1, adults whose responses were captured by Model 2 favored ecological justifications (68.3%) over taxonomic justifications (31.7%), X^2 (1) = 10.9, $p < .05$. See Table 1. When referring to taxonomic relations, participants mentioned size, physical features, species or kind. When ecological relations were mentioned, participants tended to focus on habits (39.3%) and social relations that center around animals' peaceful versus aggressive tendencies (30.4%). These two types of ecological relations (69.7%) exceeded all remaining ecological relations (30.3%), X^2 (1) = 8.6, $p < .005$. Moreover, although animals in cluster (c) were described exclusively as aggressive (7/7), those in cluster (a) and (b) were described as peaceful (10/10).

Adults adopting Model 2, like those adopting Model 1, placed reptiles and mammals together within a given cluster. They also focused primarily on ecological-social relations, distinguishing clearly between peaceful and aggressive *tshotoy*. As in Model 1, these clusters are covert (Berlin, 1992); the Wichi did not label any grouping in their classifications.

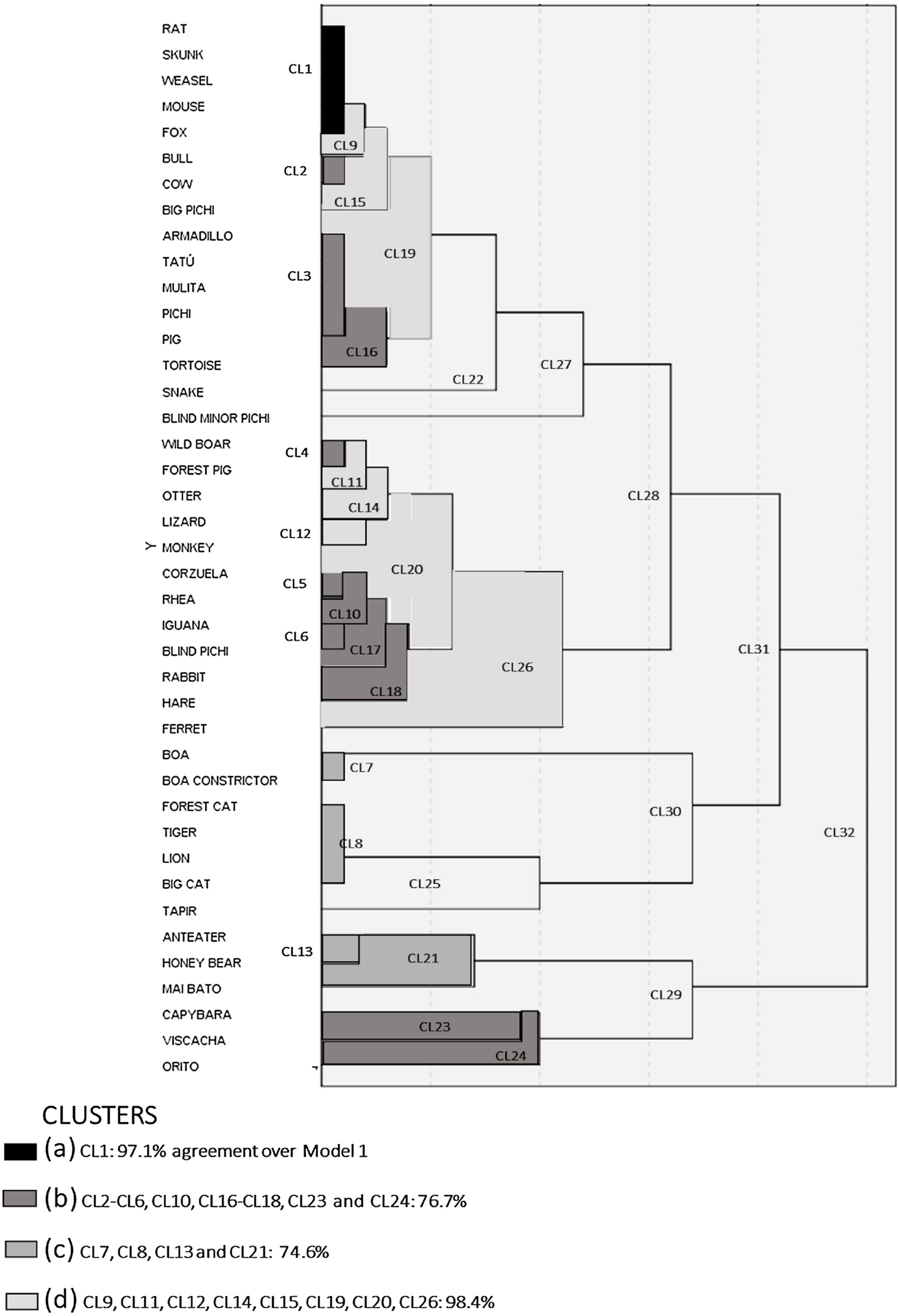

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Fig. 2. Study 1, Model 1. Summary of Model 1. The shaded areas represent the four main clusters (a), (b), (c) and (d) a higher-order 'parent' category encompassing [(a) and (b)].

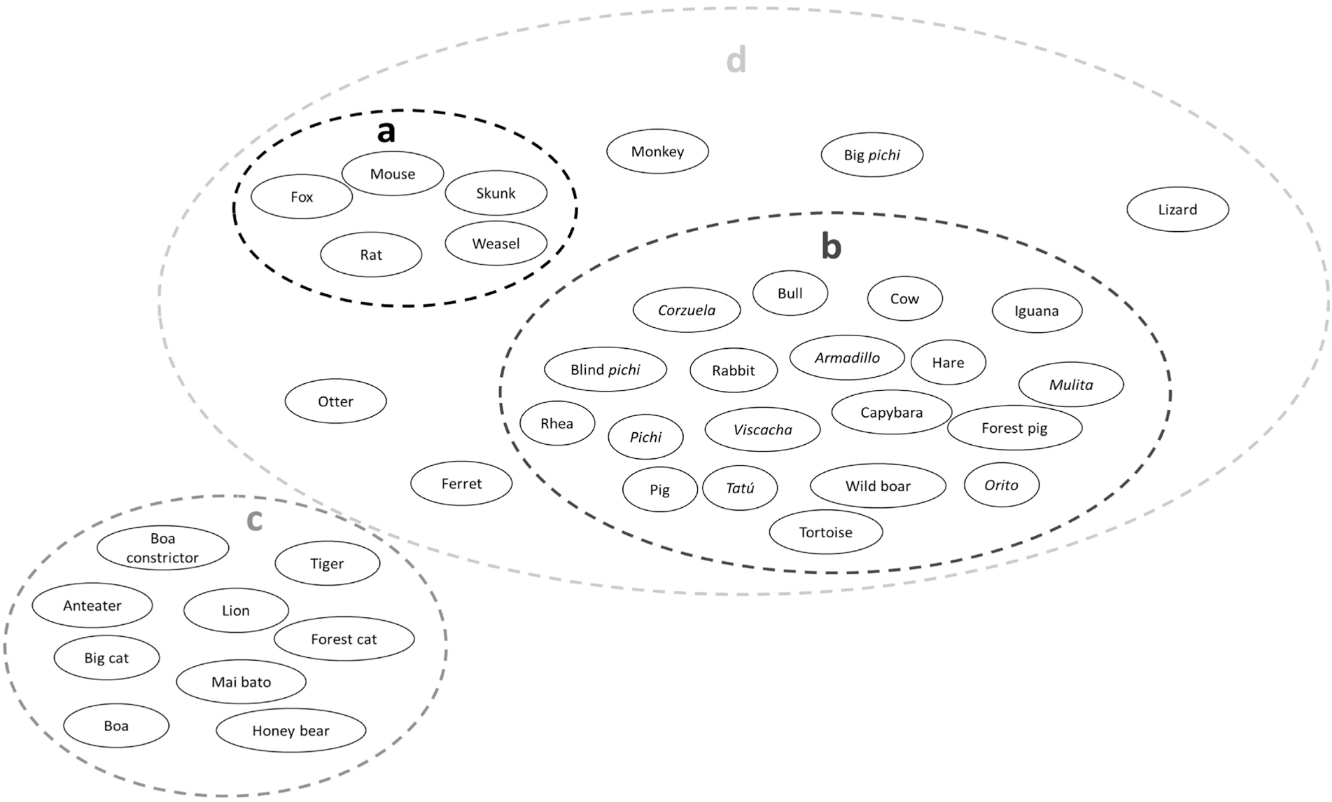

Fig. 3. Study 1. Model 1. Schematic depiction of the four major consensual clusters (a), (b), (c), (d) and their constituents.

2.1.5. Discussion

Although no single overarching consensual model of *tshotoy* emerged, an analysis of individuals' agreement patterns revealed two models, both centering on ecological – and especially ecological-social – relations. The absence of a single homogeneous model of *tshotoy* suggests that this knowledge is distributed variably within this community. Moreover, the difference between Models 1 and 2 appear to be differences of degree, rather than kind. The primary difference is that Model 1, the more richly nested model, reveals more detailed knowledge than Model 2.

3. Study 2: Wichi children

In Study 2 we traced the organization of *tshotoy* in 5- and 10-year-old children.

3.1. Method

3.1.1. Participants

Participants were 30 Wichi children, 15 5-year-olds (8 female, age range = 5–6, M_{age} = 5.7, SD = 0.4) and 15 10-year-olds (12 female, age range = 10–11, M_{age} = 10.3, SD = 0.5).

3.1.2. Materials

We selected 12 of the 41 photographs used in Study 1. See Fig. 6. Based in prior evidence from children in this community (Taverna et al., 2014), evidence from Study 1, pilot data, and advice from our Wichi consultants, we first selected the 20 *tshotoy* most likely to be familiar to children. Next, we asked four children (3 female, age range = 6–11, M_{age} = 7.2, SD = 2.5) to "make groups of these animals of the forest *(tshotoy)* as you think they are in nature". Because these children struggled with 20 photos, we further reduced the set to 12 photos. To maintain rough comparability with the adult set, we took care to include materials that permitted children to form taxonomic groupings based on principles including species (e.g., cows vs. lizards), life forms (e.g. reptiles vs. mammals). We also included a balance of animals that adults considered to be aggressive and peaceful.

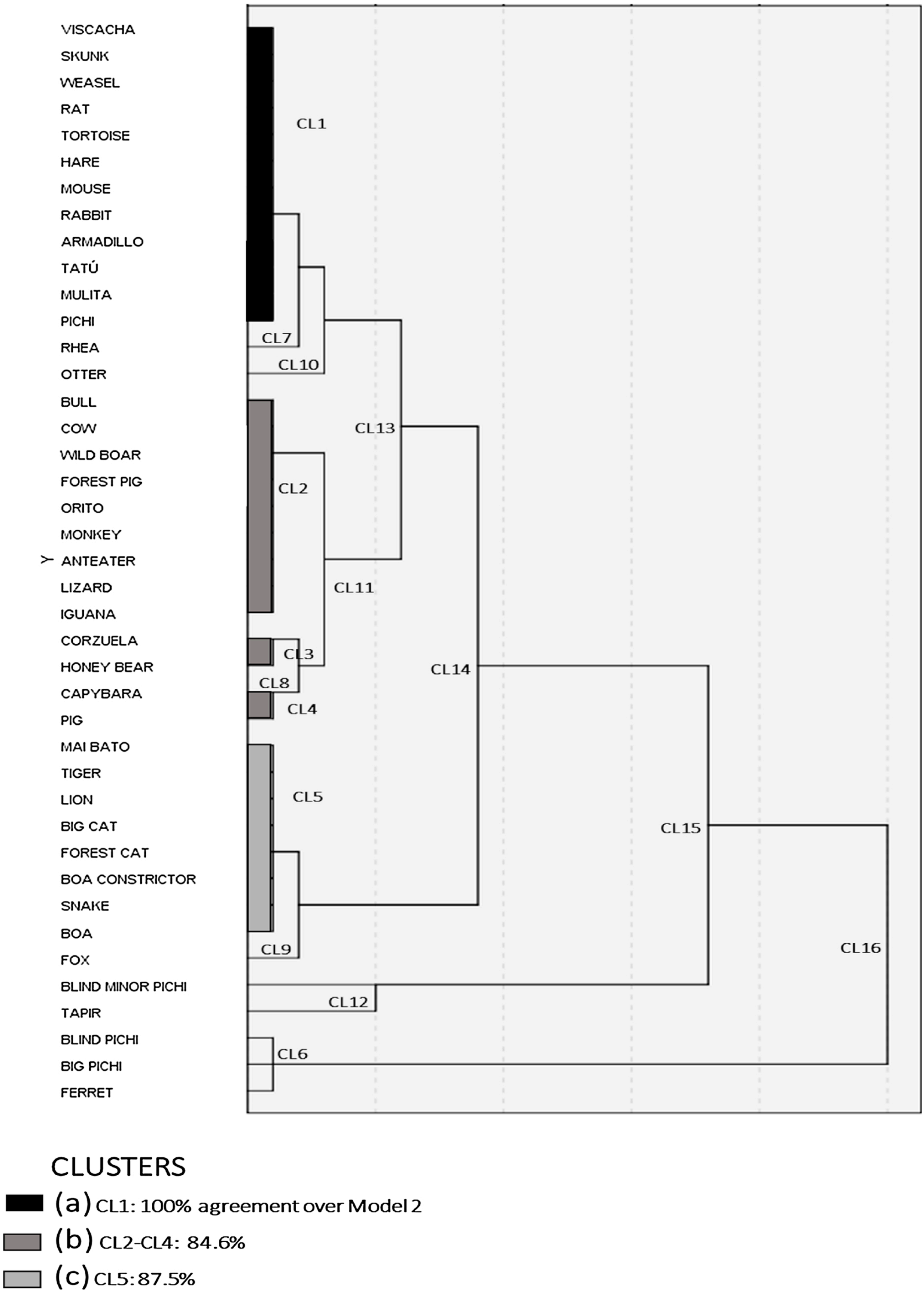

Fig. 4. Summary of Model 2. The shaded areas represent the three main clusters (a), (b), (c).

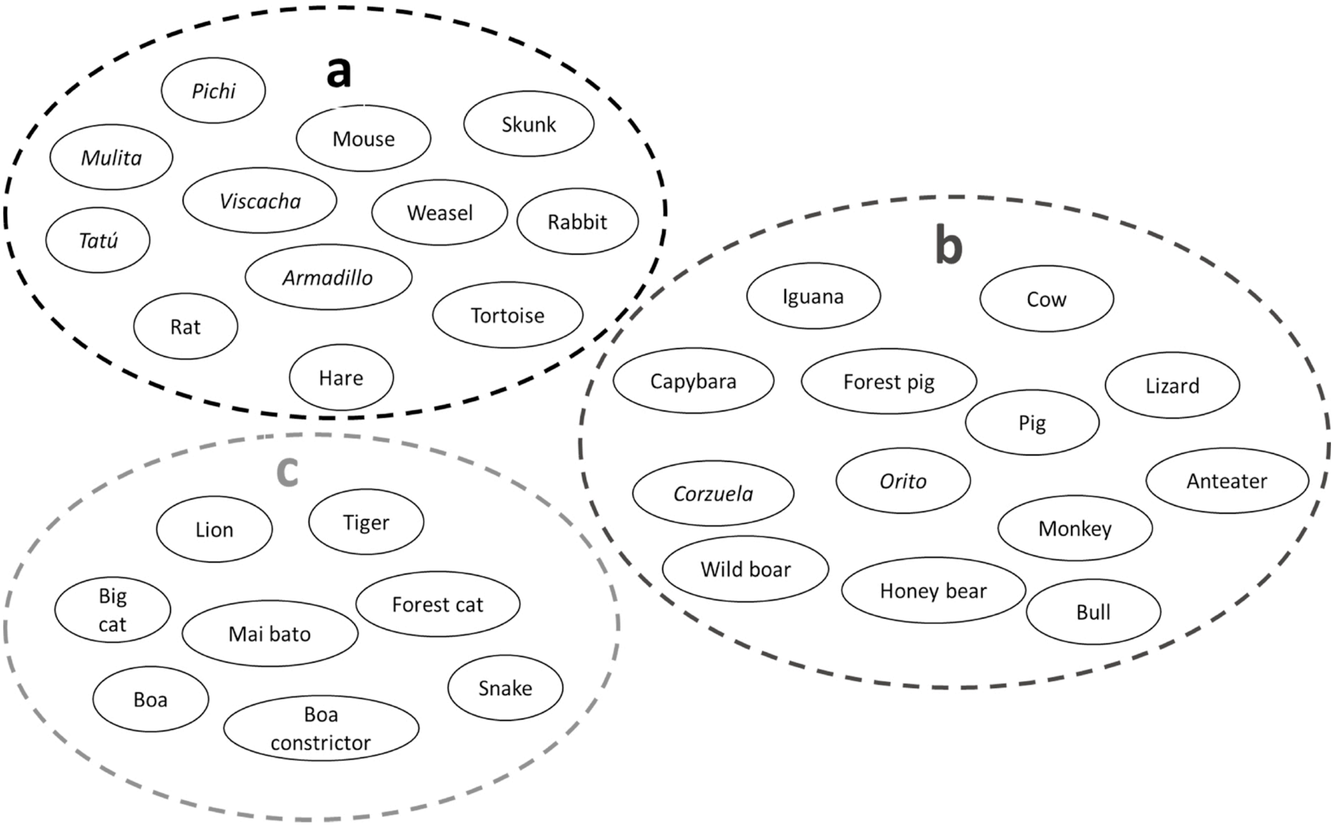

Fig. 5. Study 1. Model 2. Schematic depiction of the major consensual clusters (a), (b), (c) and their constituents.

Table 1
Studies 1 and 2. Justifications provided by both adults (Study 1) and children (Study 2), expressed as a function of relation type (taxonomic; ecological) for each model and age group.

Type of Justifications	Adults (Study 1)		Children (Study 2)		
	Model 1	Model 2	5-year-olds	10-year-olds	Total
Taxonomic Relations *e.g.,"they are from the same kind"; "they are from the same species"*	15	26	0	18	59
Ecological Relations	93	56	35	91	275
Total Relations (Taxonomic and Ecological, combined)	108	82	35	109	334
Type of Ecological Relations					
Social					
Peaceful *e.g., "they live together without trouble; they are defenseless tshotoy; can be found everywhere".*	15	10	0	27	52
Aggressive *e.g., "they can be dangerous; they can attack themselves, other tshotoy and people".*	21	7	22	40	90
Total Social	36	17	22	67	142
Utility					
Usable *e.g., "the hide is used to make handbags,* belts; *their fat can be used as medicine ".*	20	9	0	0	29
Unusable *e.g., "they cannot be eaten".*	7	1	0	0	8
Total Utility	27	10	0	0	37
Habit *e.g., "they go hunting at night; only have one litter and take care of it so much".*	18	22	2	8	50
Food-chain *e.g., "they can eat the other group; they are easy prey for the tshotoy of the other group".*	7	0	11	15	33
Habitat *e.g., "they live in the caves of the trees; some of them live under the water".*	4	7	0	1	12
Spiritual-Mythical *e.g., "the rainbow can be transformed into becoming some of these tshotoy".*	1	0	0	0	1

3.1.3. Procedure

Identical to Study 1 with one exception: children provided only a single sort. Pilot work revealed that providing multiple sorts was too taxing for most children.

3.1.4. Analysis and results

Both 5- and 10-year-olds children correctly identified most of the photographs (86.1% and 95.6%, respectively). As in Study 1, only those photographs that a child identified correctly were included in the subsequent sorting and justification tasks.

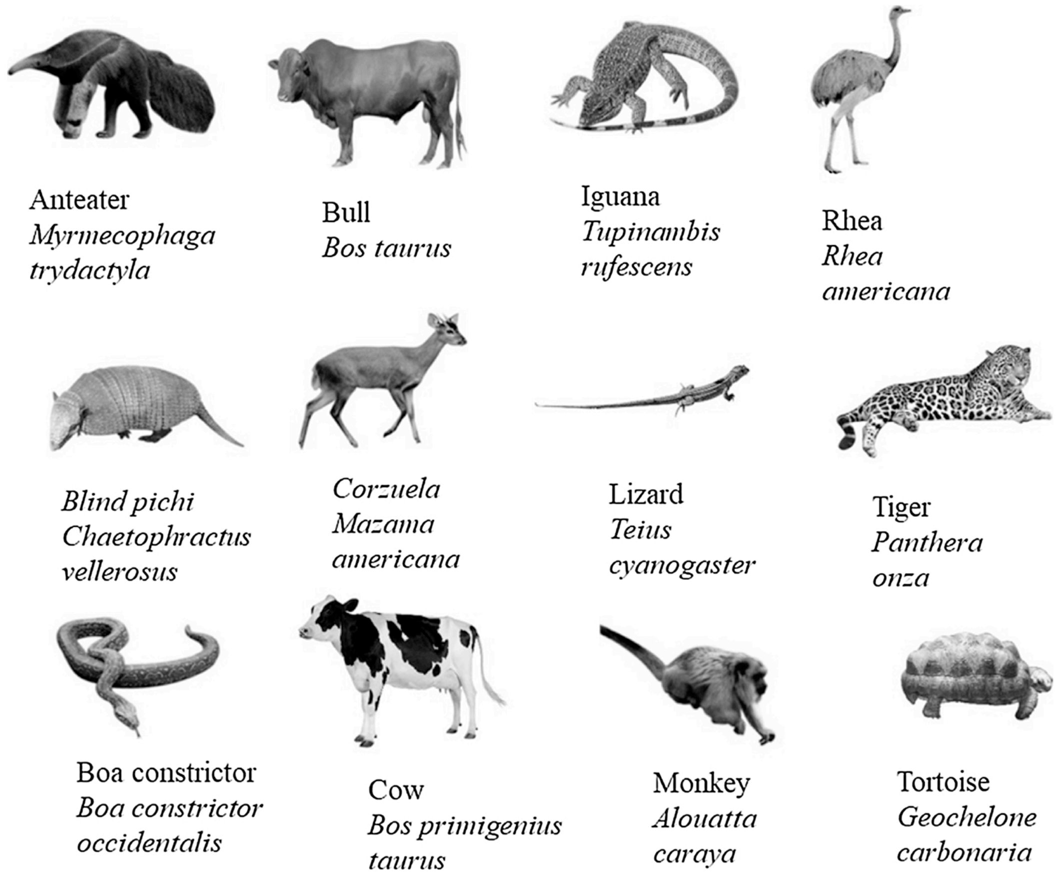

Fig. 6. Study 2. Complete set of photographs in alphabetical order with each animal labeled with its scientific name.

3.1.4.1. Cultural consensus model (CCM). To begin, we conducted an overarching factor analysis at each age. Neither 5- nor 10-year-olds converged on a single overarching model that captured the responses of the full sample. This is because at 5-year-olds, the first latent root (eigenvalue) (6.4) was less than two times larger than the second (3.7); all scores on the first factor were not positive, ranging from -.957 to .942, with a mean score of .200, and the first factor did not account for most of the variance (42.5%); moreover, three factors were needed to explain 80.9% of the variance. For 10-year-olds, although the first latent root (eigenvalue) (10.4) was almost seven times larger than the second (1.5), the scores on the first factor were not uniformly positive, ranging from -.858 to .965, with a mean score of .587 ; moreover, three factors were required to explain 85.4% of the variance.

Next, as in Study 1, we looked at the factor loadings of each individual to identify whether there was consensus within any subgroups at each age when we relaxed the classic CCM expectation of sample homogeneity. At each age, we identified a subgroup with high loadings on the first factor scores and low loadings second factor scores (5-year-olds: $n = 5$, 4 female; age range = 5–6, $M_{Age} = 5.8$, $SD = 0.4$; 10-year-olds: $n = 13$, 10 female; age range = 10–11, $M_{Age} = 10.3$, $SD = 0.5$). We submitted the data from these children to a new CCM at each age. This yielded a consensual model that highlighted ecological principles of organizations at each age.

The model for 5-year-olds had a first latent root (eigenvalue) (3.8) almost 5.5 times larger than the second (0.7), all the scores on the first factor were positive, ranging from .565 to .952, with a mean score of .860, and this factor accounted for most of the variance (76.2%). The remaining 10 participants' responses (4 females; age range = 5–6, $M_{Age} = 5.7$, $SD = 0.5$) did not yield consensus, suggesting that this task was difficult for our youngest children.

The model for 10-year-olds had a first latent root (eigenvalue) (9.1) that was 6.5 times larger than the second (1.4), all the scores on the first factor were positive, ranging from .062 to .973, with a mean score of .801 and this factor accounted for most of the variance (70.7%). The remaining 2 participants' responses (2 females; age range = 10–11, $M_{Age} = 10.5$, $SD = 0.7$) did not yield consensus.

3.1.4.2. 5-year-olds' model: cluster analysis and justifications. As in Study 1, we used cluster analyses and justifications to identify the underlying dimensions of the models at each age. See Table 1. This analysis yielded a model, depicted in Fig. 7, with seven clusters, distributed at 5 levels, organized into three main clusters (a) (73.3% agreement), (b) (80%), and (c) (87.5%), all of which clustered mammals and reptiles together. See Fig. 8. Interestingly, in their justifications, 5-year-olds offered no explicit mention of taxonomic relations. Instead, they mentioned exclusively ecological relations, and described aggressive social relations combined with habits relations (e.g., 'the blind pichi chases the monkey and scratches it') (62.9%) more frequently than all the remaining relations (37.1%), X^2 (1) = 4.8, $p < .005$. Moreover, 42.9% of the 5-year-olds captured by the model labeled the grouping as 'enemies'.

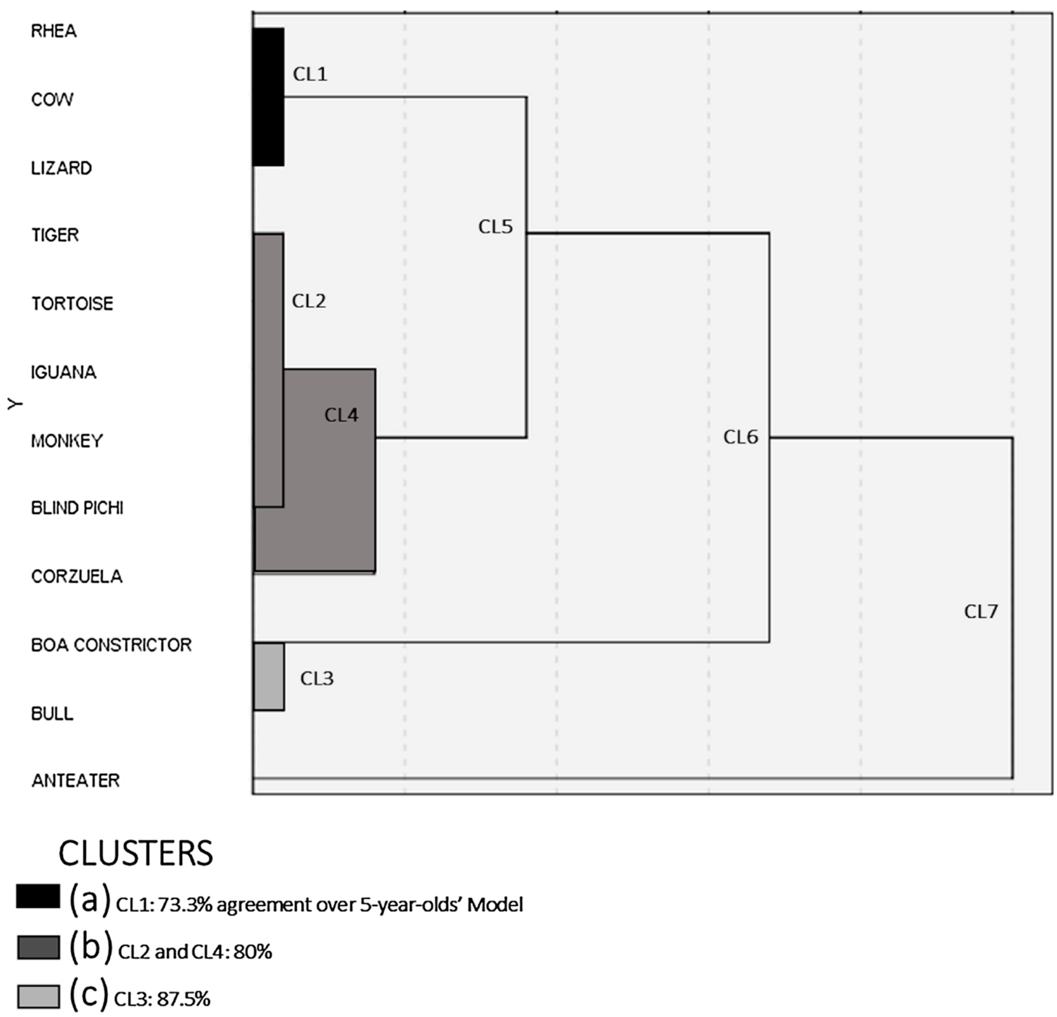

Fig. 7. Study 2. Summary of 5-year-olds' model. The shaded areas represent the three main clusters (a), (b), (c).

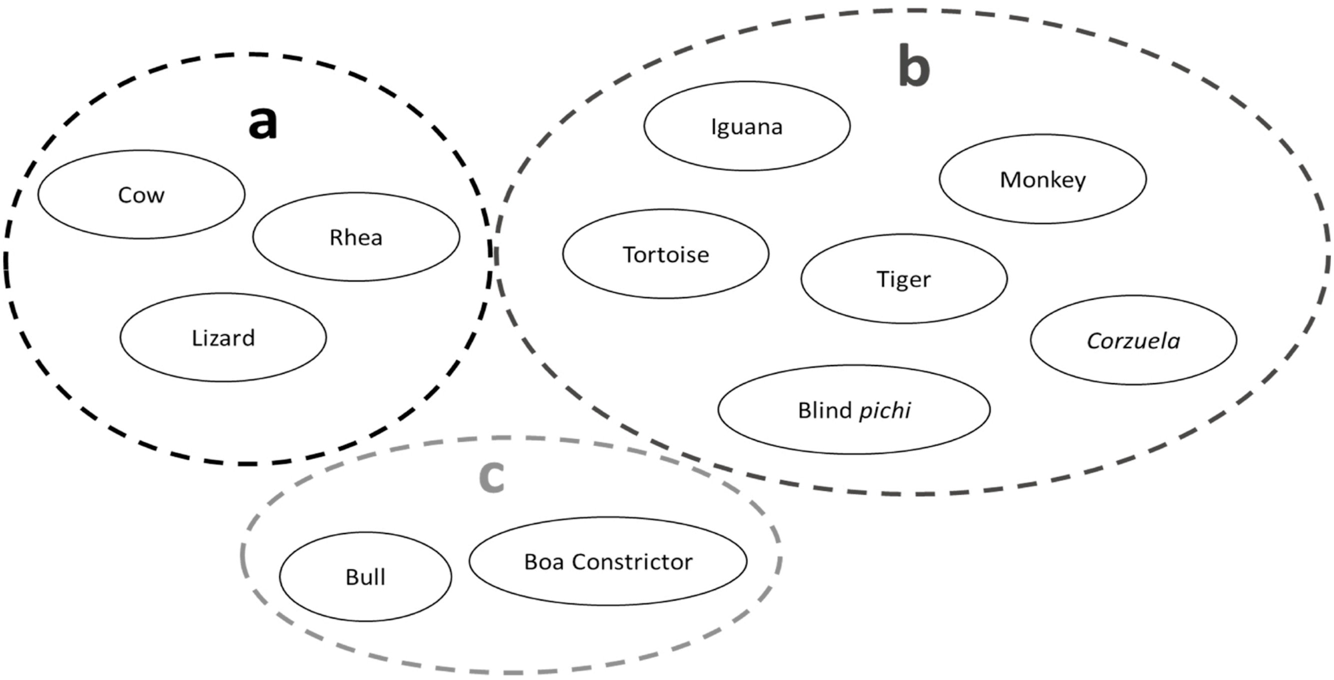

Fig. 8. Study 2. 5-year-olds' model. Schematic depiction of the three major consensual clusters (a), (b), (c) and their constituents.

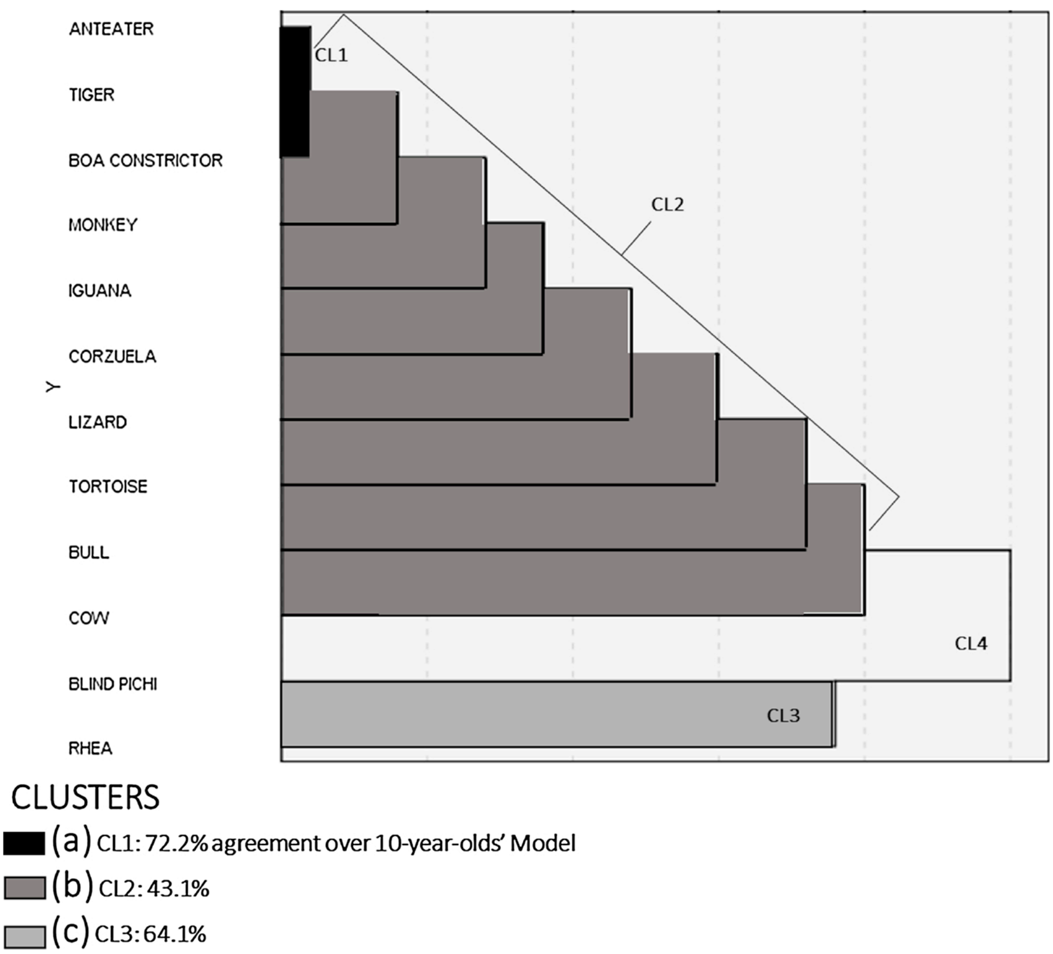

Fig. 9. Study 2. Summary of 10-year-olds' model. The shaded areas represent the three main clusters (a), (b), (c).

3.1.4.3. 10-year-olds' Model: Cluster analysis and justifications. For 10-year-olds children, the analysis yielded four clusters, distributed among four levels. See Fig. 9. These were organized into three main clusters (a) (72.2% agreement), (b) (43.1%); and (c) (64.1%), which, here again, all included both reptiles and mammals (e.g., tiger and boa). See Fig. 10.

Like adults and 5-year-olds, 10-year-olds' justification included more ecological (83.5%) than taxonomic relations (16.5%), X^2 (1) = 48.8, $p < .001$. Among the ecological justifications, 10-year-olds primarily described social relations distinguishing between aggressive and peaceful tendencies. They mentioned social relations more frequently (73.6%) than all other ecological relations combined, for any of three of the main clusters (26.3%), X^2 (1) = 20.3, $p < .001$ (see Table 1). Almost half of the 10-year-olds captured by this model labeled the groupings (46.9%), referring primarily to social relations (e.g., 'friends', 'enemies', 'family', 'brothers').

Thus, 10-year-olds reveal an ecological organization that focuses specifically on social relations and that centers on peaceful as well as aggressive tendencies of *tshotoy*.

3.1.5. Discussion

For children, like adults, ecological principles form the bedrock of the Wichi representation of *tshotoy*. Also as with adults, there was no single overarching model that captured well the responses of most children at either age. Instead, we found consensus within a subgroup of children at each age. This outcome is consistent with the notion that cultural knowledge is distributed differently among members of a community (Atran & Medin, 2008; Medin et al., 2013, 2015). Among the 5- and 10-year-old children who revealed this consensus, *tshotoy* were grouped predominantly on the basis of ecological-social relations. None of these 5-year-olds mentioned taxonomic relations; all mentioned aggressive social-ecological tendencies in combination with habits relations. Although 10-year-olds mentioned at least a few taxonomic relations, they too focused primarily on ecological relations. Unlike 5-year-olds, they mentioned both aggressive and peaceful social relations among *tshotoy*.

4. General discussion

The current results offer strong evidence for the import of ecological relations in the Wichi's construal of *tshotoy*, the animals native to their forest. Certainly, the Wichi's focus on social-ecological relations does not constitute evidence that they are unaware of taxonomic relations. Instead, these results underscore the view that taxonomic systems are not the sole organizational systems

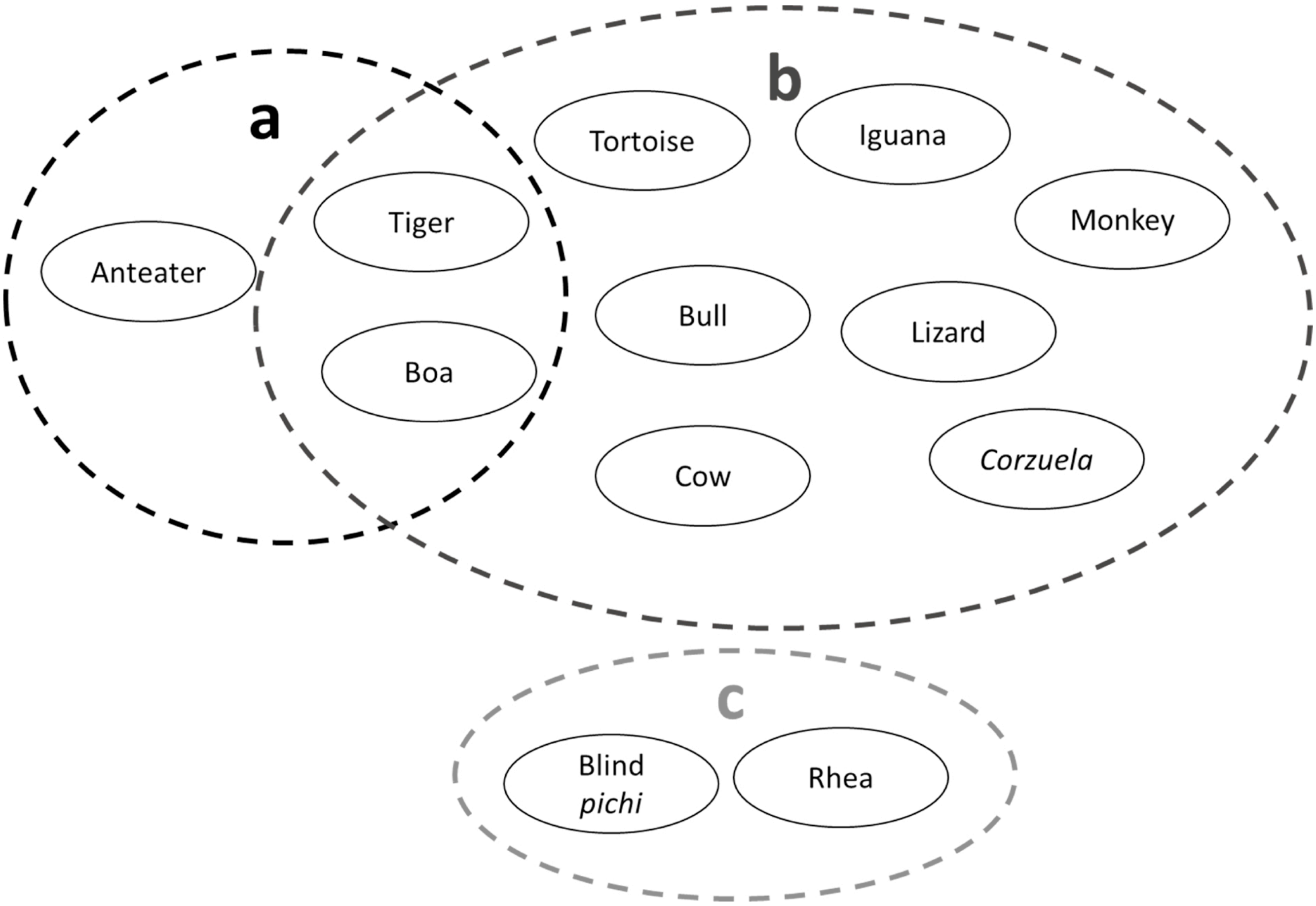

Fig. 10. Study 2. 10-year-olds' Model. Schematic depiction of the three major consensual clusters (a), (b), (c) and their constituents.

invoked for animals, especially among cultural groups with sustained knowledge and interaction with the natural world. Perhaps more provocatively, these results offer the first evidence of a distinct focus on one sort of ecological relation – social relations – within that ecological framework. These results are consistent with the view that cultural knowledge is dynamic and distributed variably within the Wichi community, and that amidst this variability, there is developmental continuity in the import accorded to social-ecological relations from childhood through adulthood. Social-ecological relations served as a foundation for all four consensual models reported here.

This focus on social-ecological relations, an organizing principle that has not been reported as dominant elsewhere in the literature, aligns closely with the Wichi belief system and epistemology. It is also consistent with evidence that *hunhat lhelhey* (inhabitants of the earth) are seen in a framework that aligns well with relational epistemology of *husek* (social goodwill). According to the Wichi, reducing aggressiveness in young children is seen as essential to their emergence as social individuals and essential to assuring harmony in the community (Palmer, 2005). This fundamental socialization is accomplished via *husek*. Indeed, given the close affinity between humans and non-human animals and the import of social *husek* (Taverna et al., 2016, 2018), it is perhaps not surprising that social-ecological principles should undergird Wichi's frameworks for organizing the forest animals.

In addition to offering new insights, our results also touch upon long-standing issues in cross-cultural cognitive research. Most importantly, to illuminate the Wichi system of conceptual organization, we focused considerable attention on ecological frameworks. This design decision was intentional, bearing in mind what has been described as "the home-field disadvantage" (Medin, Bennis, & Chandler, 2010), a design bias that favors adopting Western-inspired views as a standard in cross-cultural work. Had we focused instead on a primarily taxonomic system of organization, we would have failed to (a) respect the insights of native consultants and (b) failed to capture the development of social-ecological knowledge about *tshotoy* (animals of the forest) in this community.

In future work, it will be important to address some of the limitations of the current work. First, extending this investigation to include other cultural groups, including other communities living in the same area but who do not share the same epistemological orientations as the Wichi, will permit us to identify whether and how frameworks we have identified among the Wichi compare to others (Berlin et al., 1973, 1974).

Second, although the Cultural Consensus Model is effective with small samples of participants (Romney et al., 1986), and although our sample is comparable in size to other investigations of small, remote communities (Atran et al., 2002; Bailenson et al., 2002; López et al., 1997; Lynch et al., 2000), it would nonetheless be advantageous in future work to increase the sample size. Third, it will be important to examine whether and when the Wichi rely upon social-ecological relations as a basis for reasoning and induction. Finally, it will be important to identify more precisely whether, and how, the Wichi acquire increasingly detailed knowledge of the *tshotoy*. Although the children's models appeared to be sparser than those of adults, this may have been a consequence, at least in part, of their having provided only a single sort. Perhaps with additional sortings, children would reveal more detailed knowledge. A goal for our continued work in this community is to develop a procedure that permits us to supplement the current evidence with a more extensive examination of children's conceptual organization of the *tshotoy*.

In closing, the current results bring us one step closer to understanding how the human mind comes to organize the natural world. We look forward to additional work designed to broaden further the empirical base to include individuals from diverse cultures and diverse ages to bring into clearer focus how our experiences and cultural belief systems shape the construction of knowledge about the natural world.

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