Psychological Review
2005, Vol. 112, No. 4, 744–776

0033-295X/05/$12.00 DOI: 10.1037/0033-295X.112.4.744

The Cultural Mind: Environmental Decision Making and Cultural Modeling Within and Across Populations

Scott Atran
Centre National de la Recherche Scientifique and
University of Michigan

Douglas L. Medin
Northwestern University

Norbert O. Ross
Vanderbilt University

This article describes cross-cultural research on the relation between how people conceptualize nature and how they act in it. Mental models of nature differ dramatically among populations living in the same area and engaged in similar activities. This has novel implications for environmental decision making and management, including commons problems. The research offers a distinct perspective on cultural modeling and a unified approach to studies of culture and cognition. The authors argue that cultural transmission and formation consist primarily not in shared rules or norms but in complex distributions of causally connected representations across minds interacting with the environment. The cultural stability and diversity of these representations often derive from rich, biologically prepared mental mechanisms that limit variation to readily transmissible psychological forms. This framework addresses several methodological issues, such as limitations on conceiving culture to be a well-defined system, bounded entity, independent variable, or an internalized component of minds.

Keywords: cultural modeling, decision making, environmental management

This article describes an ongoing body of research on environmental decision making. Our research program is framed in terms of folk biology, and the focus is on the relationship between how people conceptualize nature and how they act in it. The context of primary interest is the lowland rainforest of Guatemala, but we also bring evidence to bear from other Mesoamerican and North American settings where resource conservation is at issue.

Perhaps the most central problem in environmental decision making is Hardin's (1968) "tragedy of the commons" (p. 1243) in which individuals acting according to their self-interest overuse and deplete resources. But this gloomy outcome does not always come to pass. A number of researchers have noted many examples in which commons have been and are being successfully managed (Atran, 1986; Berkes, Feeny, McCay, & Acheson, 1989; Deitz, Ostrom, & Stern, 2003; Ostrom, 1999). Key factors in success include a closed-access system and having social institutions in place to monitor use and punish cheaters (overusers, free riders).

Although it is comforting to know that the tragedy of the commons is not inevitable, current conditions of globalization do not conform well to the constraints that have so far been identified. For a variety of reasons, closed access is increasingly difficult to achieve, and local institutions are increasingly confronted by, and giving way to, intergroup conflict over resource use. Our research program provides a new theoretical perspective on resource dilemmas, particularly those involving multiple cultural groups. We argue that how people conceptualize nature is linked with how they act in relation to it. In addition, we believe that cultural differences in mental models and associated values play an important role in creating intergroup conflict and, therefore, may hold the key to addressing these conflicts.

At the level of method, we offer techniques that are designed to facilitate cross-cultural research and comparison but also aimed at avoiding the pitfall of reifying culture and treating it as an independent variable. Reifying culture wrongly equates reliable results with cultural patterning and homogeneity.

Scott Atran, Centre National de la Recherche Scientifique, Paris, and Research Center for Group Dynamics, University of Michigan; Douglas L. Medin, Department of Psychology and School of Education and Social Policy, Northwestern University; Norbert O. Ross, Department of Anthropology, Vanderbilt University.

This research was supported by National Science Foundation Grants SBR 931978, SBR 9422587, SBR 9707761, SBR 9983260, BCS 0216762, and SBR 0424629; National Science Foundation–Environmental Protection Agency Grant SES-9981762; National Institutes of Health Grant MH55079; Russell Sage Foundation Grant 87-99-02; and Centre National de la Recherche Scientifique Contract No. 92 C 0758, Ministère de la Recherche et Technologie.

This work is the summary of a combined effort by a number of long-term research collaborators: Elizabeth Lynch, Edilberto Ucan Ek', Valentina Vapnarsky, John Coley, and Ximena Lois. Other important contributors and collaborators include Jeremy Bailenson, Michael Baran, Serge Blok, Russell Burnett, Doug Cox, Paul Estin, Brett Hayes, Alejandro López, Brad Love, Bobbi Low, Richard Nisbett, Connie Pankratz, Elizabeth Proffitt, A. Kimball Romney, Hillarie Schwartz, Michael Shum, Brian Smith, Edward Smith, Paolo Sousa, Gert Storms, Christopher Timura, Sandra Waxman, and Phil Wolff. Dan Sperber, Lawrence Hirschfeld, Michael Cole, Lance Rips, Susan Gelman, Sara Holyk, Ed Hutchins, and William Batchelder provided constructive comments on drafts of this article. We are deeply grateful to our research partners and participants in Guatemala, Mexico, Brazil, Wisconsin, Illinois, and Michigan and especially to the Maya and Menominee communities that took us in.

Correspondence concerning this article should be addressed to Scott Atran, Research Center for Group Dynamics, University of Michigan, Ann Arbor, MI 48106-1248. E-mail: satran@umich.edu

Our research program is also closely tied to a distinct stance with respect to the conceptualization of culture and cultural models. Just as Darwin (1859) had to rely on an intuitive notion of species in the process of ultimately deconstructing it, our approach is aimed not at establishing some true definition or identification of culture but rather at understanding the factors and dynamics that lead to cultures as constructed categories. We begin with cultures as commonly described units—self-identified groups of individuals—and then trace the distribution of patterns of knowledge and beliefs both across and within cultures. It is these distributions, including their development and change, that constitute the object of our study. [1]

From this standpoint, it is less useful to try to estimate population parameters for cultural norms—that is, shared values, beliefs, and associated behaviors—than it is to establish the pathways that determine how (in our case, biological) ideas affect (in our case, environmental) behaviors (and vice versa). Accordingly, we describe emergent agreement patterns that are derived statistically from measurements of interinformant agreement. To the extent that these agreement patterns overlap with patterns of self-ascribed cultures, we refer to such emerging models as *cultural models*. The focus of the research, however, is not a search for agreement patterns that overlap with self-ascribed cultural units but rather understanding the underlying causes and dynamics of emerging agreement patterns.

In the present article, our focus is on illustrating in detail how the distributional view of culture plays a critical role in our program of research on environmental decision making, although the utility and implications of this approach extend beyond our specific examples.

The rest of this article is organized as follows. First, we review strengths and limitations of alternative views of culture. We go on to present a distributional view of culture and methodological tools tailored to it. Then we briefly describe the settings and populations for our research studies. With this as background, we proceed to review our research findings on mental models of the environment and their correlations with behavior.

Culture as a Notional, Not Natural, Kind

Intuitively, one might define culture as the shared knowledge, values, beliefs, and practices among a group of people living in geographical proximity who share a history, a language, and cultural identification (see Brumann, 1999, and associated commentaries for examples of this approach in anthropology). From a psychological perspective, Campbell's (1958) proposed measures of social entitativity in terms of common fate, similarity, proximity, resistance to intrusions, and internal diffusion seem applicable to cultural groups. However, it is important to note that the question of how culture should be defined is separable from the question of how best to study it. Although we think a definition of a culture in terms of history, proximity, language, and identification is useful and (if not too rigidly applied) perhaps even necessary as a beginning point, it does not follow that the cultural content of interest must be shared ideas and beliefs.

It is not easy to escape from this intuitive notion of culture any more than it is easy for biology to escape from the notion of species as ahistorical, well-bounded entities sharing an underlying essence (e.g., Mayr, 1982). In the same way that cultures are not natural kinds, biological kinds do not have the stable characteristics often attributed to them. Modern evolutionary biology is the study of change, not just stability. Continuing this parallel with evolutionary biology, we believe that modern cultural research must be able to overcome intuitive notions of culture to focus on causal processes associated with stability and change. Both biological and cultural research started with folk notions (of species and culture, respectively), and they have served each field well as starting points. Ultimately, though, such conceptions must be radically altered for further progress to be made.

In the General Discussion and Implications section we return to the parallels between species in biology and intuitive notions of culture in cognitive science. Bearing in mind these issues concerning stability and change, we turn now to current stances on how culture and cultural processes should be studied. Each of them is useful for some purposes, and all of them have limitations.

Culture as Norms and Rules

It appears natural to think that the cultural contents of interest must be shared to qualify as cultural. Note, however, that this commitment undercuts the dynamic side of cultural processes: Distinctive values, beliefs, and knowledge might or might not be consensual within a culture. For example, a culture may have a set of beliefs and practices known only to a privileged group of people (e.g., healers, elders, ruling elite) that nonetheless are powerful forces within a given culture (and distinguish one culture from another). In short, this view of culture as shared beliefs and practices not only prejudges the issue of what constitutes cultural content but also, as a consequence, directs attention away from understanding the dynamic nature of social processes.

Some influential models of culture formation and evolution in biology and anthropology take a somewhat more liberal view of consensus. They are based on group-level traits that assume cultures are integrated systems consisting of widely shared social norms (rules, theories, grammars, codes, systems, models, world views, etc.) that maintain heritable variation (Laland, Olding-Smee, & Feldman, 2000; Rappaport, 1999; D. S. Wilson, 2002). Some political scientists also tend to view cultures as socially inherited habits (Fukuyama, 1995), that is, as socially transmitted bundles of normative traits (Axelrod, 1997b; Huntington, 1996).

The interest in heritable variation loosens the restrictions on consensus and raises questions about the basis for variation. However, cognitive scientists are likely to be disappointed by the implicit assumption that the gist of cultural learning is the (more or less automatic) absorption of norms and values from the surrounding culture (by processes no more complicated than imitation; cf. Tomasello, 2001). We believe that there are two problems with such an approach: First, it is not clear how people would decide what exactly to imitate. Second, these assumptions do not pay sufficient attention to the sorts of inferential and developmental processes that allow human beings to build and participate in cultural life.

[1] The analogy with Darwin's (1859) work on biological species is incomplete in that people may see themselves as part of specific cultures and often act differently because of this identification. For example, information might or might not be shared across the boundaries of self-identified cultures.

Cultural Psychology

The recent upsurge of interest in cultural psychology (for one review and critique, see Oyserman, Coon, & Kemmelmeier, 2002, and associated commentaries) has produced a variety of intriguing findings and has done psychology a service by calling attention to cultural variation. Many of these studies show that knowledge systems previously thought to be universal actually vary widely across the world (for a review, see Cohen, 2001). The lesson drawn is that "psychologists who choose not to do cross-cultural psychology may have chosen to be ethnographers instead" (Nisbett, Peng, Choi, & Norenzayan, 2001, p. 307). In brief, cultural psychology is succeeding in divesting academic psychology of implicit and ingrained ethnocentric biases.

What defines or constitutes cultural psychology? The area draws much of its inspiration from researchers such as Hofstede (1980) and Triandis (1995), who sought to characterize cultural differences in terms of a small number of relevant dimensions. The project is successful if multiple sources of evidence converge on the same small set of dimensions. Examples of such dimensions that have received a lot of attention are individualism versus collectivism and egalitarian versus hierarchical social structure. Other researchers, such as Nisbett (2003), have used sociohistorical analysis to derive dimensions of cultural differences in world views or preferred modes of thought. Examples of these dimensions are analytic and logical (categorical, axiomatic, and noncontradictory) versus holistic and dialectical (thematic, no first principles or excluded middle). In short, Nisbett and his associates have suggested that cultural studies must include not only contents per se but also thinking processes that themselves may be differentially distributed across cultures.

Cultural psychologists import the rigor and controls of standard experimental procedure into anthropological concerns, providing clear identification of the participants, thoughts, and behaviors tested. Cultural psychologists are thus able to systematically exploit anthropological insights to demonstrate that mainstream psychology's long-held assumptions about cognitive processes can be quite mistaken.

In our opinion, cultural psychology has some limitations. The leap from statistical regularity in some sample population to the culture as a whole may suffer from precisely the sort of reasoning criticized in mainstream psychology's leap from Americans or Europeans (or, more typically, psychology undergraduates) to the world at large. The same inchoate conception of culture once used by many anthropologists and still used by most ordinary folk remains customary in much cultural psychology. In this view, culture becomes a stable and shared set of beliefs, practices, or strategies to be studied as yet another population parameter or personal attribute. This ahistorical, consensual view of culture limits the ability to explain and understand cultural differences once they are encountered. In other words, it is not clear how explanation or interpretation can be extended beyond simple description. In some cases researchers have been able to exert some experimental control by priming tendencies to act individualistically versus collectively (e.g., Briley, Morris, & Simonson, 2000; Gardner, Gabriel, & Lee, 1999). These sorts of studies reinforce the dimensional analysis and potentially extend its scope. There is always the risk, however, of circularity in analysis. If priming does not affect some candidate task measuring individualism versus collectivism, then maybe the prime was ineffective or the task does not entail individualism and collectivism.

Perhaps we are guilty of prejudging the initial phase of a two-stage project. In Stage 1, cultural psychologists tend to characterize culture as an external, historically determined system that becomes internalized in the individual through acculturation (or some other causally opaque process), either diffusely or as some specialized part of the psyche responsible for cultural (or social) cognition. A Stage 2 focus on within-culture variations in modes of thought might illuminate how different cultural institutions shape ways of thinking and vice versa.

For cultural psychologists trained as anthropologists, the focus is on the *extrasomatic* or *extragenetic* nature of culture as an integrated corpus of external control mechanisms that program individual minds and bodies, molding them in patterned ways recognizable across individuals (Geertz, 1973). We agree that expressions of the human psyche are profoundly embedded and structured within social and historical contexts, but we dissent from the invited implication of a one-way influence, with individual minds being passive recipients of culture.

So far we have followed current practice in using the term *cultural psychology* to describe the recent upsurge of cross-cultural comparisons by cognitive and social psychologists. This may be a bit misleading in that one of the pioneers of the use of the term, Richard Shweder (1990), used it to refer to a set of ideas that entail rejecting psychic unity as well as rejecting the idea of characterizing cultural differences as variation along a small number of dimensions:

> [C]ultural psychology interprets statements about regularities observed in a lab or observed anywhere else, on the street or in a classroom, in Chicago or in Khartomo [*sic*], not as propositions about inherent properties of a central processing mechanism for human psychological functioning, but rather as descriptions of local response patterns contingent on context, resources, instructional sets, authority relations, framing devices, and modes of construal. (p. 13)

To avoid confusion in nomenclature, we categorize Shweder's approach to cultural psychology under the next framework, context and situated cognition.

Context and Situated Cognition

There are alternative views of cultural psychology that call into question the use of standard forms of experimental procedure (methodological behaviorism) as fundamentally flawed on the grounds that they are ethnocentrically biased in their focus on the individual mind or brain. Instead of considering cognitions to be embedded exclusively in individual minds—with culture as just one component of individual cognition—these theorists maintain that human cognitions should be properly situated in cultural–historical context and practical activity (Cole, 1996; cf. Vygotsky, 1978). A related concern is that cultural cognitions may be better understood as distributed cognitions that cannot be described exclusively in terms of individual thought processes but only as emergent structures that arise from irreducible levels of interactional complexity involving differential linking of individual minds in a given population (Hutchins, 1995).

Researchers such as Michael Cole (1996) believe that culture cannot be entirely conceptualized in terms of cognitions, belief systems, and the like but that one must instead consider a culture's artifacts (construed broadly enough to include language). Cole (1996) argued that subjects and objects are not only directly connected but also indirectly connected through a medium constituted of artifacts. These artifacts are simultaneously material and conceptual. One consequence of this view is an emphasis on studying cognition in a context in which cognitive labor may be distributed across individuals as well as artifacts (e.g., plumb lines or computers). As context includes people's conceptions of artifacts, it is inherently relational.

We share some of these concerns raised by the situated view, such as (a) difficulties with standard experimental procedures, including 2 × 2 designs with culture, in effect treated as an independent variable (Medin & Atran, 2004); and (b) lack of concern with differential distributions of cognitions among minds within populations. For example, with respect to shared knowledge and beliefs, Cole (1996) wrote, "in order to say anything useful, it is necessary to specify sources of coherence and patterning as a part of the ongoing activities that the inquirer wants to analyze" (p. 124). We also agree that a focus on norms and rules is overly narrow, that cultural notions are intimately tied to the study of development, and that one good research avenue involves looking at how cognition plays out in particular contexts.

Other aspects of the situationist view seem vague. The idea that cognition is "stretched across mind, body, activity, and setting" (Cole, 1996, p. 141) is a useful framework notion that leads one to consider more than individual minds. However, we believe that cultural situations and institutions cannot literally enter individual minds; rather, like other sorts of environmental stimuli, they stimulate (in controlled and sequenced ways) mental processes that construct representations in accordance with a host of internal constraints, including evolved cognitive aptitudes such as the folk biology module (Medin & Atran, 2004). Cole (1996) agreed with this assessment of internal constraints: "According to the version of cultural historical psychology I am advocating, modularity and cultural context contribute jointly to the development of mind" (p. 198).

Perhaps a fair summary is that claims about cultural, historical analyses represent something of a promissory note (with respect to individual cognition), and research has tended to focus on situations and practices rather than the mediating mental representations associated with them. Strategically, this makes a certain amount of sense. In commenting on this section of the present article, Ed Hutchins (personal communication, November 9, 2004) said,

> If we situated guys have erred on the side of focusing on "situations and practices rather than the mediating mental representations associated with them" it is because the latter have received plenty of attention, and the former are so understudied that their role in constituting the human mind has not been appreciated or understood by the majority of cognitive scientists. Furthermore, I believe that a better understanding of the former will change what we think to be accomplished by the latter.

Our only disagreement with this is that although cognition has been extensively studied, cognition in context has not; hence, we see a continuing need to attend to mental representations.

Culture as a Superorganism

One of the oldest and most persistent approaches to the science of culture is to consider culture an ontologically distinct superorganism whose laws are *sui generis* and do not arise from individual thoughts and behaviors but govern how individuals think and behave in social contexts (White, 1949). Anthropologist A. L. Kroeber (1923/1963) first formulated the doctrine in this way:

> Culture is both superindividual and superorganic. . . . There are certain properties of culture—such as transmissibility, high variability, cumulativeness, value standards, influence on individuals—which are difficult to explain, or to see much significance in, strictly in terms of organic personalities and individuals. (pp. 61–62)

This American school of cultural anthropology, which viewed culture as a superorganism, soon merged with the British school of social anthropology known as functionalism (Evans-Pritchard, 1940). Functionalism holds that the beliefs, behaviors, and institutions of a society function with the machinelike regularity of a well-adapted organism to promote the healthy functioning of social groups. According to Radcliffe-Brown (1950),

> in reference to any feature of a system we can ask how it contributes to the working of the system. That is what is meant by . . . its *social function*. When we succeed in discovering the function of a particular custom; that is, the part it plays in the working system to which it belongs, we reach an understanding and explanation of it. (p. 3; cf. Malinowski, 1922/1961, p. 23: "Mental states . . . become stereotyped by . . . the institutions of tradition and folklore.")

For the last half century, anthropology has mostly abandoned pretensions to a science of culture based in the law-abiding functional regularity of the adaptive superorganism.[2] However, this view has recently made a comeback under the evolutionary guise of group selection. According to philosopher Elliot Sober and anthropologist David Sloan Wilson (Sober & Wilson, 1998), "in most human social groups, cultural transmission is guided by a set of norms that identifies what counts as acceptable behavior" (p. 150) and that "function largely (although not entirely) to make human groups function as adaptive units" (p. 173). Norms are functioning parts of a "complex and sophisticated machine designed to forge groups into corporate units" (p. 176).

From this level of analysis, one can effectively ignore mental structures when trying to make scientific sense of culture. Although human cultures perhaps developed "to function as adaptive units via many proximate mechanisms" (Sober & Wilson, 1998, p. 182), it is possible to study cultures as phenotypes without de-

[2] Functionalism, which is alive and well in biology, should not be confused with functionalism in anthropology, which has been in decline for at least half a century. Functionalism in anthropology, a dying metaphor, was initially derived from 19th-century biological functionalism, which has since developed into an insightful and instrumental research strategy. One immediate drawback to functionalism in the study of human societies is that it takes no account of intention and other critical aspects of human cognition. In biology, disregard of intention led to a breakthrough in understanding. In anthropology, it led to an ossified form of naive realism that took (often ethnocentric) summary descriptions of exotic and colonized societies for the way things truly were (or were supposed to be). To a significant extent, the present-day focus of much of anthropology—in cultural studies and postmodernism—is a reaction to functionalism's procrustean view of society. Unfortunately, rather than seek a new scientific approach that would renew dialogue with the other sciences, the dominant trend in contemporary anthropology has been to forsake all attempt at scientific generalization and to dwell on the incommensurability and irreducible diversity of different cultural representations and behaviors.

scribing the proximate computational machinery that generates them:

> As long as the proximate mechanisms result in heritable variation, adaptations will evolve by natural selection. There is a sense in which the proximate mechanism does not matter. If we select for long wings in fruit flies and get long wings, who cares about the specific developmental pathway? . . . If humans have evolved to coalesce into functionally organized groups, who cares how they think and feel? (Sober & Wilson, 1998, p. 193; see also Dennett, 1995, pp. 358–359)[3]

We believe, however, that understanding cultural formation and evolution depends profoundly on understanding the proximate cognitive mechanisms involved. Perhaps we can best summarize with an analogy: Macroeconomics is a legitimate field of study and generates important insights into economic activity on the basis of assumptions, for example, of an efficient market (and optimal individual behavior). However, these insights do not in the least undermine microeconomics, and, more to the point, observations from microeconomics, such as loss aversion (e.g., Kahneman & Tversky, 1979) and mental accounting (e.g., Thaler, 1985), have had a significant impact on macroeconomics.

The Grammar of Culture

In anthropology, there is a long tradition of considering culture along the lines of language—that is, as being a rule-bound system with its own grammar. This view of culture is most strongly associated with the structuralist school of Claude Lévi-Strauss (1963) in France and Mary Douglas (1970) and Edmund Leach (1976) in Great Britain. On this account, the bewildering variety of social phenomena and cultural productions are variations generated from a universal structure of the mind (a grammar of culture), which allows people to make sense of the world by superimposing a structure based on a few underlying principles. The structuralist's task is to gather as many variations as possible of some grammatical subsystem of culture (e.g., myth, kinship) to identify the most fundamentally meaningful components in the subsystem and to discern the structure through the observation of patterning. Following the linguistic theory of Ferdinand Saussure (1916/1966), in which phonemes (the smallest unit of linguistic meaning) are understood in contrast to other phonemes, structural anthropologists argued that the fundamental patterns of human thought are also based on a system of binary contrasts to produce more elaborate systems of cultural meaning.[4]

Structural anthropology had little knowledge of the theories of cognitive architecture developed over the last few decades by cognitive and developmental psychologists, neuropsychologists, or generative linguists. The fundamental properties attributed to the human mind, such as binary contrast, were few and simple minded (or so general and vague as to be applicable willy-nilly to any phenomenon at all).[5] This is not to deny the insights that structural anthropologists garnered into the relations among different aspects of cultural life within and across populations (e.g., linking myth, kinship, folk biology, hunting and cooking practices, residential architecture). Instead, it is only to deny that structuralist theories provide any principled causal explanation concerning how these relations might have come about.

More current anthropological views of the grammar of culture are committed less to a specific theory of the cognitive architecture responsible for cultural productions than to the belief that culture consists of a bounded set of rule-bound systems, each with its own grammarlike structure. A more recent work in linguistic anthropology described the culture as grammar view as follows:

> To be part of a culture means to share the propositional knowledge and the rules of inference necessary to understand whether certain propositions are true (given certain premises). To the propositional knowledge, one might add the procedural knowledge to carry out tasks such as cooking, weaving, farming, fishing, giving a formal speech, answering the phone, asking for a favor, writing a letter for a job application. (Duranti, 1997, pp. 28–29)

Anthropology, then, is the discipline of writing the grammar of culture (Keesing, 1972, p. 302). From this perspective, it seems that virtually any patterned activity that numbers of people share in can be considered grammatical, from pottery making to storytelling. For example, "religion belongs to the elementary grammar of culture" (Kannengeiser, 1995, p. 112; cf. Lawson & McCauley, 1990). However, there may be nothing interestingly grammatical

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[3] Sober and Wilson (1998) cited numerous examples from a worldwide ethnographic survey, *The Human Relations Area Files* (HRAF), first compiled by anthropologist George Murdock (1949) over half a century ago, to demonstrate that human cultures are functionally built and maintained as superorganisms (cf. D. S. Wilson, 2002). However, analyses based on the HRAF that purportedly demonstrate the functionalism of group-level traits, or norms, and group selection face problems of circularity because the entries to the HRAF were chosen and structured to meet Murdock's selection criteria for being properly scientific—that is, functionally discrete parts of an adaptive social structure, existing independently of individuals but patterning their behaviors in lawful ways.

[4] A countercurrent to structuralism developed in anthropology, known as cultural materialism and spearheaded by Marvin Harris (1974). The emphasis is supposed to be on objective, etic units of behavior and material patternings of practices, artifacts, population settlements, and so forth rather than on subjective, emic notions of meaning and thought (by analogy with phonetic vs. phonemic analysis in linguistics). A mixture of Marxism and functionalism, cultural materialism relies on what is (at least to us) a wholly mysterious notion of cause that somehow produces ideas from behaviors. For example, according to Harris, the Aztec religious practice of large-scale human sacrifice stems from the fact that Mesoamerica has relatively few large mammals; hence, apart from the other humans they eat, people in the region have few substantial sources of protein (Harris, 1974). This sort of analysis resonates with many of the assumptions of sociobiology. According to biologist Edward O. Wilson (1978), "some of the most baffling of religious practices in history might have an ancestry passing in a straight line back to the ancient carnivorous practices of humankind" (p. 98). Such accounts often invoke ordinary material causes (genetic adaptations for carnivorous behavior) to explain ordinary material effects (cannibalism). Nevertheless, they fail to provide a hint of how the putative distal causes (genetic) enter into known material relations with more proximate causes (mental and public representations) to actually produce the forms of behavior to be explained (religious beliefs, practices, and artifacts causally connected within and between human minds and bodies). Such accounts wave away the superstructure or ideology of cultural forms as nonmaterial or epiphenomenal by-products of underlying material causes (ecological, economic, or genetic; see Atran, 2002, Chapter 8). We hold that ideas are just as material as behaviors and are indispensably constitutive of the causal chains that produce cultural regularities.

[5] In November 1974, Scott Atran interviewed Lévi-Strauss and asked him why he believed binary operators to be one of the fundamental structures of the human mind. Lévi-Strauss replied, "When I started there was still no science of mind. Saussure, Marx, Mauss and music were my guides. Since then things have changed. Psychology now has something to say."

(generated by few and finite rules) about how various cognitive systems link up together to make up religion (Atran, 2002; Atran & Norenzayan, 2004) or science (Atran, 1990, 1998) or culture.

I Culture

A somewhat similar view that is more sophisticated but also problematic has recently arisen among (some) evolutionary psychologists. It is modeled on Noam Chomsky's (1986) distinction between the internal, individual grammar that a given person possesses ("*I* language"; e.g., someone's particular knowledge of American English) and the external language ("*E* language"; e.g., the countless dialects, words, and stylistic differences of the English language as it has developed across the world over the last thousand years or so). Just as the English language was shaped—and is still being shaped—by broad historical events that did not take place inside a single head (including the Norman invasion of England and the global Internet), so were Western European, Chinese, and Navajo culture (Pinker, 2002, p. 71).[6]

If the analogy holds, then psychology's contribution to an understanding of culture might best focus on how children grow an *I* culture through the combination of an innate, biologically specified culture acquisition device and exposure to stimuli in the world (or, equivalently, how individuals are capable at all of participating in "*E* culture"). As Gary Marcus (2004) proposed, "The very ability to acquire culture is, I would suggest, one of the mind's most powerful learning mechanisms" (p. 27). This suggests a line of inquiry for culture studies parallel to that taken by generative linguistics over the past 50 years, in which the fundamental guiding questions include, "What do people know when they know culture?" and, "How do people come to acquire culture?"

Unlike the structuralist version of culture as grammar, this version does not prejudge the complexity or variety of cognitive mechanisms that may be involved in cultural acquisition. Like more current anthropological versions, however, it seems to assume that *I* culture is a bounded system, or an integrated collection of systems, generated (under appropriate experience) by some articulated set of cognitive principles.

However, we contend that there is no systematically bounded or integrated culture as such. There is nothing at all grammatical or generatively rule bound about the relations that connect, for instance, language, religion, the nation state, and science (or that connect the capacities to acquire knowledge of, and participate in, languages, religions, nation states, and sciences). There are only family resemblances to what is commonsensically referred to as culture (or religion or science), but no overarching or integrated structure.

Generativist (Agent-Based) Models of Culture

Recent advocates of agent-based computational models of cultural phenomena also sometimes borrow self-consciously from the framework of generative linguistics, where few and finite rules generate rich and complex structures. For most current agent-based models, however, the focus is not on the generative power of mental mechanisms as such (as it is for advocates of cultural grammar or *I* culture) but on connectionist and constructivist modeling of how (micro)processes at the level of individual decisions and actions yield macrostructural cultural norms and other social regularities, such as spatial settlements (Dean et al., 1999), economic classes (Axtell, Epstein, & Young, 1999), political alliances (Axelrod & Bennett, 1993), voting patterns (Kollman, Miller, & Page, 1992), ecological management networks of religious water temples (Lansing & Kremer, 1993), and so on.

To the generativist, explaining the emergence of macroscopic societal regularities, such as norms or price equilibria, requires that one answer the following question: How could the decentralized local interactions of heterogeneous autonomous agents generate the given regularity (Epstein, 1999, p. 41)?

In agent-based models of cultural phenomena, there is no central, top-down control over individuals. Rather, an initial population of autonomous, heterogeneous agents, situated in a specified spatial environment, begins to interact according to rather simple local rules (e.g., if Agent X manifests Behavior A in the immediate, spatially proximate neighborhood of Agent Y at Time T, then X and Y will both manifest A at Time T1; never attack an immediate neighbor; trade with a neighbor only if that neighbor is red). Over time, these concatenated individual interactions generate—or grow—macrostructural regularities from the bottom up:

> Of course, there will generally be feedback from macrostructures to microstructures, as where newborn agents are conditioned by social norms or institutions that have taken shape endogenously through earlier agent interactions. In this sense, micro and macro will typically coevolve. But as a matter of specification, no central controllers or higher authorities are posited *ab initio*. (Epstein, 1999, p. 42)

There is much in this approach that we find congenial, including (a) the interpretation of society (or culture) as a dynamic and distributed computational network created by and for its constituent interacting individuals; (b) the realization that individual agents have bounded computing capacity and incomplete knowledge with regard to their own intentions and actions as well as the intentions and actions of others; (c) the understanding that information in society is transmitted, canalized, formed, and possessed through endogenous interaction pathways (e.g., social networks); and (d) the realization that emergent macrostructural patterns and processes are neither wholly external to nor wholly internalized in individuals.[7]

From a cognitivist standpoint, however, the requisite mental microprocesses in current agent-based models are relatively simple

[6] In all fairness, Pinker (2002) explicitly called for treating cultural phenomena in terms of an "epidemiology of mental representations" (p. 65) in the sense of Sperber (1996; see the following text) and was well aware of the diverse and partial character of distributions of mental representations among individuals in a population. This makes his analogy of *I* grammar with *I* culture all the more puzzling.

[7] There is much mystery and obfuscation surrounding the notion of emergent structures and processes. One thing emergence is not (at least from an agent-based modeling perspective) is an ontological trait beyond the constituent individual decisions and actions that give rise to it. The aim of agent-based modeling is, precisely, to identify the microprocesses that are necessary and sufficient to deductively generate the macrostructures (Axelrod, 1997a). Nevertheless, actual modeling may (and often does) fall short of this goal because no explanation, in terms of microprocesses, may be fully available at present. In this sense (of not yet reducible in practice but expectedly reducible in principle), mental structures may be considered emergent from networks of neuronal activity (Hempel & Oppenheim, 1948) or the laws of biology emergent from physics (cf. Nagel, 1961). In addition, even where a reduction is, in principle, possible, it may be more efficient and effective to perform analyses at higher levels, just as it is more efficient and effective to analyze a computer program at an algorithmic level than at a machine level (or at the level of the physics that implements machine-level codes).

(e.g., imitation, following a conventional rule). These models also frequently incorporate functionalist views of cultural macrostructures as adaptive systems (cf. Sober, 1996)—a simplifying assumption that can lead to theoretical insights and provoke new empirical research (e.g., to the extent that cultural systems inevitably fall short of adaptive equilibrium) but that may not produce accurate descriptions or explanations of cultural stability. This same taste for simplicity is associated with a relative neglect of ecological context (save for spatial proximity of agents) and social processes (other than dyadic contacts). These limitations are matters of practice, not principle, and reflect the goal of seeing just how much complexity can derive from minimal assumptions.

The most straightforward way to integrate our approach with agent-based modeling is to substitute empirical observations on cultural processes for the sorts of simplifying assumptions we have described. Our enterprise (as well as that of other distributional theorists, e.g., Boyd & Richerson, 1985) is compatible with agent-based cultural modeling. Our eventual contribution to agent-based generations of cultural macrophenomena is to (a) enrich microspecifications of agent behaviors and decisions by specifying the cognitive mechanisms involved and (b) furnish ethnographically plausible patterns and principles for agent behaviors and decisions. Sufficiently enriched, agent-based modeling could become a key scientific instrument for understanding the distribution and stabilization of cultural phenomena and a potentially powerful tool for empirical research.

Summary

There are no absolute standards for evaluating different notions about what constitutes relevant cultural contents or processes and how they should be studied. Framework theories are typically judged not by whether they are right or wrong but rather by whether they are useful. Utility, in turn, may vary as a function of goals. All of the above approaches have strong value relative to the default condition of much of experimental psychology, which focuses solely on American undergraduates at majority universities. The relative merits of one approach versus others can be understood in terms of its position on underlying dimensions, such as scope and specificity. The situated view and cultural psychology represent two end points on this continuum. Cultural psychology aims to identify a small set of cognitive processes that (are thought to) operate very widely. Viewing cultures in terms of shared norms and values also can reveal important cultural differences. In contrast, situationists are more impressed with the lack of transfer of cognitive skills across settings (e.g., Lave & Wenger, 1991).

The framework theory that we endorse draws on insights from a number of the theories we have just reviewed. In particular, our focus is on cultural processes, and, consequently, our approach is a first cousin of both the situation and the agent-based modeling approaches. We now turn to our approach and lay out its methodological and conceptual implications.

Cultural Epidemiology

In the norms and rules approach (including memetics; Blackmore, 1999; Dawkins, 1976; Dennett, 1995; cf. Atran, 2001a), there is a basic assumption that memory and transmission mechanisms are reliable enough for standard Darwinian selection to operate over cultural traits (i.e., the rate of mutation is significantly lower than the selection bias). On this view, inheritable variants (of ideas, artifacts, behaviors) are copied (imitated, reproduced) with high enough fidelity so that they resemble one another more than they do unrelated forms. Only then can they be repeatedly chosen as favorable for cultural survival or eliminated as unfavorable by selection.

We believe that these assumptions are limited because they pay insufficient attention to psychology; in particular, they tend to neglect the sorts of inferential and developmental cognitive processes that allow human beings to build and participate in cultural life. For these reasons, we also believe that these various proposals for cultural replication, which are intended as generalizations of Darwinian processes of replication in biology, either suffer from vagueness (e.g., memetics) or pertain to highly limited sets of phenomena (e.g., the coevolution of animal domestication and lactose tolerance in Eurasian societies, or learning by imitation). Instead, we propose to look at cultures in terms of mental representations (and attendant behaviors) that are reliably but diversely distributed across individuals in a population (the population itself being circumscribed by the intersection of these various distributions). This is what we mean by cultural epidemiology.[8]

Boyd, Richerson, and their colleagues (e.g., Boyd & Richerson, 1985, 2001) have modeled the distributions of beliefs and practices within and across populations and also the stabilizing role of psychological biases in transmission, such as conformity to preferences that already prevail in the population and emulation in deference to the beliefs and behaviors of prestigious people (Henrich & Boyd, 1998; Henrich & Gil-White, 2001). We focus on the stabilizing role of cognitive structures in the production and transmission of ideas (and attendant behaviors) that achieve widespread cultural distribution. These may not be exclusively or even mainly shared as nearly identical mental representations across individual minds nor transmitted more or less intact from mind to mind through any other sort of high-fidelity replication (Atran, 2001a; Sperber, 1996). Imitation has strong limits with respect to replication—not only is it just a single way of transmission, but also, given the many-to-one mappings between acts and mental repre-

[8] The notion of cultural epidemiology has two distinct traditions: one focused on the relatively high-fidelity reproduction and patterning of cultural (including psychological) traits within and across human populations, and one focused on the ways cognitive structures generate and chain together ideas, artifacts, and behaviors within and across human populations. Jacques Monod (1971), the Nobel Prize biologist, was the first to use the concept of culture as contagion—although more as metaphor than as theory. Cavalli-Sforza and Feldman (1981) were pioneers in working out a theory in which culture is conceptualized as distributed through a population; however, no microscale cognitive processes or structures were modeled or considered, only macroscale social–psychological traits. Two more fully developed epidemiological approaches soon emerged. Boyd and Richerson (1985) were able to show how biases in transmission, such as prestige or conformism, could help to explain the spread and stabilization of macrosocial–psychological traits among populations. Sperber (1985) provided the first theoretical blueprint for how individual-level microcognitive structures (as opposed to invocation of imitation or other cultural reproduction processes) could account for cultural transmission and stabilization. Until now, there has been little fruitful interaction between these two traditions (see Laland & Brown, 2002, but also Henrich & Boyd, 2002). We believe that these two epidemiological traditions are compatible, and our empirical example suggests that they can be mutually informative (see *The Learning Landscape* section).

sentations of them (including their meaning), there is no guarantee of any sort of fidelity. (Indeed, *imitation* often seems to us a term of folk psychology that needs explanation rather than explains.) We suggest that much of the cultural transmission and stabilization of ideas (artifacts and behaviors) involves the communication of poor, fragmentary, and elliptical bits of information that manage to trigger rich and prior inferential structures.

The idea that cultural content may be distributionally unstable and seldom reliably replicated is far from new (e.g., Linton, 1936; Roberts, 1964; A. F. Wallace, 1961; see Gatewood, 2001, for a review). For example, A. F. Wallace (1961) suggested that

> culture shifts in policy from generation to generation with kaleidoscopic variety, and is characterized internally not by uniformity, but by diversity of both individuals and groups, many of whom are in continuous and overt conflict in one subsystem and in active cooperation in another. (p. 28)

What may be relatively novel in our approach is the focus on variability as the object of study. The degree to which cognitive content is actually shared or similarly inferred across individual minds may depend on many factors in addition to preexisting cognitive structures, such as the way the physical and social environments channel the transmission of information (e.g., mountains hinder the communication and spread of ideas, classrooms facilitate them). The various distributions of ideas across populations may also be determined to a significant extent by the history of economic, political, and military relations between and within groups. In the empirical body of this article, we provide examples of how these different sorts of canalizing factors—cognitive, environmental, and historical—interact to produce culturally identifiable behaviors.

At the risk of some oversimplifying, we summarize in Table 1 the eight approaches to culture under discussion according to their stances on five key issues. As we suggested earlier, the cultural epidemiology view is most similar to the agent-based and situated cognition views. It differs from both these views in its focus on inference. Specifically, we suggest that these preexisting and acquired inferential structures account for the cultural recurrence and stabilization of many complexly integrated ideas and behaviors (see Atran, 2002; Boyer, 1994, for religion) and set the parameters on allowable cultural diversification (Sperber & Hirschfeld, 2004).

The Distributional View and Methodology

Our choice of methodology is chiefly motivated by theoretical concerns related to a view of cultures as variably distributed patterns of modularly constrained cognitions within given populations. Here, we describe techniques for modeling cultural consensus to show systematic variation in how folk biological knowledge is put into action to generate behaviors relevant to human survival. In addition, consensus modeling permits recovery of more graded patterns of variation within and between populations (down to the level of the individual and up to the level of combining cultural patterns to show metacultural interaction and consensus). This enables us to explore the behavioral consequences and cognitive coping strategies (including patterns of information flow and exchange between individuals from different populations) that are, for example, associated with processes of knowledge loss and devolution (described in Medin & Atran, 2004; see also Atran, Medin, & Ross, 2004).

It is our view that cultures can be effectively studied as causally distributed patterns of mental representations, their public expressions, and the resultant behaviors in given ecological contexts. People's mental representations interact with other people's mental representations to the extent that those representations can be physically transmitted in a public medium (language, dance, signs, artifacts, etc.). These public representations, in turn, are sequenced and channeled by ecological features of the external environment (including the social environment) that constrain psychophysical interactions between individuals (Sperber, 1996).

Representations that are stable over time within a culture, such as those that recur across cultures, are stable because they are readily produced, remembered, and communicated.[9] The most memorable and transmissible ideas are those most congenial to people's evolved, modular habits of mind. One could argue that some of these habits of mind evolved to capture recurrent features of hominid environments relevant to species survival (Medin & Atran, 2004). One plausible example is the apparently universal and spontaneous disposition to categorize all and only plants and animals into mutually exclusive groups of essence-based species (i.e., folk generic species, e.g., cat and redwood) and to further taxonomize these groups into classes of groups under groups (e.g., folk life forms, e.g., mammal and tree; or folk specifics and varietals, e.g., tabby and short-haired tabby). In all societies, it appears, this is done in a uniform, well-structured manner that is "not arbitrary like the grouping of stars in constellations" (Darwin, 1859, p. 431; see also Berlin, 1992).

Once emitted, such core-compatible ideas spread contagiously through a population of minds (Sperber, 1985). They are often learned without formal or informal teaching and, once learned, cannot be easily or wholly unlearned (Atran & Sperber, 1991). For example, when learning about a new biological species—no matter how poor and fragmentary the stimuli are (e.g., a single instance of a fuzzy drawing)—people automatically interpret it to have a unique causal essence that enables it to be assigned a fixed place in their folk biological taxonomy.

A significant departure from a shared norms and rules perspective is that the variable distribution of ideas is treated as signal, not noise. The distribution view uses a set of techniques for assessing groupwide patterns that statistically demonstrate cultural consensus or lack thereof. In our work we have relied extensively on the cultural consensus model (CCM) of Romney, Weller, and Batchelder (1986), an important tool for analyzing commonalties and differences within and across cultural groups. The CCM has been used as an effective tool by cognitive anthropologists (e.g., Moore, Romney, Hsia, & Rush, 2000; Romney & Batchelder, 1999; Romney et al., 1986).

[9] A reviewer correctly pointed out that stability is also determined by the real world consequences of ideas. The spread and persistence of cultural representations is also affected by their effects and by the law of unintended consequences. Prior historical contingencies and differences within and between groups (economic, social, military), unforeseen events, and feedback loops (e.g., of stereotyping on the beliefs and behaviors of those who are stereotyped) alter outcomes associated with even the most stable representations. These altered outcomes, in turn, affect the efficacy (and, hence, stability) of the representations and associated actions intended to produce the outcomes.

Table 1
Approaches to Cultural Research and Their Stance on Five Issues

	Issue				
Approach	How should culture be studied?	Cultural change	Within-cultural variability	Cognitive processes and their relevance	Role of domain-specific processes
Shared norms and values	Shared values, ideas, customs	Viewed as loss	Viewed as noise	Learning and memory	Not addressed
Cultural psychology	Shared values, world views, processing mechanisms	Not addressed	Not addressed	Inference, reasoning, perception (cognitive tool box)	Not addressed
Situated cognition	Cognitions, belief systems, and artifacts	Cultures are dynamic	Variability associated with different practices and artifacts	Distributed, often context specific	Important to development
Culture as superorganism	Emergent system affecting individuals	Adaptive	Acknowledged, but not relevant	Ignored as inappropriate unit of analysis	Depends on domain-specific functionality
Culture as grammar	Shared knowledge, procedures, rules	Not addressed	Not addressed	Mental structures revealed by cross-cultural comparisons	Not addressed
I culture	Bounded rulelike system organized by cognitive processes	Not addressed	Driven by *E* culture	Universal cultural acquisition device	Important
Agent-based modeling of culture	Beliefs, rules, and norms as products of simple micro-processes	May be emergent outcome from perturbation of steady state; dynamic	Treated as signal, key to analyzing cultural transmission processes	Imitation, rule following	Not usually addressed
Cultural epidemiology	Distribution of ideas, beliefs, and behavior in ecological contexts	Cultures are dynamic	Treated as signal, key to analyzing cultural processes	Inference, reasoning, perception, and notions of relevance	Important

Note. *I* culture = culture as internalized in the mind of a specific individual; *E* culture = external culture, as it applies to an entire population, including external signs, institutions, and artifacts.

The CCM

Before we describe the CCM in detail, three general points are in order: (a) The CCM does not prescribe which ideas should be studied any more than analysis of variance (ANOVA) dictates which variables should be measured. (b) It is not a theory of culture (cf. Garro, 2000) but rather a tool that can be used to evaluate such theories. (c) Although its most natural use and interpretation focus on consensus, it also can be effectively used to examine within- and across-groups differences (ANOVA could also be used to detect between-groups differences, but it is less effective in identifying within-group patterns and pinpointing cross-groups differences).

The CCM assumes that widely shared information is reflected by a high concordance among individuals. When there is a single cultural consensus, individuals may differ in their knowledge or cultural competence. Estimation of individual competencies is derived from the pattern of interinformant agreement indices on the first factor of a principal-components analysis (essentially, factor analysis). These competency scores should not be mistaken for scores of expertise. The cultural model provides a measure for culturally shared knowledge, and, hence, the levels of competencies measure the extent to which an individual shares what everyone else agrees on.

There are three standard assumptions of the original version of the CCM: (a) Each item has a (culturally) correct answer (items are dichotomous), (b) items are independent given the culturally correct answers, and (c) each respondent has a fixed competence over all questions (i.e., the items are homogeneous). Batchelder and Romney (e.g., Batchelder & Romney, 1989; Karabatsos & Batchelder, 2003; Romney, Batchelder, & Weller, 1987) have analyzed the effects of relaxing these axioms or assumptions in a number of subsequent publications.

Although the CCM is a formal model designed for fixed-format questionnaires (true–false, matching, or multiple choice), it can also be used as a data model for more open-ended responses, such as sorting items into a hierarchical taxonomy (see Romney et al., 1987). In this instance, the individual informant data consist of an item-by-item matrix of distances between all pairs of items, and these are used to establish similarities or agreement indices between all pairs of participants. The participant distance matrices are then correlated with each other and represent a measure of the degree to which each participant's taxonomy agrees with every other participant's taxonomy. The participant-by-participant correlation matrix is the input to the principal-components analysis.

Assuming that the correlation between two informants' sorting patterns is entirely due to the connection of each of them to the consensus knowledge, the data model approach creates a quantity in the first factor that is a proxy for consensus knowledge (W. Batchelder, personal communication, January 1, 2004; see Romney, 1999, for further discussion and an application). For interval data, the first factor loading in a principal-components analysis becomes an estimate of how much an individual knows. In other words, the data model provides estimates of consensus as the correlation of the individual with the aggregate. This data model is similar to reliability theory, with the role of individual and item reversed, and produces an insignificant reliability overestimation compared with the formal model. This is because an item in the formal model is supposedly correlated with the cultural truth, whereas an individual in the data model is correlated with an aggregate including that individual (A. K. Romney, personal communication, 1995; see also Romney et al., 1986).[10]

A cultural consensus is found to the extent that the data, overall, conform to a single-factor solution. Specifically, the first latent root—or eigenvalue—is large in relation to all other latent roots, and individual scores on the first factor are strongly positive. A good guideline is when the ratio of the first to the second eigenvalue is at least 3:1.

Of course, general agreement may be coupled with systematic disagreement, and the CCM is an effective tool for uncovering both shared and unshared knowledge. Another desirable characteristic of the CCM is that degree of agreement can be used to determine the minimum sample size needed to estimate the cultural consensus within some range of tolerance. In some of our studies as few as 10 informants were needed to reliably establish a consensus.

Assuming that a single-factor solution is satisfactory, the first factor scores for each informant represent an estimate of cultural competence. For example, if one person has a first factor score of .90, then the best estimate is that his or her responses reflect 90% agreement with the overall consensus. Lower competence scores indicate less agreement with the consensus. For example, a person with a first factor score of .80 has made more errors or disagrees more with the consensus than the informant with a .90 score. After the consensus parameters are estimated for each individual, the expected agreement between each pair of subjects is generated (as the product of their respective consensus parameters). In the above example, the expected agreement between the two informants is $.90 \times .80$ (or .72). These products are used to generate an informant-by-informant expected agreement matrix. Next, the expected agreement matrix is subtracted from the raw agreement matrix to yield a matrix of deviations from expected agreement (cf. Hubert & Golledge, 1981). If raw and residual agreement are significantly associated, then a significant portion of residual agreement consists of deviations from the consensus. One can then explore other factors (e.g., cultural subgroups, social network distance), which might predict or explain the residual agreement. For example, Boster (1986) found that among the Aguaruna Jívaro (Ashuar) people there was a shared cultural model for the identification of various varieties of manioc and that deviations from this shared model were related to membership in kin and residential groups (i.e., agreement within these groups is higher than what one would predict on the basis of the overall cultural model).[11]

Another marker for reliable residual agreement is when an analysis over two or more groups reveals systematic differences in

[10] There are a few simplifying assumptions associated with the use of the CCM as a data model. One is that the sorting method produces interval data and that the answer key consists of the simple mean (rather than a weighted mean based on competence scores). The other is that individual response characteristics (e.g., response bias) do not contribute to the correlation between two individuals (W. Batchelder, personal communication, January 26, 2004; Romney, 1999; see also Batchelder & Romney, 1988). Using hierarchical sorting rather than simple sorting reduces the potential contribution of response bias, and in other applications we apply a correction for guessing (Atran et al, 1999; Medin et al, in press).

[11] This method is potentially flawed if the assumption of item homogeneity is violated. In that case, overall agreement and residual agreement may be spuriously correlated. Accordingly, we typically use within- versus between-groups residual agreement as our measure.

factors beyond the first. If two groups differ in their second factor scores, then within-group agreement extends beyond the overall consensus. For example, Medin, Lynch, Coley, and Atran (1997) asked tree experts to sort local species of trees and found clear overall consensus, coupled with second factor scores correlating strongly with occupation (e.g., parks maintenance, taxonomist, landscaper). Subsequent comparisons revealed systematic differences in the basis for sorting across these groups.

In the case of an existing consensus, the CCM justifies the aggregation of individual responses into a cultural model. The CCM gives an estimate of the levels of agreement among the informants. Therefore, it is possible to use this model to explore agreement patterns both within and across different populations, the latter describing potential metacultural models. This promotes exploration of possible pathways of learning and information exchange within and between cultural groups, illuminating more general processes of cultural formation, transformation, and evolution.

Once cultural differences are found, we can proceed to ask a series of more analytic questions about things, such as (a) are these ideas spread by means of abstract models and inference strategies, or is the information conveyed in quite literal, concrete form? (b) Do factors such as income, occupation, density of social networks, or a variety of other input conditions moderate cultural differences (either within or between groups)? Within the present framework, the goal in studying variation is to have a theory about the distribution of ideas and flow of information, not to isolate some reified entity, culture (see Ross, 2004).

Summary

In a companion article, we argue that there are universal constraints on how people organize their local knowledge of biological kinds (Medin & Atran, 2004). These evolutionary constraints form a learning landscape that shapes the way inferences are generalized from particular instances or experiences. It produces consensus even though specific inputs vary widely in richness and content. Thus, many different people, observing many different exemplars of dog under varying conditions of exposure to those exemplars, may nonetheless generate more or less the same concept of *dog*. To say an evolved biological structure is innate is not to say that every important aspect of its phenotypic expression is genetically determined. Biologically poised structures canalize development but do not determine it—like mountains that channel scattered rain into the same mountain–valley river basin (Waddington, 1959).

In this article, we argue that a culturally specific learning landscape further constrains the canalization process, much as an artificially built dam further channels the flow and shapes the path of water in a natural river basin (Atran, 2002; Sperber, 1996). The existence of any systematic distribution of ideas and behaviors, or cultural path, results from an integration of distinct cognitive, behavioral, and ecological constraints that neither reside wholly within the mind nor are recognizable in a world without minds (in this respect we agree with the situated cognition view). Cultural paths do not exist apart from the individual minds that constitute them and the environments that constrain them, any more than a physical path exists apart from the organisms that tread it and the surrounding ecology that restricts its location and course. As Inagaki and Hatano (2002) suggested, it is the confluence of these various sources of constraints that makes cross-cultural comparisons possible and meaningful.

Garden Experiments in Mesoamerica and North America

There is little or no detail available in typical normative accounts of social structure in the anthropological literature that would allow evaluation of patterns of individual variation, agreement, and disagreement within and between groups. Without such detail, normative claims are difficult to verify or falsify. The overarching reason is simple: Anthropologists are typically instructed to go out into the field alone for some months or—in exceptional cases—some few years and bring back a description of the society studied. The popular image of the anthropologist with a pith helmet and notebook is not very far off the mark, only now the pith helmet is a baseball cap or canvas fedora, and the notebook is a personal computer. In this situation, there is little alternative to normative description (excepting the narratives of antipositivist postmodernism, which do little to foster dialogue with the larger scientific community).

Detailed analyses of the relations among ecology, technology, social networks, and so forth require large interdisciplinary efforts, over many field seasons, at a cost that usually exceeds typical ethnographic fieldwork by one or more orders of magnitude. The pertinent academic and government funding institutions are not set up for this kind of project, so the effort is rarely made (for a notable exception, see Henrich et al., 2001). We have been fortunate to be involved in two such efforts: one in Mesoamerica, and another in North America.

A case study on the importance of cultural models versus environmental determination comes from a variation on the common garden experiment in biology. When members of a species have different phenotypes in different environments, samples are taken from both environments and replanted in only one. If the differences still exist, they are probably genetic (two genotypes); if not, then they are probably environmental (one genotype producing two phenotypes). Here we use a variation on this experimental approach. Our aim is not to distinguish genetic nature from environmental nurture but rather to isolate the role of certain sociocultural factors (social networks, cognitive models) from other economic (sources and level of income), demographic (family and population size), and ecological factors (habitat and species) in environmental management. Evidence for the importance of culturally transmitted factors on behavior would be data showing that groups of people who have different cultural histories and cultural ideas behave differently in the same physical environment.

Study Populations and Context

In the next several paragraphs we describe the main study populations in our research.

Mesoamerican Populations

A key focus of our work concerns three cultural groups in the same municipality in Guatemala’s Department of El Petén: native Itza’ Maya, Spanish-speaking immigrant Ladinos, and immigrant Q’eqchi’ Maya. Itza’ and Q’eqchi’ were each circumscribed by entirely overlapping and perfectly redundant criteria of proximity of residence, ethnic self-identification, and a multigenerational history of pervasive family interconnections. The Q'eqchi' were also identified by their mother tongue. The Ladino population was initially circumscribed by proximity of residence, language (Spanish), ethnic self-identification, and lack of a community-wide history of family interconnections. In addition, members of each community readily and distinctly identify the group affiliation of members of the other communities. This initial circumscription of cultural groups obviously relied on common-sense conceptions of cultural differences, but our analyses and subsequent findings were not bound by these initial selection criteria (see the observations on circularity in cultural research in the General Discussion and Implications section).

In all groups, men are primarily occupied with practicing agriculture and horticulture, hunting game and fish, and extracting timber and nontimber forest products for sale. Women mainly attend to household gardening and maintenance. The climate is semitropical, with quasi-rainforest predominating (tropical, dry forest or hot, subtropical, humid forest). Topographic and microclimatic variation allow for a dramatic range of vegetation types over relatively small areas, and sustaining both this diversity and people's livelihood over the last 2 millennia has required correspondingly flexible agroforestry regimes (Atran, Lois, & Ucan Ek', 2004; Sabloff & Henderson, 1993).

Native Itza' Maya. The Itza', who ruled the last independent Maya polity, were reduced to corvée labor after their conquest in 1697 (Atran et al., 2004). San José was founded as one of a handful of reductions for concentrating remnants of the native Itza' population (and fragments of related groups). In 1960, the military government opened the Petén (which includes 35,000 km^2, about one third of Guatemala's territory) to immigration and colonization. In the following years, about half the forest cover of Petén was cleared. In a project engineered by the U.S. Agency for International Development and supported by a debt for nature swap, Guatemala's government set aside remaining forests north of 17°10′ latitude as a Maya Biosphere Reserve, a designation recognized by the United Nations Educational, Scientific, and Cultural Organization in 1990. The San José municipality now lies within the reserve's official buffer zone between that latitude and Lake Petén Itza' to the south. Today San José has some 1,800 habitants, about half of whom identify themselves as Itza', although only older adults speak the native tongue (a lowland Mayan language related to Yukatek, Mopan, and Lakantun).

Immigrant Ladinos. The neighboring settlement of La Nueva San José was established in 1978 under jurisdiction of the Municipality of San José. The vast majority of households (about 600 people) are Ladinos (native Spanish speakers, mainly of mixed European and Amerindian descent), most of whom were born outside of Petén. The majority migrated to the area in the 1970s as nuclear families stemming from various towns of southern Guatemala.

Q'eqchi' Maya. The hamlet of Corozal, also within the Municipality of San José, was settled at the same time by Q'eqchi' speakers, a highland Maya group from the Department of Alta Verapaz, just south of Petén. Q'eqchi' filtered in as nuclear families, migrating in two waves that transplanted partial highland communities to Corozal: (a) directly from towns in the vicinity of Cobán (the capital of Alta Verapaz), and (b) indirectly from Alta Verapaz via the southern Petén town of San Luis (home to a mixed community of Q'eqchi' and Mopan Maya). Q'eqchi' immigration into Petén began as early as the 18th century, though massive population displacement into Petén is recent. The Q'eqchi' now constitute the largest identifiable ethnic group in Petén while maintaining the smallest number of dialects and largest percentage of monolinguals (R. Wilson, 1995, p. 38; cf. Stewart, 1980). This reflects the suddenness, magnitude, and relative isolation of the Q'eqchi' migration. Although many of the nearly 400 Q'eqchi' of Corozal understand Spanish, few willingly converse in it. Q'eqchi' is not mutually intelligible with Itza'. To help understand results with lowland Q'eqchi' immigrants, we also studied a native highland Q'eqchi' group.

North American Populations

Resource conservation and conflict over it are also important issues in Wisconsin, where majority culture and Native American hunters and fishermen may conceptualize nature in distinct ways.

Menominee. The Menominee ("Wild Rice People") are the oldest continuous residents of Wisconsin. Historically, their lands covered much of Wisconsin, but they were reduced, treaty by treaty, until the present 95,000 hectares (about 240,000 acres) was reached in 1854. There are 4,000–5,000 Menominee living on tribal lands in and around three small communities. Over 60% of Menominee adults have at least a high school education, and 15% have had some college. The present site was forested then and now—there are currently about 88,000 hectares of forest. Many of the vast Great Lakes forests did not survive the post–Civil War flurry of logging. In contrast, Menominee have practiced logging on a sustainable basis for the last 150 years. The Menominee reservation is managed by a tribal legislature. Sustainable coexistence with nature is a strong value (Hall & Pecore, 1995). Hunting and fishing are important activities for most adult men and for many women. Fishing is practiced on the reservation's many lakes and streams. The tribe sets specific rules for both fishing and hunting on the reservation, one of them specifically outlawing the "wanton destruction" of any species.

Rural majority culture. Adjacent to the Menominee reservation is Shawano County, which consists of farmland, small forests, and numerous lakes and rivers. The county was well settled by 1850, and a substantial portion of the current population can trace its origins in the area to 19th century immigration. As for the Menominee, hunting and fishing play a big role in the social and recreational life of the majority culture people. Most fishing is on the Wolf River or Shawano Lake (which also attracts a lot of fishing tourists). Compared with Menominee fishermen, fishing for food source is a lesser priority for majority culture fishermen, who are more interested in fishing for sport. Thus, it is not surprising that catch and release fishing plays a somewhat more important role off the reservation than on it. Finally, although Menominee can purchase a fishing license for off-reservation fishing, majority culture people cannot fish on the reservation. Fishing is done during all seasons, including ice fishing in winter.

Folk Ecology and the Spirit of the Commons

In earlier studies, we found that Itza' Maya informants consistently appealed to ecological relations on category-based induction tasks, unlike U.S. college students, who focused on taxonomic relations: for example, generalizing a property of bats to horses on the grounds that horses are likely to be bitten by bats (reviewed in Medin & Atran, 2004). Although we did not have corresponding data from Q'eqchi' and Ladino adults on such tasks, the Itza' propensity for ecological reasoning, coupled with their record of sustainable agroforestry, suggested to us that there may be a connection between folk ecological models and behavior. Furthermore, the fact that the Ladino and Q'eqchi' populations practice agroforestry in a much less sustainable manner provided the opportunity to explore whether understandings of the forest are correlated with action on it. These conjectures led us to a series of systematic cross-cultural and within-cultural comparisons that are pertinent to a variety of conceptual issues in cognition, decision making, and culture theory (Atran et al., 1999, 2002; Medin, Ross, Atran, Burnett, & Blok, 2002; see also Ross, 2002; Ross & Medin, 2005). Evidence for the importance of culturally transmitted cognitive models on behavior would indicate that groups of people who have different cultural histories and cultural ideas behave differently in the same physical environment.

We have used a threefold approach to understanding causal relations among individual cognitions, human behaviors that directly affect the environment, and cultural patterns that emerge from population-wide distributions of cognitions:

1. Folk ecology involves a cross-cultural methodology for modeling people's cognitions of the ecological relations among plants, animals, and humans.

2. Cultural epidemiology involves ways of mapping individual variation and interinformant agreement in the flow of ecologically relevant information within and between societies, using social network analysis to trace potential transmission pathways in transfer of knowledge.

3. Spiritual values and the commons involve operationalizing the role of noneconomic entities and values, such as supernatural beings, in environmental cognition and behavior.

The lowland Maya region faces environmental disaster, owing in part to a host of nonnative actors having access to the forest resources (Schwartz, 1995). A central problem concerns differential use of common-pool resources, such as forest plants, by different cultural groups exploiting the same habitat. As we noted earlier, one strong view is that individual calculations of rational self-interest collectively lead to a breakdown of a society's common resource base unless institutional mechanisms restrict access to cooperators (Berkes et al., 1989; Hardin, 1968). The reason is clear: In the absence of monitoring and punishment, exploiters gain the same benefits as cooperators, but at reduced cost. Cooperators are driven to extinction, and exploiters flourish until the commons is destroyed. Still, exclusive concern with economic rationality and institutional constraints on action may not sufficiently account for differences in environmental behaviors (Ostrom, 1998). To make better sense of these differences, we examined links between environmental cognitions and behaviors.

Folk Ecology

Although folk taxonomies are structured similarly across diverse cultures, this leaves aside important insights into how people actually parse the content of local biodiversity and reason about it. More generally, it ignores how people cognize the environment in ways relevant to behavior. There are precedents for our attempt to fill this void (e.g., Posey, 1983); however, to our knowledge, what follows is one of the first attempts to show the role of cognitive and cultural orientation in deforestation and land use.

The Common Setting

As noted earlier, Petén's forests are a common-pool resource that is rapidly being depleted. The deforestation rate, which averaged 287 km^2 yearly between 1962 and 1987, nearly doubled to 540 km^2 in 1988–1992, as the population rose from 21,000 to over 300,000. Population estimates for 1999–2000 ranged from 500,000–700,000. A new European-financed paved road now links Guatemala City to Flores (the former Itza' capital of Petén). Projections based on remote sensing and ground measurements indicated a 14.5% increase in rate of deforestation during 1999–2000. No doubt a major cause of deforestation is population pressure from the overcrowded and tired lands of southern Guatemala. However, our data indicate that different populations that engage in the same activities have very different impacts on the environment, suggesting a more complex relation between population processes and ecological degradation.

For all three groups, people pay rent to the municipality for a farm plot. All actors pay the same rent (set by the municipal council). Rent does not vary as a function of the productivity of the land and is not based on a share of the product. Each household (about five persons) has usufruct rights (i.e., use, but not ownership title) on 30 manzanas (21.4 hectares, or about 50 acres) of *ejido* land (municipal commons). Farmers pay yearly rent of less than a dollar for each manzana cleared for swidden plots, known as *milpas,* whose primary crop is maize. All groups practice agriculture and horticulture, seek fish and game, and extract timber and nontimber forest products for sale.

People can hold plots in scattered areas and can change plots. Plots from all groups may abut. Hunting is tolerated on neighbors' plots, but not access to another's crops or trees. Itza' and Ladinos interact often, as their villages are 1 km apart. Q'eqchi' live 18 km from both groups; however, daily buses connect the Q'eqchi' to the other two groups (who also farm regularly around the village of Corozal).

Multiple converging measures of soils, biodiversity, and canopy cover indicate that Itza' promote forest replenishment, Q'eqchi' foster rapid forest depletion, and Ladinos fall somewhere in between (Atran et al., 1999, 2002). For example, for every informant in each population, we sampled 1-hectare (2.5-acre) plots from their agricultural land (*milpa*), fallow land (*guamil*), and forest reserve. For each plot, we measured species diversity, tree count, coverage (square meters of foliage for each tree crown), and soil composition. Measurements of behavior patterns and their consequences for soils corroborate patterns from reported behavior, suggesting that Itza' agroforestry practice encourages a potentially sustainable balance between human productivity and forest maintenance. Given the results from our sample plots, we estimated that Q'eqchi' forest-clearance rates (i.e., amount of land cleared divided by number of years that land is cultivated) are more than five times greater than those for Itza' (Atran et al., 2002). Ladino rates are twice that of Itza'. Remote sensing confirms the pattern of deforestation along Q'eqchi' migration routes for Petén (Sader, 1999).

Despite these objective differences in practices, Itza' tend to believe that Ladinos have more destructive practices than do Q'eqchi' (11 of 14 Itza' indicated this in an informal survey). Several factors may mediate this misperception. First, both Itza' and Q'eqchi' see themselves as Maya and might also subscribe to an underlying essential ethnic and racial unity (see Gil-White, 2001). Second, the Q'eqchi, but not the Itza', have retained corporate rituals for planting and harvesting (which the Itza' are now starting to adopt). These rituals tend to reinforce communal sharing and responsibility, which Itza' mistakenly believe extend to Q'eqchi' attitudes and actions toward the forest. Third, as we show later, Itza' interact with Ladinos on issues about the forest and so may be more aware of the relative ignorance of the Ladinos.

Mental Models of Folk Ecology

Because analyses revealed no reliable between-populations differences in age, family size, land available to cultivate, or per capita income from all traceable sources, we sought to determine whether group differences in behavior are reflected in distinct folk ecological models. In preliminary studies, we asked informants from each of the three groups, "Which kinds of plants and animals are most necessary for the forest to live?" From these lists we compiled a consensual set of 28 plants and 29 animals most frequently cited across informants from the communities (plant kinds were all generic species, except for two life forms, grass and bush). The 28 plants in the study include 20 trees and 1 ligneous vine counted among the species in the preliminary study. Although these 21 species represent only 17% of the total number of species enumerated, they account for 44% of all trees in Itza' parcels, 50% in Ladino parcels, and 54% in Q'eqchi' parcels. This confirms the salience of the species selected for the folk ecology study (see Table 2).

Plant–animal interactions. Instructions and responses were given in Itza', Spanish, or Q'eqchi'. Twelve informants from each population were asked to explain how each plant helped or hurt each animal and how each animal helped or hurt each plant. Note that the focus of both the questions and the answers was on patterns of individual actions rather than long-term population change or stability. Thus, a predator hurts its immediate prey but may help protect the prey from consequences of overpopulation. Our informants would report this type of relation as the predator hurting the prey (see Atran et al., 2002, for more detail).

The procedure had two parts. We asked participants how each plant affected each animal. The task consisted of 28 probes, 1 for each plant. On each trial, all animal picture cards were laid out, and the informant was asked whether any of the animals "search for," "go with," or "are companions of" the target plant and whether the plant helped or hurt the animal. Questions were pretested for simplicity and applicability across cultures. Unaffiliated animals (those that a given informant said had no specific relation to any of the plants) were set aside. For each animal, informants were asked to explain how the plant helped or hurt the animal (plant → animal). Next, they were asked how each animal helped or hurt each plant (animal → plant). To explore interactions among people and plants, we asked each informant to explain whether people in his or her community actually help or hurt each item on the plant list, and vice versa.

For each task, we used the CCM to determine whether a single, underlying model of ecological relations held for all informants in a population. We collapsed over the different ways one kind might help or hurt another, and the dependent variable for each pair was whether the plant or animal in question helped, hurt, or had no effect on the other kind. Agreement across informants was determined by whether their answers matched or mismatched for each pair. To establish consensus, all tasks involved 12 participants from each group, with equal numbers of men and women. Data were adjusted for guessing (Romney et al., 1986).

Plants affecting animals. Each of the three groups produced a distinct model on the forest ecology task. Two results are apparent regarding how participants see plants affecting animals: (a) Itza' and Ladinos show a highly similar pattern of relations, and (b) Q'eqchi' perceive many fewer relations, and those tend to be a subset of those seen for the other two groups. The overwhelming majority of interactions within each group involved plants helping animals by providing them food. Plants providing shelter to animals was also a common response. An ANOVA for plants helping animals showed that Q'eqchi' reported, on average, many fewer relations (46.8, 5.8%) than either Ladinos (163.2, 26.1%) or Itza' (187.5, 23.1%), who did not differ from each other, $F(2, 33) = 23.10$, $p < .001$. There was a maximum of 812 relations. Itza' and Ladinos showed a large overlap for which plants help which animals: $r = .82$ for Itza' and Ladinos versus $r = .42$ for Itza' and Q'eqchi' and $r = .54$ for Ladinos and Q'eqchi'.

A large cross-groups consensus emerged: The first factor was 12.3 times the second and explained 67% of the variance. Often, all Q'eqchi' reported no effect, making the modal answer "no effect." Thus, Q'eqchi' responses drove the overall consensus. Given this situation, residual analyses are more effective than simple measures of interinformant agreement in revealing cultural models. We analyzed a 3×36 residual agreement matrix. For each of 36 informants (12 in each group) there were three measures: average residual agreement of that informant with members of the same group, and that informant's average residual agreement with members of each of the other two groups. Within-group agreement proved reliably greater than across-groups agreement: for each group, $F(2, 22) > 23.00$, $p < .001$.

At a finer level of detail, we examined pairs of groups for within- versus across-groups agreement. The Itza' and Q'eqchi' samples had greater within- than between-groups residual agreement. The Ladino sample showed higher within- than between-groups residual agreement vis-à-vis Q'eqchi' but did not share more residual agreement with one another than with Itza'. This asymmetrical residual agreement is consistent with the idea that the Ladinos are learning from the Itza'.[12]

One distinction between Itza' and Ladino samples was the latter's tendency to generalize the beneficial effect (on animals) of economically and culturally important plants, such as mahogany (the prime wood export) and ceiba (Guatemala's national tree), without apparent justification (Atran et al., 2002). Relations noted by Q'eqchi' were basically subsets of those reported by other groups. Overall, Ladino and Itza' consensual models converge on how plants help animals. The Q'eqchi' model is a severely limited subset of the Itza' and Ladino models.

Animals affecting plants. Reports of how animals affect plants yielded even larger differences. Q'eqchi' nominated too few interactions (they agreed on only 10 of 812 possible relations) for consensus analysis. Itza' and Ladinos showed strong cross-groups

[12] This is not the only interpretation. Asymmetrical residual agreement can arise if the in-group consensus is weaker in one of two groups of equal size. For example, if the Ladinos are shifting from a consensual agreement that no relation is present to the Itza' belief that some relation is present, then one might well observe asymmetrical residual agreement. Indeed, when we do a CCM that just combines Itza' and Ladino data, the asymmetry reverses; that is, the Ladinos but not the Itza' show reliable residual agreement.

Table 2
Petén Forest Plants and Animals

Reference no.	Plant name	Scientific name
	Fruit trees	
P1[a]	Ramon	*Brosimum alicastrum*
P2[a]	Chicozapote	*Manilkara achras*
P3[a]	Ciricote	*Cordia dodecandra*
P4[a]	Allspice	*Pimenta diocia*
P5[a]	Strangler fig	*Ficus obtusifolial, Ficus aurea*
	Palms	
P6[a]	Guano	*Sabal mauritiiforme*
P7[a]	Broom palm	*Crysophilia stauracantha*
P8[a]	Corozo	*Orbignya cohune* *Scheelea lundellii*
P9	Xate	*Chamaedorea elegans, Chamaedorea erumpens, Chamaedorea oblongata*
P10	Pacaya	*Chamaedorea tepejilote*
P11	Chapay	*Astrocaryum mexicanum*
	Grasses/herbs	
P12	Herb/underbrush	Various families
P13	Grasses	*Cyperaceae/Poaceae*
	Other plants	
P14[a]	Mahogany	*Swietenia macrophylla*
P15[a]	Cedar	*Cedrela mexicana*
P16[a]	Ceiba	*Ceiba pentandra*
P17[a]	Madrial	*Gliricidia sepium*
P18[a]	Chaltekok	*Caesalpinia velutina*
P19[a]	Manchich	*Lonchocarpus castilloi*
P20[a]	Jabin	*Piscidia piscipula*
P21[a]	Santamaria	*Calophyllum brasilense*
P22[a]	Amapola	*Pseudobombax ellipticuml, Bernoullia flammea*
P23[a]	Yaxnik	*Vitex gaumeri*
P24[a]	Kanlol	*Senna racemosa*
P25[a]	Pukte	*Bucida buceras*
P26[a]	Water vine	*Vitis tilaefolia*
P27	Cordage vine	*Cnestidium rufescens*
P28	Killer vines	Various epiphytes

Reference no.	Animal name	Scientific name
	Arboreal animals	
A1	Bat	*Chiroptera*
A2	Spider monkey	*Ateles geoffroyi*
A3	Howler monkey	*Allouatta pigra, Allouatta palliata*
A4	Kinkajou	*Potus flavus*
A5	Coatimundi	*Nasua narica*
A6	Squirrel	*Sciurius deppei, Sciurius aureogaster*
	Birds	
A7	Crested guan	*Penelope purpurascens*
A8	Great curassow	*Crax rubra*
A9	Ocellated turkey	*Meleagris ocellata*
A10	Tinamou	*Tinamou major, Crypturellus* species
A11	Toucan	*Ramphastos sulfuratus*
A12	Parrot	*Psittacidae* in part
A13	Scarlet macaw	*Ara macao*
A14	Chachalaca	*Ortalis vetula*
A15	Pigeon/dove	*Columbidae*
	Rummagers	
A16	Collared peccary	*Tayassu tacaju*
A17	White-lipped peccary	*Tayassu pecari*
A18	Paca	*Cuniculus paca*
A19	Agouti	*Dasyprocta punctata*
A20	Red-brocket deer	*Mazama americana*
A21	White-tailed deer	*Odocoileus virginianus*
A22	Tapir	*Tapirus bairdii*
A23	Armadillo	*Dasypus novemcintus*
	Predators	
A24	Jaguar	*Felis onca*
A25	Margay	*Felis wiedii*
A26	Mountain lion	*Felis concolor*
A27	Boa	*Boa constrictor*
A28	Fer-de-lance	*Bothrops asper*
A29	Laughing falcon	*Herpetotheres cachinnans*

Note. From "Folkecology, Cultural Epidemiology, and the Spirit of the Commons: A Garden Experiment in the Maya Lowlands, 1991–2001," by S. Atran et al., 2002, *Current Anthropology, 43,* p. 427. Copyright 2002 by The University of Chicago Press. Adapted with permission.
[a] Species counted in tree-frequency study.

consensus but also greater residual agreement within than between groups. Negative reports of animals hurting plants occurred with equal frequency (8.0% of cases by Itza', 8.2% by Ladinos) in the two groups. It is striking, however, that Itza' were 4 times more likely than Ladinos to report positive interactions and 3.4 times more likely to report reciprocal relations (a plant and animal helping each other).

With respect to positive relations, Itza' reported that different classes of animals differentially affect classes of plants, whereas Ladinos did not. To illustrate, plant kinds were collapsed into four classes (fruit, grass/herb, palm, and other), as were animal classes (arboreal, bird, rummager, and predator). An ANOVA using plant classes, animal classes, and interaction type (positive or negative animal–plant relations) revealed a Plant × Animal interaction for Itza' but not for Ladinos, $F(9, 99) = 26.04$, $p < .0001$[13]: (a) Arboreals were much more likely to interact with fruit trees than with other plant groups, (b) birds were also most likely to interact with fruit trees but also had moderate levels of interactions with palms, (c) rummagers interacted primarily with grasses/herbs and to a lesser extent with fruit trees, and (d) predators showed few, if any, interactions with plants.

[13] Participants were given two scores for each pairing of animal and plant groups, reflecting the proportion of positive and negative interactions acknowledged. A score of .25 for negative arboreal–fruit interactions indicates that the participant identified negative interactions for one quarter of all possible pairings of arboreal animals and fruiting plants. Scores were entered into 2 (type of interaction: positive, negative) × 4 (animal group: bird, rummager, arboreal, predator) × 4 (plant: fruit, grass/herb, palm, other) ANOVAs. Thus, tests of Plants × Animals had 9 and 99 degrees of freedom. Ladinos showed main effects of interaction type, $F(1, 11) = 6.95$, $p < .05$; plant, $F(3, 33) = 9.89$, $p < .0001$; and animal, $F(3, 33) = 14.40$, $p < .0001$; but not a Plant × Animal interaction.

On a qualitative level, although both groups acknowledged that animals have a large impact on fruit trees, Itza' differed from Ladinos in understanding these relations. In their justifications of plant–animal relations, Ladinos almost always saw animals as harming plants by eating fruit. Itza' justifications revealed a more nuanced appreciation of the relation between seed properties and processing: If the seed is soft and the animal cracks the fruit casing, the animal is likely to destroy the seed and thus harm the plant, but if the seed is hard and passes through the animal's body rapidly, then the animal is apt to help the plant by dispersing and fertilizing the seed (Atran & Medin, 1997).

A more detailed examination of positive and negative relations reinforces the view that Itza' and Ladinos attend to the same relations but interpret them differently. The two groups have essentially the same model of negative relations—for no animal–plant pair did the proportion of Itza' nominations of a negative relation differ from the corresponding Ladinos' proportion by more than .40. For a given animal–plant pair, both positive and negative relations could be reported. For both groups, there was a reliable, positive correlation between reporting a positive relation for a pair and reporting a negative relation for that same pair (for Itza', $r = .62$, $p < .01$; for Ladinos, $r = .57$, $p < .01$). The group difference on number of positive animal–plant relations was mediated by the fact that Itza' were much more likely to report a positive relation, even when a negative relation was also present. We examine this difference in more detail when we consider mechanisms of cultural transmission.

These findings suggest a complex Itza' folk ecological model of the forest, wherein different animals affect different plants and relations among plants and animals are reciprocal. On a qualitative level, the Ladinos appear to be operating under a different cultural model. In a preliminary interview in which we asked Ladinos how animals help plants (thus presupposing that they do), the typical response was, "Animals do not help plants; plants help animals." Ladinos also possess a relatively elaborate model, but relations are more unidirectional and less specific. Q'eqchi' acknowledge a much reduced role for plants and almost no role for animals in the folk ecology of the forest.

Human impact on plants. For each species, we asked what its value was for people and what people's effect was on the species. Human impact was assessed on a scale from *negative* (-1) through *neutral* (0) to *positive* (1). For each population, we simply added the individual responses and divided by the size of the population. Each population had sufficient statistical consensus among informants to warrant aggregating individual responses of the population into a cultural model of impact signature—that is, what people believe their impact is on plant species (see the Appendix). Thus, if 9 informants reported a positive impact and 1 a negative impact, the overall score would be eight twelfths, or .67. The Appendix also reports the ecological centrality of the plants in the eyes of each population: The ecological centrality of a given plant is the proportion of plant–animal associations in the population's consensual ecological model for that plant (we discuss the relations between ecological centrality and other factors shortly).

Impact signatures for Itza' and Ladinos were moderately correlated ($r = .65$, $p < .001$), which suggests somewhat similar views of how members of their respective communities affect plants. Signatures for Q'eqchi' were negatively correlated with those of Itza' ($r = -.28$) and Ladinos ($r = -.16$), which suggests a very different model of human effects on plants. Itza' reported beneficial impact on all ecologically and economically important plants and absolute commitment to protect ramon and chicle (*Manilkara achras*). Itza' call ramon "the *milpa* of the animals" because many bird and mammal species feed on its fruits and leaves (Atran, 1993). The chicle tree is also visited often by animals and, as with ramon, has a long history of local use. Extraction of chicle latex for chewing gum was Petén's prime cash source in the past century. Itza' reported variable impact on herbaceous undergrowth, strangler figs (*Ficus* species, which nourish many animals but kill other trees), and yaxnik (*Vitex gaumeri*), which Itza' see as a marginally useful forest weed. Itza' reported harmful impact on pukte (*Bucida buceras*), another forest weed; on kanlol (*Senna racemosa*), a village weed; and on vines cut for water and cordage.

Ladinos also reported a highly positive impact for valuable plants (including the ceiba, *Ceiba pentandra*, Guatemala's national tree). For palms, they reported a positive impact only for those used for thatch (corozo palm fruits are also sold to a local nongovernmental organization [NGO]). For most plants, they reported variable impact. Q'eqchi' reported a positive impact only for thatch palms and a negative impact on Petén's most important cash sources: chicle, tropical cedar (*Cedrela mexicana*), mahogany (*Swietania macrophylla*), and xate (decorative *Chamaedorea* dwarf palms collected for export).

It is interesting to note that ramon and chicle, whose native uses the Spanish documented at the time of the conquest (Landa, 1566/1985), are the two most frequent species encountered in northern Petén forests (Agrar-und Hydrotechnik Gmbh & Asesoría y Promoción Económica, 1992). Moreover, only the Petén variety of ramon appears to bear fruit any time of the year (Peters, 1989). This suggests that intergenerational patterns of care of ramon and chicle by Maya have produced a highly anthropogenic forest, which Itza' continue to foster and tend.

The fact that Itza' believe (on average) that they have a beneficial impact on important species does not logically entail or causally imply that Itza' should choose costly conservation methods to protect certain trees. However, it is a matter of fact that they do (see below). Given that the other two groups do not protect the trees that Itza' do, Itza' conservation may not make sense.

The correct interpretation of Itza' conservation is not clear. One could offer a group selection argument (sacrifice of individual advantage for the benefit of the group as a whole) by suggesting that Ladinos see the Itza' success in the forest and (will eventually) come to adopt their practices. Another possibility is that the Itza' simply have not (yet) adjusted their practices to take into account the behaviors of individual Q'eqchi' and Ladinos. Later on, we suggest that individual actions in accordance with spiritual values may be part of the story and that such values work to refine calculations of self-interest.

Ground truthing. Itza' folk ecological models also relate directly to observed behavior. Regression analysis revealed that, for Itza', ratings of human impact (the proportion of informants reporting their actions as helping or hurting particular species) and weed status (factoring out plants considered to be weeds) predicted frequencies of trees counted in informant parcels ($r^2 = .46$, $p = .004$, with both predictors reliable). No comparable relation emerged for Ladinos or Q'eqchi'. Regressions also revealed different predictors of human impact on plants for each group. For Itza', ecological centrality (number of associations in the group's consensual ecological model for a given plant) and combined utility (value of a plant for wood, shelter, and cash combined) predicted reported human impact ($r^2 = .44$, $p < .001$, with both predictors reliable). In short, ecological importance and overall utility predicted which plants the Itza' seek to protect, which, in turn, predicted the plants encountered in sample plots.

For Ladinos, cash value was the only reliable predictor of impact, indicating that Ladinos protect plants that have cash value. For Q'eqchi', none of these variables predicted impact signature, and the (nonsignificant) correlations were consistently negative, indicating that the Q'eqchi' tend to destroy valuable plants. In sum, the three groups have very different mental models of the forest and correspondingly distinct patterns of use. Only Itza' seem to have a positive vision, based on species reciprocity, of the role of plants, animals, and humans in helping the forest to survive. For neither of the other two groups is there a reliable association between mental models of the forest and patterns of use.

The Itza' model is of considerable importance for an understanding of successful forest management. From a culture theory perspective, it is also important to address the mental models of the two immigrant groups. First, how do migrants acquire their knowledge of a new environment? Second, why is the Ladino model so similar to the model of the Itza' Maya?

Cultural Epidemiology in the Concrete

Social Networks

Social network analysis bears out the close relation in mental models and forest behaviors. For each community, we began with 6 men and 6 women not immediately related by kinship or marriage. To ensure maximum social coverage from our sample, initial informants could not be immediate blood relatives (children, grandchildren, parents, grandparents, siblings, first cousins, nieces, nephews, uncles, or aunts), affines (spouses, in-laws), or godparents (*compadres*). Each informant was asked to name, in order of priority, the seven people outside of the household "most important for your life." Informants were asked in what ways the people named in this *social network* were important for their life, how often they interacted with these people, and what kind of relation they had with them (family, work, friend, etc.). After the initial interviews, we extended our sample size with the snowball method (e.g., we asked the first and seventh person of each of the 12 initial networks the same questions). When either the first or last person named was not available, we interviewed either second or sixth person named. The decision to establish network closure after just one iteration (one round) was based on previous studies suggesting that, in practice, it is rarely necessary to seek direct ties involving more than one intermediary.

Expert Networks

Some days after we elicited the social network, we asked each informant to name, in order of priority, the seven people "to whom would you turn if there were something that you do not understand and want to find out about the forest/fishing/hunting." Informants were asked about the kind of information they would seek in these *expert networks*.

The three populations markedly differ in their social and expert network structures, with different consequences for the flow of information about the forest. First consider social networks, which are summarized in the graphs shown in Figure 1. The circle graph of the Ladino network shows a clear gender division of the community.[14] The Itza' social network is the most diffuse, and the two clusters correspond not to gender but to the two major moieties (subgroups, often organized in terms of practices, e.g., intermarriage rules). The multidimensional scaling (MDS) that accompanies each circle graph in Figure 1 uses the pattern of connections as a similarity metric and scales the similarity relations—in this case—in a two-dimensional space (while preserving the connections shown in the circle graph): For the Itza', the first dimension differentiates the two major moieties, and the second reflects the presence of clans and families that are connected in different ways to the major moieties but not each other.[15] Q'eqchi' form the most socially interconnected community. They show a dense, highly interconnected network, with no dominant individual or subgroup. The following analysis supports this impression.

Lambda Sets

To measure social connectedness, we used the group lambda level. Lambda sets describe the line connectivity of nodes (Borgatti, Everett, & Shirley, 1990). The line connectivity for a pair of nodes is equal to the minimum number of lines that must be removed from the graph to leave no path between them. For our purposes, we use the group as the lambda set and calculate the minimum connectivity (rather than the average) as an index of overall group cohesiveness. In the case of the Itza', for example, if one link is removed, then at least one member of the group gets separated from the group. For Ladinos, two links must be removed to separate at least one member from the group. For Q'eqchi', four links must be removed to separate at least one member from the group. Level 5 ($\lambda = 5$) includes 90% of Q'eqchi', 21% of Ladinos, and only 10% of Itza'. In short, the Q'eqchi' are the most and the Itza' the least interconnected.

The dense and interconnected social structure of the Q'eqchi' community favors communal and ceremonial institutions that organize accountability, and these institutions are manifestly richer among Q'eqchi' than among Itza' or Ladinos. Only Q'eqchi' practice agroforestry in corporate groups: Neighbors and kin clear and burn each household's plot, kin groups seed together, and the community sanctions unwarranted access to family stands of copal trees (*Protium copal*), whose resin is ritually burned to ensure the harvest. This implies that institutional monitoring of access to resources, cooperating kin, commensal obligations, an indigenous language, and knowledge of the land (including recognition of important species) may not suffice to avoid ruin of common-pool resources. These are some of the elements that Ostrom (1990) has identified as crucial for sustaining common-pool resources. However, for the Q'eqchi' of Corozal, continued corporate and cere-

[14] Persons C1–R are women, and A–Q are men. At the top center of the Ladino circle graph is person D1. This is the same person as W in the Itza' network (he is the mayor of the municipality and the only Itza' in the Ladino social network).

[15] Ethnographic interpretation of the MDS scaling reveals an Itza' community divided into two social factions: one dominated by Y, the other by V–W and T–N. Person V is W's father, and Person T is N's father. V and T are also cited as two of the top three Itza' forest experts. Y and V head two families that have continuous genealogical links to preconquest Itza' clans of the same name, Chayax and Tesucun.

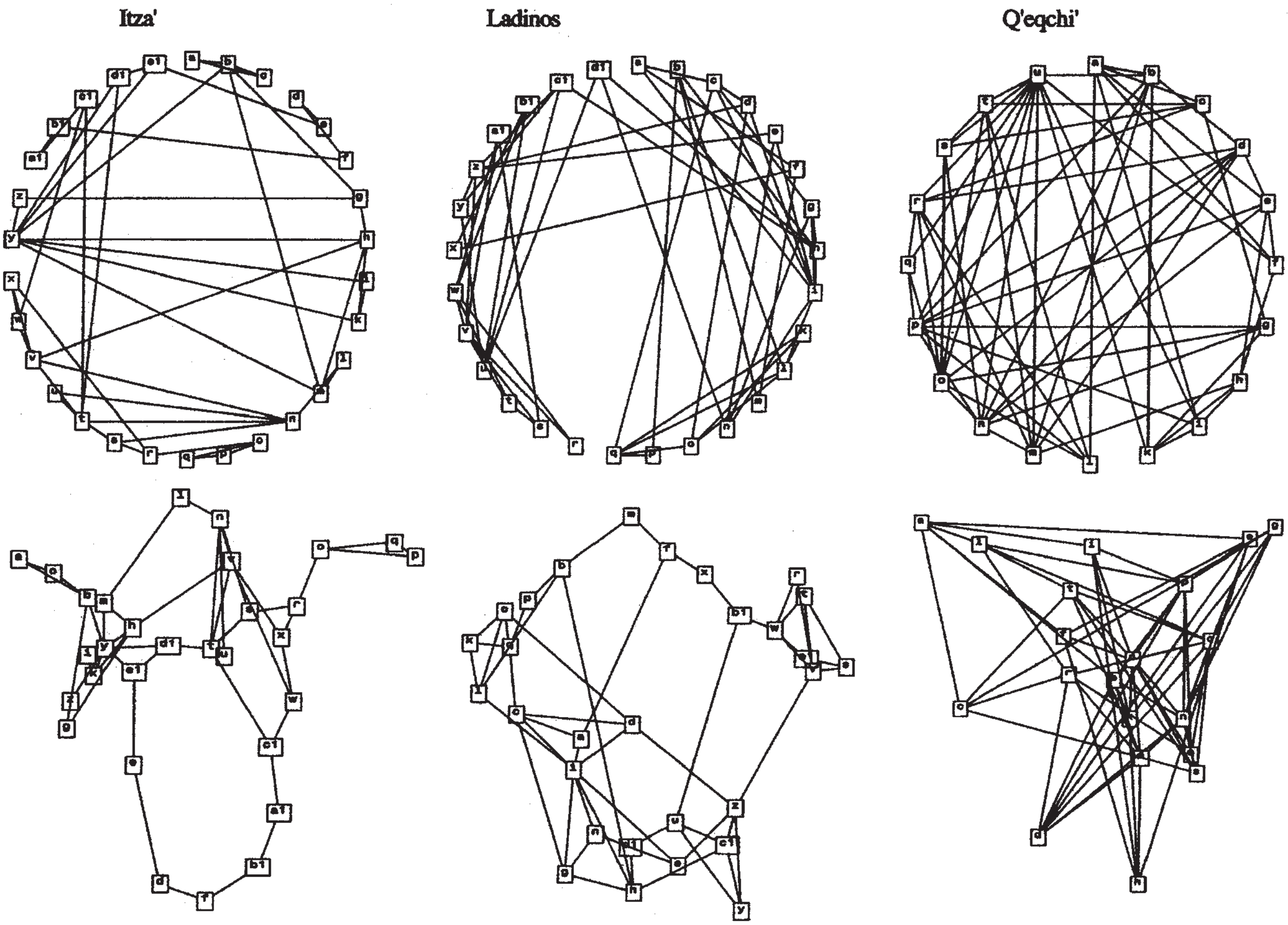

Figure 1. Social networks for Itza', Ladinos, and immigrant Q'eqchi'. Circle graphs (top) and multidimensional scaling (bottom) are alternative representations of the same data sets. From "Folkecology, Cultural Epidemiology, and the Spirit of the Commons: A Garden Experiment in the Maya Lowlands, 1991–2001," by S. Atran et al., 2002, *Current Anthropology, 43,* p. 433. Copyright 2002 by The University of Chicago Press. Reprinted with permission.

monial ties to the sacred mountain valleys of the Q'eqchi' highlands do not carry corresponding respect for lowland ecology. Although Q'eqchi' recognize the species of the area, they appear to be lacking (a) the relevant information of which species are important to protect and (b) values that might support respective behavior. The relatively closed corporate structure that channels information focused on internal needs and distant places likely impedes access to relevant ecological information (e.g., which species ought to be protected) important to commons survival.

Relation Between Social and Expert Networks

Overall, Itza' informants almost exclusively cited Itza' as experts. Ladinos cited both Ladinos and Itza' as experts, with Ladino women tending to nominate Ladino men (75% of the time), who, in turn, nominated Itza' men the majority (56%) of the time. Q'eqchi' informants cited neither Ladinos nor Itza'; it is striking that the two most common nominations were a Washington-based NGO and a Guatemalan governmental agency. The remaining Q'eqchi' nominations overwhelmingly consisted of Q'eqchi' men.

The greatest overlap in the social and expert networks occurred among Itza', and the least overlap was found among Q'eqchi'. For Itza', 14 of the most cited social partners were among the 22 most cited forest experts. Although the Itza' social network is not highly centralized, the most cited social partner was also the second most cited forest expert, whereas the top forest expert was also the third most cited social partner. For Ladinos, 11 of the most cited social partners were among the 25 most cited forest experts. Of these 11, all were Ladino men. The top Ladino experts, in turn, mostly cited the same Itza' experts as the Itza' themselves did, which suggests diffusion of information from Itza' experts to a select group of socially well-connected Ladino men. For Q'eqchi', who have by far the most densely connected and centralized social networks, only 6 of the most cited social partners were among the 18 most cited forest experts (these were cited less often as experts than were outside institutions).

Q'eqchi' had the lowest agreement on who the forest experts are, and Itza' had the highest. Although the social network of the Q'eqchi' might allow for speedy and repeated processing of new information, their expert network has two limitations. First, Q'eqchi' seem not to have established links to reliable outside sources of information other than national and international NGOs, with whom they do not interact frequently. Second, within their community they do not have established and trustworthy sources of important information about the forest ecology (clearly identified experts). As a result, (a) there is only little chance for new information to enter the system, and (b) what outside information there is seems unlikely to penetrate deeply into the Q'eqchi' community, because it is not conveyed by socially relevant actors (identified experts).

For Itza', expert information about the forest appears integrally bound to patterns of social life as well as to an experiential history traceable over many generations, if not millennia. For Ladinos, expert information is also likely to be assimilated into the community. Because Ladino experts (i.e., Ladinos most cited as experts by other Ladinos) are socially well connected, information that may come through Itza' experts (i.e., those Itza' most cited as experts by other Itza' as well as by Ladino experts) has access to multiple interaction pathways.

Networks and Information Transmission

One possibility consistent with the Itza' social and expert network structure is that ecological knowledge is directly transmitted from socially well-connected forest experts to other Itza'. To evaluate this possibility, we analyzed patterns of residual agreement in relation to social and expert network structure. We focused exclusively on the nonempty cells because knowledge transmission should primarily take the form of noting an existing relation, not the absence of relations. Analyses within the Itza' sample revealed little residual agreement, and this agreement was inconsistent across different tasks. In no case could we discern relations between residual agreement and social or expert network proximity. In other words, Itza' social structure does not show evidence of specific pathways for learning about the forest, at least among our sample.

Lack of residual agreement could largely reflect asymptotic, high repetition of information among all informants and the resulting high level of expertise. A related possibility derives from the fact that our informants were mainly Itza' elders. They might have learned from their parents and grandparents and may be passing knowledge down to children, grandchildren, nephews, and nieces but not to other elders. We are currently collecting folk ecological models and social and expert networks across three generations of Itza' and Ladinos, and these data will bear more strongly on social transmission of information.

There also is an alternative scenario to learning about the forest that is more consistent with independent discovery than direct social transmission of ecological knowledge. When asked how they learn about the forest, Itza' mostly claimed to acquire knowledge elicited in our tasks by "walking alone" in the forest they call "the Maya House." For Itza', diffusely interconnected social and expert networks suggest multiple social pathways for individuals to gain, and for the community to assimilate and store, information about the forest. Such independently gained information might then be culturally assimilated through a similar reference framework providing salient interpretations and inferences (through cultural stories, values, etc.).

Our analysis of cultural models and social transmission is frankly speculative, but it does have testable consequences, which we explore in the next section of this article. The general idea is that a person's cultural upbringing primes attention (a) to certain observable relations at a given level of complexity and (b) to connect these observations through certain inferences (e.g., that animals and plants have reciprocal relations). In addition, each person may be culturally attuned to the relevant discoveries of other individuals whose knowledge forms part of the emergent cultural consensus. Such emergent belief structures resemble framework theories in their ability to integrate various background assumptions and to take particular experiences and events and give them general relevance in terms of a much larger ensemble of complexly related cases (Wisniewski & Medin, 1994).

Ladino folk ecological beliefs may be at least partially parasitic on the Itza' network in the following sense: Whereas Itza' may observe the forest for what is important, Ladinos may observe not only the forest but also the Itza' for what is important. The Ladino network points to Person I as the best socially connected individual. He is also the most often cited Ladino forest expert and the founder of the community. When he was asked, he reported mostly Itza' Maya as forest experts. This is a common feature for Ladino experts, and it appears to result in systematic cross-cultural learning. The highest competence scores among the Ladinos in the combined Itza'–Ladino model of plant–animal relations belong to those Ladinos who most cited Itza' as their experts (Atran et al., 2002).[16] Ladino experts are also the most socially well-connected members of the Ladino community. Putting these findings together suggests both that Ladinos are learning from Itza' and that the social and expert network structure facilitates this spread of knowledge between the Ladino and Itza' communities.

Over time, socially well-connected expert Ladinos converge toward the consensus of Itza' experts, at least with respect to plants helping animals. For example, we found that judgments of plant–animal associations for the mostly highly rated Ladino expert actually composed a proper subset of the judgments made by the most highly rated Itza' expert (details in Atran et al., 2002).[17] It is improbable that Ladinos, who approximate Itza' response patterns for hundreds of species relations, actually observe and copy what

[16] For Ladinos, three of the four most cited experts were also the three named most by Itza'. We combined Itza' and Ladino responses about plant–animal relations and found a metacultural consensus (first factor scores all positive, ratio eigenvalue 1:2 = 10.4, variance accounted for = 52%). Then we regressed gender and frequency of being cited as an expert against Ladino first-factor scores in the combined consensus model. For Ladino scores, $r^2 = .63$, $F(2, 10) = 6.97$, $p = .02$, with gender ($p = .02$) and expertise ($p = .008$) reliable. One subgroup of men (with one woman) averaged 5.8 expert citations, 6.0 social network citations, and a culture competence (i.e., mean of first factor scores) of .73 (vs. .75 for Itza'). Averages for the other subgroup (with one man) were respectively 0.0, 1.3, and .59.

[17] Representations of the Itza' network indicate that the top Itza' expert, Node Y, is also the best socially connected individual (see Figure 1). His expertise has been independently confirmed. For example, in the Bailenson, Shum, Atran, Medin, and Coley (2000) study of tropical bird classification among American birdwatchers and Itza', Y scored highest among Itza' on measures of correspondence with scientific (classical evolutionary) taxonomy. The Ladino network points to the most cited Ladino expert, Expert I, as the best socially connected individual in his community. He is also the founder of the community.

Itza' say and think about each of the species pairs in question. How, then, are Ladino experts learning specific contents? And why do they acquire only certain aspects of the Itza' model?

The Learning Landscape

In line with evolutionary models of social learning, one may assume that, when in doubt or ignorance about a certain domain of activity vital to everyday life, people look to those with knowledge to emulate them (Boyd & Richerson, 1985; Henrich & Boyd, 1998). Observers typically do not have direct access to the deep knowledge they wish to emulate, only to surface signs or markers of that knowledge. One promising strategy is to first look for knowledge from those to whom deference (respect) is shown by others (Henrich & Gil-White, 2001). At least in many small-scale societies, knowledge bearers tend to be elders, political leaders, economically well off, and so on. In the Itza' case, forest experts are experts in a variety of relevant domains (e.g., soils, trees, hunting, collecting plants), elder men, and former political town leaders.

Informally, we have noted that Ladinos today continue to express doubt about their forest knowledge and express a desire to acquire knowledge from the Itza'. Apparently, the most respected and socially well-connected Ladinos attend to those Itza' to whom other Itza' defer, and these Ladinos, in turn, become subjects of emulation and sources of knowledge for other Ladinos. But how do Ladinos go about obtaining the relevant knowledge without initially knowing how it is relevant?

First of all, there may be some transmission of norms or rules—we have witnessed Itza' showing Ladinos how to control burns when clearing land for *milpa* and discussing where to plant different species of fruit trees. Other learning factors may be involved in transmitting knowledge, including normative prototypes and narratives, but in fairly indirect ways. Thus, Ladino prototypes and stories of Itza' experts as forest wizards may share little actual content with the normative pronouncements and narratives of the Itza' themselves. Moreover, Itza' disavow teaching the Ladinos anything about the forest. The line of reasoning that follows is frankly anecdotal but one that should motivate further research.

For present purposes, of greatest relevance is evidence suggesting Ladinos may be acquiring knowledge through different isolated examples that trigger inferential structures to support generalizations. Our data suggest that two distinct forms of inference may affect mental models of the forest: (a) inferences from general knowledge of ecological relations, such as whether relations are positive or negative and where in the forest they are likely to occur, and (b) category-based induction over ecological and taxonomic groups. Consider the first form of inference. A Ladino may observe or hear about a particular exemplar of ecological knowledge from a respected Itza' (perhaps embedded in a story), such as the observation that Itza' elders look for fallen ramon fruits after spider monkeys have passed through the trees. Itza' do this because they know that spider monkeys like to play with and chew on ramon fruits and then throw them onto the forest floor. From such a description of Itza' behavior, a Ladino observer may deduce that (a) ramon is desired and useful for people and (b) spider monkeys can affect ramon seeds. They might also incorrectly infer that spider monkeys hurt the ramon tree (throwing the fruits to the ground), not knowing the fact (not reported in the story) that half-chewed fruits are even more likely than unchewed fruits to generate new ramon stands. In short, they tend to construe symmetrical relations asymmetrically.

Another form of inference is category relatedness. Although Ladino observers seem to lack the Itza' cultural bias of conceiving species relations reciprocally, they are nevertheless able to spontaneously induce much more from a single instance of experience than simply (a) and (b).[18] For example, we should expect Ladinos to generalize their observations along much the same lines as Itza' do when Itza' and Ladino taxonomies coincide. In the above scenario, Ladinos should automatically infer that howler monkeys and kinkajous similarly affect ramon because Ladinos, like Itza', recognize both generic species as belonging to the same intermediate folk taxon as the spider monkey (see López, Atran, Coley, Medin, & Smith, 1997). Further correspondences are predictable from the similarity between the two groups' appreciations of ecological associations. For both groups, the ramon and chicle trees have very similar ecological profiles. Thus, both groups should readily generalize relations from, for instance, spider monkeys and ramon trees to kinkajous and chicle trees. Analysis of response patterns indicates that this is consistently the case.

Given that these relations are true, we cannot separate inferring from independently learning these six relations. In that sense the data are asymmetrical, because the only truly informative data would be an uneven patterning that would undermine our suggestions about inferences. Nonetheless, it is striking that all six relations are close to unanimous in both groups, despite the diversity of experience with the forest and wide range of competence scores.

We also have tentative evidence for a form of inference based on plausible reasoning. For example, in the absence of direct observation of nocturnal, furtive felines, it is plausible to believe that they hide out under the protective cover of leafy fruit trees to prey on other animals that feed on the fruit. Female Ladinos, who seldom venture into the forest, overwhelmingly (75%) inferred that felines seek out fruit trees. Male Ladinos (17%) and Itza' (16%) knew better, because they go into the forest. Because Itza' hunt at night, they were generally aware (63%) that felines stalk their prey

[18] We have independent evidence that people in these communities form and use taxonomic hierarchies that correspond fairly well to classical scientific taxonomy (and especially so at the generic species level). For example, using standard sorting experiments (see Medin & Atran, 2004), we elicited highly consensual mammal taxonomies (see López et al., 1997). For each population there was a single factor solution (Itza' = 7.2:1.0, 61%; Ladino = 5.9:1.0, 50%; Q'eqchi' = 5.8:1.0, 48%). First factor loadings were uniformly positive, and mean first factor scores reflected highly shared competence for each population (Itza' = .77, Ladino = .71, Q'eqchi' =.68). The aggregated Ladino taxonomy correlated equally with Itza' and Q'eqchi' taxonomies ($r = .85$), indicating very similar structures and contents. All three populations grouped taxa according to general-purpose similarity rather than special-purpose concerns (e.g., wild peccary with domestic pig, house cat with margay). Special-purpose clusters, such as domestic versus wild or edible versus nonedible, can also be elicited (Lois, 1998), but they do not belong to the general consensus of "kinds that go together by nature" (cf. the idiosyncratic version of Itza' folk taxonomy in Hofling & Tesucun, 1997).

in areas of grassland and underbrush rather than deep forest, whereas few Ladinos (12%) showed such awareness. A reviewer suggested that these data may simply indicate a social learning system in which women are influenced by women and men by men. To evaluate this idea, we conducted a residual analysis of the Ladino plant–animal relations to see whether residual agreement was higher within men and within women than across genders. It was not. Instead, we found that women agreed with women reliably more than men agreed with men, $F(1, 10) = 9.64$, $MSE = 3.16$, $p = .01$. We think this result reflects the stability of inference processes at the family and genus level on the part of women, relative to the diversity of concrete experience among Ladino men.

A key constraint on inductive inference is the interpretation of the base event itself. In the above scenario, if the Ladino observer lacks a cultural propensity for conceiving of species relations reciprocally, then he or she will neither learn that spider monkeys help ramon trees nor infer that kinkajous help chicle trees. In one line of follow-up work, we have been examining ecological models among younger (30–50-year-old), Spanish-speaking Itza'. Relative to older Itza' speakers, we have found considerable overlap but also what appear to be systematic under- and overgeneralizations for the case of animals affecting plants. In contrast to the Ladinos, the younger Itza' generalize along lines of reciprocal relations and report as many positive animal–plant relations as do the older Itza'. This suggests that the younger Itza' retain the cultural bias for construing species relations reciprocally.

In some cases, younger Itza' overgeneralizations reflect their reciprocal construal of an asymmetrical relation, as is apparently the case for younger Itza' who see the bat and several birds as helping palms by seed dispersal. It is interesting that the younger Itza' agree with each other on their overgeneralizations, which suggests that these overgeneralizations are principled and linked to observations, even though, according to the elders, they are incorrect.[19]

In brief, individual Ladinos and younger Itza' seem to project fragmentary observations of older Itza' behavior to a richly textured cognitive model of folk ecology by inference in addition to any effects of direct instruction, imitation, or invocation of norms (even the notion of reciprocity that we invoke to interpret Itza' responses is only a gloss for a distributed network of ideas, i.e., a reliable pattern of interinformant agreement showing recognition of plants positively affecting animals and of animals positively affecting plants).

These data on learning and inference are far from definitive, and, in some cases, they rely on accepting the null hypothesis, that is, failure to find relations between social network distance and residual agreement. To support our speculative account and to develop and evaluate alternative hypotheses, we need the sort of data on social and experts networks and ecological models across multiple generations that we are currently collecting. At a minimum, however, we think we have shown that the acquisition of ecological models involves inferences and that cultural notions such as reciprocity can guide the interpretation of observations.

In summary, we believe that social learning involves inferential processes that are mobilized according to several factors: (a) domain-specific cognitive devices (e.g., taxonomy for biological kinds), (b) prior cultural sensitivity to certain kinds of knowledge (e.g., species reciprocity in ecological relations), (c) awareness of lack of knowledge and the motivation to acquire it (doubt), (d) selective attention (e.g., Itza' deference and attention to the forest itself, whereas Ladinos also focus on the behavior of Itza' elders), and (e) preexisting values (weighted preferences) with respect to a given cognitive domain (e.g., overvaluing economic utility relative to other determiners of interest, e.g., sacredness or role in the economy of nature; see below).

Overall, then, Ladino knowledge is a subclass of Itza' knowledge that underrepresents the ecological complexity of Itza' knowledge. To be sure, the Ladinos use their own taxonomic and ecological knowledge of the forest to generalize their inferences from Itza' behavior. From studies of other Ladino communities in Petén, it seems that some Petenero Ladino communities have learned to think and act much as Itza' do after three or four generations of the kind of contact described between our Itza' and Ladino samples (Schwartz, 1990). These accounts are of a more anecdotal nature and need further experimental support. On a general level, though, these ethnographic accounts are in line with our findings.

Spiritual Games

Anthropologists and sociologists target shared rules, or norms, as functional building blocks of cultures and societies. Economists and political scientists see norms as institutional means to solving public goods problems, such as "the tragedy of the commons" (Fukuyama, 1995; Hardin, 1968; Ostrom, 1990). The general idea is that, to solve problems of rational choice inherent in balancing individual and collective needs, individuals must be made to forsake a measure of self-interest and to sacrifice resources in accordance with institutional norms that function to maintain the public good.

Yet evidence from our garden experiment indicates neither the primacy of norms in explaining cultural differences in regard to the tragedy of the commons nor that institutional mechanisms are exclusive or primary means for preserving common resources. Immigrant Q'eqchi' form the most socially interconnected, institutionally structured community but are least likely to preserve the resource base (perhaps because the community is so culturally hermetic). The affective involvement of the Q'eqchi' with the landscape of their homeland may resemble Itza' involvement with Petén, but, if so, little of it carries over from the highlands to the lowlands. An NGO operative summed this up, quoting Q'eqchi' Maya in the Petén: "In the mountains [of Cobán] we use the land with God's permission, but not in Petén" (G. Grünberg, personal communication, July 1998; see Atran et al., 2002, for details of highland Q'eqchi' folk ecology).

The Itza' community is the most socially atomized and least institutionalized (at least in terms of coordinated agricultural schedules), but its individuals most clearly act to maintain the common environment. If neither institutionalized learning nor institutional control mechanisms are responsible for commons maintenance among Itza', what is?

Values

How do people manage limited resources in a sustainable manner without apparent institutional constraints to encourage and

[19] One might interpret this cultural bias toward reciprocity as a shared abstract expectation, but it requires additional supportive observations.

monitor cooperation? Multiple factors are involved in explaining the stability of representations within and across our study populations. In our companion article (Medin & Atran, 2004), we discuss two such factors: (a) modular processes that may be triggered by minimal experience (e.g., folk biological taxonomy, presumed essence based on generic species and associated inference processes), and (b) ecological reasoning that is more sensitive to experience and more variable across groups. In addition, as noted here, there is evidence of other psychological biases involved in stabilization, including sensitivity to conformity and prestige (Boyd & Richerson, 1985; Henrich & Boyd, 1998).

We asked people from each of the three Petén groups to rank order each of 21 plant species in terms of importance according to members of their own community, members of each of the other two communities, God, and forest spirits. All three groups in the study believe in the existence of forest spirits, called *Arux* by the Itza'. As we show, the underlying concepts of these spirits, however, differ across the communities in ways relevant to our study. We looked for correlates of these rankings for each of the groups, examining ecological centrality, human impact, cash value, and total number of uses as predictor variables.

Only Itza' men saw the forest spirits as actively protecting the forest: Their rankings from the point of view of the forest spirits were significantly related ($r^2 = .63$), $F(2, 18) = 15.50$, $p = .0001$, to Itza' reports of ecological centrality (number of associations in a group's consensual ecological model for a given plant) and human impact (the extent to which people report their actions as helping or hurting particular species). Each of these factors is reliable when its correlation with the other factor is partialed out. Ladinos and Q'eqchi' state a belief in forest spirits, and Ladinos even provide normative and narrative accounts of spirit life similar to those of Itza'. Yet we found no reliable group consensus in these two populations, nor did we find reliable interactions among spirit preferences, human impact, ecological centrality, and use for these populations. Finally, Itza' rankings of God's preferences (i.e., how Itza' believe God rates the importance of each species) were related to the measure of combined use but not to ecological centrality. The same was the case for the Ladinos and the Q'eqchi', who believe that God—watching out for the humans—protects the species most important to humans. For these two groups, forest spirits appear to be an extension of God, supporting God by protecting the same species.

Finally, we asked members of several local and international NGOs with over a decade of experience in the area to rank the same trees as did Itza' and Ladinos in terms of importance to forest life. The aim was to see whether and how well NGO preferences correspond to ecological centrality, the values of the local groups, and/or metrics such as cash value. Cash value proved to be important, and ecological centrality played no role at all. The most valued species for the NGOs were, in rank order, mahogany, tropical cedar, allspice, and chicle. These are the most important trees for the extractive economy and export market. The worst predictor of NGO rankings was male Itza' rankings of spirit preferences ($r^2 = .06$) and Itza' ratings of ecological centrality ($r = -.23$). NGO preferences partially predicted consensus on preferences expressed by Ladinos ($r^2 = .72$, $p < .01$) and Itza' ($r^2 = .44$, $p < .05$). (The Q'eqchi' did not reach a consensus on preferences.) In short, NGOs appear to focus more on economic development rather than on the welfare of the forest. It is not clear whether the NGOs thought that cash value was the most important facet of importance or whether they simply tended to be much more familiar with trees that have cash value and based their judgments on familiarity.

To date, rational-decision and game-theoretic accounts involving human use of nonhuman resources generally have not considered nonhuman resources (e.g., the forest) and humans both as players in the same game, presumably because natural resources are assumed not to have motives, desires, beliefs, or strategies for cooperation or deception that are sensitive and systematically responsive to corresponding aspects of human intention. There is work in which decision makers take into account population dynamics of exploited populations, but, to our knowledge, there is essentially no work suggesting that these resources are interacting agents intentionally providing rewards and punishments for decision-maker behaviors.

Of course, it is always possible to build game-theoretic models in which humans and nonhumans interact with mutual intentionality (e.g., domestication of dogs) or in which none of the actors have intentions (e.g., bacteria and their hosts). However, our data suggest that people's conceptualization of resources may make a difference in how they play the game. For example, people's agroforestry behavior may differ as a function of whether they consider the forest to be a passive object or an actor that intentionally responds to their actions. Indeed, one claim for animistic and anthropomorphic interpretations of species in many small-scale societies is that the intention gap between humans and species is thus bridged (at least to human satisfaction) with outcomes mutually beneficial to the survival of species and of the human groups that live off of those species (cf. Bird-David, 1999).

In informal interviews and conversations, Itza' men and women express the belief that they will be punished if they violate spirit preferences. It is important to note that this punishment is not carried out by humans and that no human-based sanctioning system is in place to enforce compliance with the spirits' rules. Therefore, the Itza' forest spirits (*Arux*) cannot be understood as a social institution, even though the concept of *Arux* is socially constructed. Especially for men, the spirits are intermediaries or spokesmen for the forest species. This has intriguing implications for ecological decision theory and game theory in that individual Itza' may be basing their cognitive and behavioral strategies for sustaining the forest more by playing a game (i.e., negotiating costs and benefits of mutual cooperation) with spirits than by playing a game with other people (on the wider role of spirits in Itza' life and religion, see Atran, 2001b; on false-belief tasks with God, forest spirits, and people, see Knight, Sousa, Barrett, & Atran, 2004).

From a long-term perspective, Itza' spirit preferences may represent the statistical summary of mutually beneficial outcomes over generations of human–species interactions. Note that, as mentioned by Hardin (1968), evolution itself provides mechanisms for interactive games that commensurate the apparently incommensurable (e.g., strategies of bacteria and their hosts), and so may human minds (semantically rather than biologically) in ways consistent with maintaining absolute or asymptotic respect for sacred or taboo values—moral beliefs—basic to long-term survival and quality of life (Fiske & Tetlock, 1997; Medin, Schwartz, Blok, &

Birnbaum, 1999; see also Atran & Norenzayan, 2004; Tanner & Medin, 2004).[20]

No doubt economic rationality and institutional constraints are important factors in determining and describing actions on common-pool resources, but they may not suffice. There also appears to be an important cognitive dimension to behavioral research on how people learn to manage environmental resources. Valuation studies raise the possibility that cognition of supernatural agents may serve not only to guarantee trust and foster cooperation among nonkin, as standard commitment theories assume (Frank, 1988; Irons, 1996), but also to foster human interaction with nonhuman resources in relations of indirect reciprocity (Alexander, 1987).

Summary

It is no surprise that native Maya with centuries-old dependence on a particular habitat have a richer model of forest ecology than immigrants. However, longevity in a given context does not guarantee sustainable agroforestry practices. Our observations suggest that Itza' have a complex of knowledge, practices, and beliefs that is associated with sustainability. One should be very cautious in moving from correlations to cause—we do not know whether any one component of the Itza' belief system is either necessary or sufficient to support Itza' practices. Given that important proviso, the extent to which knowledge, values, and beliefs about the forest spirits reinforce each other is remarkable.

It is also surprising that Ladino immigrants, who share no evident tradition with native Maya, come to measurably resemble them in thought and action. Network analyses reveal reliable but noninstitutionalized linkages that allow socially well-connected Ladinos access to Itza' forest expertise. We speculate that the highest overlap, or fidelity, among individual patterns may stem, in part, from inference based on individual exposure to role models.

These results also have clear implications for cultural models and the study of cultural processes. Our program of research would barely have gotten off the ground if we were constrained to consider culture as an independent variable. In that framework, we would have noted that Itza' know more about the forest and are more likely to protect it than the Ladinos and Q'eqchi'. However, we would have failed to attend to (a) evidence strongly suggesting that Ladinos are learning from the Itza' (based on residual agreement patterns and the link between competence scores and distance from Itza' experts), (b) evidence for two forms of inferential learning (plausible and category-based inference) as an alternative to an accumulation of facts, (c) evidence that reliance on plausible inference varies within and across cultural groups, (d) evidence of gender differences among Itza' in the perceived role of the forest spirits, and (e) evidence that cross-groups (from Itza' to Ladinos) and cross-generational transmission of knowledge of the forest take strikingly different forms. In short, the distributional view of culture made our work possible, and, to the extent that our work represents progress, it reinforces the distributional approach (as well as related approaches that treat variability as signal rather than noise). We turn now to observations that further reinforce this view.

Further Observations From Mesoamerica and North America

So far we have focused on a single case study—or garden experiment—in Petén. Several outstanding issues remain. For example, to what extent are our methods and theoretical approach generalizable to other populations and settings? To what extent are our findings about differences in populations that live off the same habitat the result of transgenerational differences in exposure and experience (e.g., recent immigrant vs. long-standing settler populations) or the result of enduringly different mental models?

To address these and related issues, we have used the same techniques to monitor ecological cognition and social networks for highland Q'eqchi' Maya (Aldea Paapa, Alta Verapaz, Guatemala), Yukatek Maya (Xk'opchen) and Ladinos (Xkomha) in Quintana Roo (Mexico), Lacandon Maya (Ross, 2001, 2002) in Chiapas (Mexico), and Native American Menominee and majority culture rural groups along the Wolf River in Wisconsin (Medin et al., 2002).

Highland Q'eqchi'

One open issue is whether Q'eqchi' immigrants arrive in Petén with a cognitive model that is already impoverished with respect to knowledge of species relations or whether they are simply unable to use richer highland models because these are inappropriate to lowland ecology (only a modest subset of species from the two settings overlap). Several hypothetical scenarios are possible. (a) Highland Q'eqchi' may show impoverished models similar to those of lowland Q'eqchi'. Multiple reasons could underlie such a finding, including the impact of a largely deforested highland area. (b) Lowland Q'eqchi' may show significantly less complex ecological models than their peers in the highlands, who parallel the Itza' in some respects. Again, potential causes include the novel ecology in which lowland Q'eqchi' find themselves as well as social processes that led to the migration of a specific group of Q'eqchi' Maya to the lowlands (migrants are not a random sample of individuals from a community). Nonetheless, preliminary findings provide some useful information concerning the relation between highland and lowland Q'eqchi' understanding of forest ecology. As with the Petén groups, highland Q'eqchi' viewed plants as positively affecting animals, first by providing food, and second by furnishing shelter. Consensus on positive plant–animal

[20] As researchers have noted (Baron & Spranca, 1997; Tetlock, 2003), although people with sacred values sometimes seem to treat them as having infinite utility (e.g., in refusing to consider trade-offs), this is something of a logical impossibility inasmuch as infinite value implies that people with such values should spend literally all their time and effort protecting and promoting that value. For this reason, these researchers (see also Thompson & Gonzalez, 1997) have suggested that such values may be only pseudosacred, further noting that people with protected values may nonetheless engage in indirect trade-offs. One may be tempted to think of protected values as self-serving posturing, but the reality of acts such as suicide bombings undermines this stance (Atran, 2003). Moreover, protected values necessary to an individual's identity may take on truly absolute value only when value-related identity seems threatened with extinction, just as food may take on absolute value only when sustenance for life is threatened.

relations was marginal (ratio of eigenvalue 1:2 = 3.0, variance = 44%). Nearly 20% of all possible plant–animal relations were positive. Although the differing species in the two locales undermine any direct comparisons, the 20% figure is comparable to that seen for Itza' and Ladinos and higher than that seen for immigrant lowland Q'eqchi.' Highland Q'eqchi' reported more negative animal–plant relations than their lowland counterparts (2.3%) but fewer than Itza' or Ladinos (about 8%). We continue to bear in mind noncomparable species in the two settings but note that highland Q'eqchi' reported less than 1% positive animal–plant relations, which is somewhat lower than Ladinos (2.1%) and far lower than Itza' (8.2). Overall, highland Q'eqchi' seem to have a finer appreciation of the local ecology in their highland homeland, but this knowledge is substantially less rich than that of lowland Itza' and, at best, comparable to that of the immigrant Ladinos.

Highland Q'eqchi' showed good consensus on how humans negatively affect plants (ratio of eigenvalue 1:2 = 7.7, variance = 75%) but no consensus on how humans positively affect plants. Measures of human impact and use confirmed this pattern in content-specific ways. Regression analyses showed that food value and ecological centrality predicted highland Q'eqchi' reports of human impact ($r^2 = .58$, both predictors $p = .06$). Food value and impact were positively correlated—that is, highland Q'eqchi' tend to protect food plants. By contrast, ecological centrality and impact were negatively correlated, as were ecological centrality and food value. Highland Q'eqchi' do not consider food plants to be ecologically important and do not protect plants that they consider to be ecologically important. The main correlate of ecological importance was plant use for firewood ($r^2 = .54$). Firewood and cash sale (as for lowland Q'eqchi' immigrants) were arguably the least productive categories in terms of forest regeneration. Cash sale of important plants is not part of a local system of production but is driven by an extractive economy that depends mostly on demand from outside markets, some even outside the region. Altogether, it appears that highland Q'eqchi' models of species relations are relatively impoverished compared with existing Itza' models in the Petén, and, hence, one might argue that immigrant Q'eqchi' brought with them a lack of concern with maintaining forest biodiversity. Our findings among lowland Q'eqchi' are supported by similar observations in other communities in the Petén and adjacent areas of Belize (Carter, 1969; Fagan, 2000). Some of these notions may be tied to spiritual values and emotions relating the Itza' Maya (but not the Q'eqchi') to the landscape of Petén. For example, when environmentally related economic difficulties arise (e.g., banana blight, hurricanes), immigrant leaders may send delegations to sacred places in the Q'eqchi' highlands to seek aid and redress from highland spirits (cf. Schackt, 1984). However, our immigrant Q'eqchi' do not concern themselves with lowland spirits or consult Itza'.

Although these observations are preliminary, it appears that migration and the subsequent displacement of individuals affects the relation these people have with their immediate habitat. Lowland Q'eqchi' Maya have arguably much stronger religious ties to their gods than Itza' Maya have, yet their gods are in the highlands. As a consequence, sacred values, per se, are not sufficient for sustainability. We are currently exploring these issues with cross-generational studies with the Petén populations as well as with Lacandon Maya—to which we now turn.

Lacandon Maya

Our studies with the Lacandon Maya were mainly concerned with intergenerational change among the men of the two adult generations living in the community of Mensäbäk. The rationale for this focus was twofold. First, given the distributional view of culture, we might explore within-culture differences that go beyond expertise effects. Second, within-culture differences among Lacandon Maya hold particular interest. Members of the second generation of married adults were born or grew up in villagelike communities, whereas fathers and grandfathers originated from dispersed households and settlements.

To elicit mental models of folk ecology, we used free listing to generate a tally of species "most important for the forest to live." The CCM produced a single-factor solution (eigenvalue 1:2 = 16.4, variance = 87%), indicating a single underlying model shared by all informants. Nevertheless, members of the two adult generations separated on both their first and second factor loadings, which further suggests two submodels for the members of the two generations.

One difference is that members of the first generation reported significantly more interactions than members of the second generation. The first generation's consensual model exhibits a clear structure that separates the animals and plants along lines of taxonomy and habitat (Ross, 2001, 2002). This separation is based on specific plant–animal relations that involve certain physiological characteristics, such as having a hard shell (as we found with Itza').

We used the expert networks to explore possible links between relation to an expert and levels of agreement. Second-generation adults clearly regard first-generation adults as experts; however, we could find no evidence for a relation between proximity to an expert and ecological knowledge. In addition, we failed to find reliable residual agreement between fathers and sons. As a whole, these data only describe expertise differences among the members of the Lacandon community. The differences appear to reflect a marked shift in recent history: namely, a dramatic change in settlement patterns that distanced the younger generation from forest life. The expertise differences observed cannot be easily explained as differences in amount of factual knowledge. Rather, differences in perceived goals (the need to tend the forest) and learning landscape (like Itza', Lacandon elders say that one learns by "walking alone" in the forest) lead individuals to draw different conclusions from the same observations.

Other research suggests that overall patterns of knowledge and behavior among native Lacandon Maya versus Tzeltal and Tzotzil Maya (born to immigrant families from the highlands that had settled into the area) resemble those of Itza' versus Q'eqchi' immigrants (Nigh, 2002). The fact that these descendants of immigrants have lived all their life in the forest indicates that mere personal exposure to the local ecology is not a deciding factor.

Finally, we turn to observations from Wisconsin. Here, cultural differences in mental models of nature appear to lead to misperceptions of values and intergroup conflict.

Wisconsin Studies

The research in Wisconsin addresses the generalizability of our approach across different population settings and the issue of the extent to which cultural differences depend on historically shallow (recent immigration) versus deep (transgenerational) exposure and experience in the area. As was noted earlier, both Wisconsin populations have coexisted in this area for at least a century and a half (first contact goes back another 150 years). The Wisconsin studies concern fishing and hunting rather than agroforestry, but the theoretical question is the same: Are there distinct conceptualizations of nature that underlie the Menominee tradition of sustainable forestry (e.g., Hall & Pecore, 1995), healthy rivers and lakes, and abundant fish and game (Schmidt, 1995)? Do cultural differences in these conceptualizations affect practices and intergroup perception? Results to date are most extensive for fish and fishing, but preliminary observations strongly suggest the same patterns for hunting.

We sought to avoid confounding culture with expertise by focusing on experts in each group. Expertise was based on peer nomination and later verified by a task assessing familiarity with 46 local species of fish. In other work we have asked for nominations of experienced but less expert fishermen (Medin et al., 2002), and our experts show reliably greater familiarity with local fish than do fishermen nominated as less expert.

Our initial studies showed that expert Menominee fishermen are more likely to sort ecologically than are expert majority culture fishermen. Using the procedure we described earlier, we asked experts to sort 44 local species of fish into groups and then to lump and split groups to produce a hierarchical taxonomy. We then correlated sorting distance across informants and conducted an overall consensus analysis. We found a clear consensus (ratio of first to second factor = 7.6:1.0; first factor accounts for 57% of the variance; mean first factor score = .75). In addition, residual analysis revealed that Menominee experts showed reliably greater within- than across-groups agreement (the interaction of population and within- vs. between-cultures agreement was reliable), $F(1, 30) = 8.32$, $p < .01$. The consensual fish–fish distances for each group were used in an MDS analysis. The MDS for the Menominee data required three dimensions to obtain a good fit, compared with two dimensions for majority culture experts. Further exploration showed that the first factor in the Menominee MDS correlated reliably ($r = .72$, $p < .01$) with characteristic habitat. No such dimension emerged for majority culture experts. Both groups shared dimensions that correlated with size and desirability (though characteristic adult size was fairly well correlated with taxonomic similarity, and no expert mentioned size as a basis for categorization). In addition, sorting justifications revealed that Menominee were significantly more likely to provide an ecological justification as part of their initial sorting (40% vs. 6%), $F(1, 30) = 18.70$, $p < .0001$. These findings encouraged us to directly probe folk ecological models (Medin et al., 2002, in press).

In the first follow-up study, we explored perceptions of species interactions. On many grounds, one would not expect group differences in perceived fish–fish interactions. First of all, informants from both groups engage in essentially the same activities in terms of when, for what, and how they fish. Second, activities associated with fishing are intimately intertwined with fish–fish interactions. To be successful in fishing, one needs to know where fish are found and what they are eating. Food chains are an important component of fish–fish interactions. Third, our informants were experts who had fished, on average, for several decades, and one might expect a convergence of knowledge, especially when that knowledge is relevant to certain activities.

Twenty-one familiar species were selected and represented on name cards. The experimenter randomly picked one fish as a base card and compared it with every other species (presented in random order). For each informant, this procedure yielded 420 potential fish–fish relations. For each fish–fish pair, the informant was asked whether the base species affects the target species and vice versa (e.g., "Does the northern affect the river shiner?" and "Does the river shiner affect the northern?"). Informants were then asked whether the species affect each other in other ways. Responses were coded into 19 categories, such as A eats B; A eats the spawn of B; A helps clean the bottom, which helps B when it spawns; and so forth. Food-chain relations (e.g., A eats B) were the most frequent response.

The CCM was used to probe for a single, general cross-groups model for fish–fish interactions as well as for each group's particular cultural model. Four different CCMs were run, corresponding to different criteria for agreement. Agreement was assessed on four levels: (a) both informants reported some kind of relation (no matter what the specific relation was), (b) both agreed on either a positive or a negative relation (no matter what the specific relation was), (c) both agreed on a food-chain relation, and (d) both agreed on a reciprocal relation (no matter what the specific relations were). The first two CCMs looked at different criteria for agreement, with the second being more restrictive (if one informant said that black suckers help northerns by being a food source and another said that black suckers hurt northerns because they eat their eggs, they would be coded as agreeing by the first criterion and as disagreeing by the second criterion). The second two analyses looked only at specific types of relations. For example, if one informant said only that northerns eat black suckers and another said that northerns eat black suckers and that black suckers eat the eggs of northerns, then by analysis (c) they would agree on one food-chain relation (northerns eating black suckers) and disagree on the other one. In this sample example, for analysis (d) the two informants would be coded as disagreeing because only the second informant saw the relation as reciprocal.

Separate CCMs were also performed both on raw agreement and on the agreement adjusted for guessing. In each case, we found consensus for the combined metacultural model as well as for separate cultural models on three levels: (a) existence of a relation, (b) helping or hurting relations, and (c) food chain relations.[21] Menominee showed above chance agreement for the reciprocal relations: Sixty-nine percent of the agreement pairs were positive (by chance, half should be positive). Cross-groups agreement was very close to chance (48% of agreements).

For all relations cited by at least 70% of the members of one group, we further found that (a) 85% were reported by both groups, (b) 14% (45 relations) were reported by Menominee but not majority culture experts, and (c) 1% (4 relations) were reported by majority culture but not Menominee experts. Overall, Menominee reported reliably more relations than their majority culture counterparts (62% vs. 46% of possible relations). In short, the majority culture ecological model appears to be a subset of the Menominee model, a finding that parallels our results from the sorting task as well as the Itza'–Ladino comparison on the forest ecology task. As we show shortly, however, this difference is not a difference in the knowledge between the two groups.

[21] The consensus was much weaker and limited to the Menominee experts for reciprocal relations. In this case, we found consensus for reported reciprocal relations only in regard to raw observed agreement.

On a more specific level, Menominee experts reported significantly more positive relations (one species helping another) than their majority culture counterparts did, whereas members of both groups mentioned about the same number of negative relations. The groups also differed substantially with respect to reciprocal relations. On average, Menominee informants mentioned 59.5 reciprocal relations, compared with 34.6 for majority culture fish experts. Majority culture experts differed from their Menominee counterparts in that they were likely to report the prototypical adult-species relation (e.g., majority culture experts were likely to report that northerns eat walleyes and not mention that a large walleye may eat a small northern).

The two cultural groups share a substantial amount of knowledge of species interactions, as indexed by this task. This should come as no surprise. Much of expert knowledge stems from actual observation while looking for fish, fishing, and even cleaning the catch (e.g., stomach contents usually tell what the fish had been eating recently). However, the task also reveals clear cultural differences in the models of the individuals. These differences may be caused by the fact that the responses of majority culture informants concerning ecological relations seemed to be filtered through a goal-related framework. Goals may influence reports of ecological relations in at least two ways. One is to focus on ecological relations that apply to adult fish rather than those associated with the entire life cycle. Indeed, many of the relations reported by Menominee experts but not majority culture experts involve spawn, fry, or immature fish.

A second difference is that relations present in pursuing goals may be overgeneralized in the sense that they may be reported where they do not apply. Majority culture experts tend to report bait fish being affected by predator fish, even when the particular bait fish and predator tend not to be found in the same waters. Other than these few overgeneralizations, the nominated relations appear to be accurate.

These two observations suggest that some differences are more the effect of habits of the mind—higher saliency or accessibility of some knowledge over other knowledge. The original task took 1 to 1.5 hr. Given that the informants had to report on 420 possible relations, the task had a rapid pace. This might have led to a difference in reported relations as a function of differences in knowledge accessibility. If so, we might expect that the cultural differences in ecological knowledge would disappear if we used an unspeeded task directly probing for ecological information. In one additional experiment, we asked the experts to sort local fish species according to where they are found, and, indeed, the cultural differences were absent.

In a second follow-up experiment we probed a subset of the fish–fish interactions and proceeded at a considerably slower pace. Again, the group differences disappeared, and the main effect of the slower pace was that it led the majority culture experts to be much more likely to mention relations involving immature fish and to be more likely to mention reciprocal relations (Medin et al., in press). In short, both groups share essentially the same model and knowledge base, but there appear to be clear cultural differences in how this knowledge is organized. Knowledge organization, in turn, affects what is salient or “easy to think.” These results also undermine the idea that the differences in the faster paced ecological task reflect differences in being eager to please the experimenter—if that were the case, then the slower pace should have worked to amplify, not diminish, differences.

We have also begun to examine folk biological models in less expert Menominee and majority culture populations. Results from our initial sorting task reveal an interesting picture of explanations given for sorting. Like Menominee experts, Menominee nonexperts tended to give relatively more ecological justifications (40%) and fewer goal-related (29%) and taxonomic–morphological (31%) justifications. The majority culture nonexperts, by contrast, gave fewer ecological justifications (16%) and more goal-related (43%) and taxonomic–morphological (41%) justifications. Whereas the pattern of Menominee justifications is robust across the two levels of expertise, the majority culture pattern changes, such that, with expertise, majority culture informants come to give more taxonomic–morphological and fewer ecological and goal-related justifications. Some majority culture experts explicitly mentioned how their orientation toward fishing had changed over the years, moving away from the stereotypic sportsman’s model that targets fishing contests or going for the trophy fish.

Intergroup Perception

The above group differences in goals and ways of conceptualizing fish appear to have significant consequences for intergroup perception and conflict. In related work, we have asked Menominee and majority culture experts to (a) rank order the importance to them of 15 species of fish, (b) rank order six goals associated with fishing, and (c) give approval or disapproval ratings for a variety of fishing practices (e.g., taking more than one’s limit, keeping undersized fish, fishing on spawning beds). In a later interview, we asked these experts to perform these tasks again, indicating first how they think equally expert fishermen from their own community might answer them and second how equally expert fishermen from the other community might answer them.

Overall, the two groups were remarkably accurate at predicting how the other group would rank order the importance of the 15 species. For example, Menominee fishermen place greater importance on trout and lesser importance on trophy-type fish (e.g., musky), and both groups were aware of this. In addition, Menominee fishermen place greater priority on fishing for food, and both sets of experts correctly predicted this difference in goals.

With respect to practices, there were several cultural differences in patterns of approval and disapproval, but they paled in comparison with perceived differences. This difference between perception and reality was almost exclusively concentrated in majority culture perceptions of Menominees. Majority culture experts thought that Menominee experts would approve of every practice that was roundly condemned by both groups. This even included the practice of going to areas where sturgeon are spawning in the spring and pretending to fish for other fish in hopes of getting a sturgeon on the line (sturgeon are a protected species, and it is illegal to use hook and line to catch them). Individual Menominee experts are more disapproving of this practice than are majority culture fishermen; majority culture fishermen made the opposite judgment. This is a striking difference, especially given that the sturgeon is considered to be sacred for many Menominee, who would likely find the above practice disrespectful. We think that some majority culture experts knew that Menominee value the sturgeon but inferred majority culture goals (wanting to wrestle with a big fish) to Menominees as the underlying reason for this valuation.

This misperception of Menominee attitudes, values, and practices was large but not uniform. In keeping with the distributed view of culture and cultural processes, we have explored correlates of stereotyping or misperception. One correlate is majority culture expert sorting strategies. Majority culture experts who produced goal-related sorts, such as creating a category of undesirable fish, showed stronger stereotyping; experts who created an ecological category showed less stereotyping. There was also a strong and reliable correlation between knowing that Menominees attach relatively higher priority to trout and the absence of stereotyping. This may be a proxy for degree of contact with Menominee fishermen, and we are investigating this possibility further by collecting social and expert network data with a focus on intergroup linkages. Overall, these data show that behaviors and stated goals are not transparent in the case of intergroup perceptions. The same behavior can have very different meanings in alternative cultural frameworks, and the resultant misunderstandings can produce intergroup conflict over resources (see Nesper, 2002, for a dramatic illustration of this point for the case of Native American fishing rights).

Summary

These studies reinforce the distributional view of culture. Residual analysis indicated that expert Menominee and majority culture fishermen have a shared model but that, in addition, Menominee fishermen have a distinct model based on salience of ecological relations. These differences, coupled with differences in underlying subordinate goals, can give rise to dramatic intergroup misperception, even when both groups share the same superordinate goal of resource conservation. The interaction of culture and expertise in the basis for sorting also suggests different developmental trajectories in the two groups. In fact, we have other developmental data showing parallel cultural differences in sensitivity to ecological relations in young Menominee and majority culture children (Ross, Medin, Coley, & Atran, 2003). These trajectories invite further analysis.

Our data show that expertise cannot be separated from cultural milieu, even when people engage in more or less the same activities. In that respect, cultural paths (in the sense of reliable distributions of conceptual representations in a population of minds) appear to provide something of a framework theory for organizing experience. This is seen, for example, in the Itza' Maya tendency to see reciprocal relations (animals helping plants as well as being helped by them) and in Menominee fishermen's ecological orientation. The parallels between the Itza' and Menominee are striking, especially when one notes that both groups also have sustainable forestry practices. As with Itza' and Lacandon, some Menominee men express the belief that if a person treats nature in a greedy or wasteful manner then spirits will punish that person, and they offer tobacco as a prayer of thanks.

General Discussion and Implications

Implications for Theories of Decision Making

In the area of decision making and the commons, the prevailing view—at least in economics and political science—has been that human behavior in society is driven by self-interest, mitigated by institutional constraints. Like models of induction that rely on universal similarity, abstract decision models use a homogeneous notion of utility, in which content biases and protected values simply are annoying. For example, protected values are annoying because their utility may be hard to measure or to place on a common scale (Baron & Spranca, 1997; Ritov & Kahneman, 1997). Content biases only serve to distort rational calculations of utility (but see Tanner & Medin, 2004, for a contrasting view).

Thus, analyses of the commons problem may appear to be trapped somewhere between isolated individual interests, which lead inevitably to commons destruction, and a focus on institutions that has little need for cognitive science. To be sure, there is a good body of social science research that identifies certain conditions for cooperation in artificial experimental situations (e.g., Messick & Brewer, 1986; Ostrom, 1998), but it is hard to see how to transfer these findings to complex, real world situations such as we find in Petén and Wisconsin. Furthermore, this body of research provides no role for content or values other than in terms of fungible (transparently interchangeable) gains and losses. There is no place for absolute or sacred human values (Rappaport, 1979), for distinct kinds of concerns (see Tenbrunsel & Messick, 2001, for a nice counterexample), or for calculating the interests of nature (E. O. Wilson, 1992).

We find that content-structuring mental models are pertinent to environmental decision making. They not only predict behavioral tendencies and stated values but also correlate reliably with the measurable consequences of those behaviors and values—even down to the level of soil composition and the number and variety of trees found on people's land (Atran et al., 1999, 2002). Perhaps most striking is that the Itza' construal of the value of a forest species as relational and subjectively defined seems to recognize nature as a player with a stake in its own future. This is a different way people have of going about their business, and their environments may be the better for it. We think this sort of analysis opens the possibility of making models of decision processes more insightful for understanding human–environment interactions.

Methodologies for Modeling Culture

We have presented a view of cultures as composed of causally distributed networks of mental representations, their public expressions (e.g., artifacts, languages, dances), and resultant behaviors in given ecological contexts. Ideas and behaviors become cultural to the extent that they endure among a given population. Just as it was (and still is) difficult for biology to discard the essentialized notion of species in favor of species as a historical, logical individual (Ghiselin, 1981), it is difficult to abandon the common-sense notion of culture as an essentialized body (of rules, norms, and practices). In biology, it makes no sense to talk about species as anything other than more or less regular patterns of variation among historically related individuals. Neither can one delimit species independently of other species. So, too, it makes little sense to study cultures apart from patterns of variation.

Although we used common-sense notions of culture in setting up comparisons of Itza' versus Ladinos versus Q'eqchi', our analyses indicate the extent to which these common-sense constructs represent statistically reliable distributions of cognitionsand behaviors. Social network analyses further reveal that members of each of these communities almost never include people identified with other communities among their intimate social relations. These common-sense cultural constructs allowed us initially, if roughly, to distinguish populations that subsequently revealed themselves to consist of reliably distinct cognitive, behavioral, and social–relational patterns.

Our use of the common-sense notion of culture to initially distinguish populations is not a case of circular reasoning, because patterns of similarities and differences within and between populations could not be predicted in advance. As with Darwin's (1859) use of the common-sense notion of species, which first focused his attention, subsequent discoveries revealed only rough correspondence between the common-sense construct (species) and historically contingent patterns of evolution (more or less geographically isolated and interbreeding populations). Darwin continued to use the common-sense idea of species (A. R. Wallace, 1889, p. 1) only as a heuristic notion that could ground attention as diverse and often inconclusive scientific analyses advanced, while denying it any special ontological status or reality (Atran, 1999).

Likewise, intuitions about what constitutes a culture may continue to help orient research but should not be mistaken for a final or correct framework of explanation. Thus, although our findings reinforce separating the Q'eqchi' from the other groups, they also strongly suggest that Itza' and Ladino populations are beginning to merge on a number of dimensions (male expertise, residential proximity, converging use of Spanish as the principal language, etc.). In fact, researchers in the area from several disciplines now refer to a more generalized Petenero culture that joins Itza' and Ladinos but still generally excludes the Q'eqchi' (Schwartz, 1990). This somewhat anecdotal evidence needs to be substantiated with systematic observations.

Like modern biology, the distributional view of cultural phenomena takes individual variation not as deviation but as a core object of study. From this perspective, issues of cultural acquisition, cultural transmission, cultural formation, and cultural transformation are intricately interwoven and, together, constitute the object of study (see also Ross, 2004). We have also seen how the CCM (Romney et al., 1986) can be a valuable tool for analyzing patterns of relative agreement and disagreement within and across populations. In addition, social network analysis provided the means to examine likely pathways for learning and communicating information. Together, consensus modeling and network analysis enabled us to systematically explore the aforementioned issues in an integrated fashion.

To illustrate, consider again our Itza' and Ladino study populations. First of all, somewhat to our surprise, we could not reject the possibility that the consensual ecological model of the Itza'-speaking elders was based on a series of independent discoveries. We found no reliable residual agreement that could be traced through either social or expert networks. We know that this finding does not owe to the insensitivity of our measures, because these same networks revealed evidence that Ladinos were learning from Itza'. Our analyses suggest that the relevant conceptual biases for acquiring reciprocal understanding of species relations are diffused throughout Itza' networks (extending, as we also saw, to younger Itza'). In this sense, reciprocity pervades Itza' culture.

The Ladino settlement of La Nueva did not begin as a culture in any sense: It was founded by nuclear families stemming from scattered towns and villages with no apparent historical connections among them. Today, at least with respect to models of nature, Ladinos are forming patterns of cultural consensus by assimilating ecologically relevant information over expert and social networks, over- and undergeneralizing that information in conformity with their taxonomies, and interpreting information in accordance with their own conceptual biases (e.g., nonreciprocity). In other words, the Ladinos are forming their unique cultural understanding of the forest, transforming (with varying fidelity) Itza' cultural models into their own.

Conclusion: A General Approach to the Study of Culture and Cognition

In this article, we have argued that an effective way to study culture and cultural processes is through the study of variation within and across populations. From the theoretical perspective of decision theory, our work extends the tragedy of the commons to situations involving multiple groups transmitting knowledge and belief systems in distinct patterns that can be traced to historically conditioned conceptions of nature and social and expert network distance. This same perspective is also relevant to application: Cultural cognitions affect environmental values, decision making, and prospects for human survival under conditions of global change (Atran et al., 2004).

Our work casts a different light on the tragedy of the commons and associated game-theoretic analyses. First, individual cognitions or mental models of resources are not irrelevant to environmental decision making, as assumed by content-free framing in terms of utilities. A related observation is that the Itza' consider the ecologically central ramon tree to be sacred and always worthy of protection and, unlike the other two groups, would never use ramon as firewood. We have already noted that research in the psychology of decision making sometimes views sacred or protected values as a hindrance to proper decision and a source of cognitive biases (e.g., Baron & Spranca, 1997). There is, however, other evidence suggesting that protected values may be associated with the absence of framing effects and related biases (Fetherstonhaugh, Slovic, Johnson, & Friedrich, 1997; Friedrich et al., 1999; Tanner & Medin, 2004). Second, differing conceptions of a common resource may require different abstract analyses, as we saw in the case of the Itza' belief in the forest spirits as guardians of the forest. In short, our unified approach to culture and cognition can inform—and, indeed, transform—models of cultural cognition, such as environmental decision making.

This article on the cultural mind, together with our companion article on the native mind, reviews a decade-long project on human conceptions and dealings with respect to nature that has naturally branched in several directions. Despite this complexity, the overall project nicely illustrates a unified framework for studying culture and cognition. In our companion article, we focus on the role of a folk biology module in stabilization of folk biological knowledge. In the present article, we found that folk biological knowledge is only one of a number of key ingredients in the cultural stabilization of folk ecological knowledge and practice.

Our previous work on category-based induction enabled us to identify inferential patterns in acquisition and transfer of folk biological knowledge. We saw that these patterns reflect both universal constraints on biological inductions and culturally specific biases in construal and organization of information. The view of culture as a patterned distribution of cognitions and behaviors, which we used in this article, sets the stage for addressing issues of learning, inference, and transmission of information within and between cultural groups.

To explain cultural consensus and stabilization of folk ecology, we focused on the likely causal roles of (historically conditioned) mind-internal mental models for representing and processing cultural cognitions and on mind-external ecological factors (including social arrangements) for transmitting cultural cognitions. We found that statistically consensual cultural cognitions and practices—or cultures, for short—involve complex causal chains that go both inside and outside the mind. These chains irreducibly link individual minds and their internal representations with psychophysical interactions among individuals and their external environment (including interactions with other individuals).

By targeting the microprocesses (including evolved cognitive aptitudes, e.g., the folk biology module) by which these cultural chains form, we have sought to account for regularities and recurrences in sociocultural macrophenomena. This contrasts with standard explanations in social psychology that seek to account for individual cognitions in terms of the influences of sociocultural macrophenomena—in which the material causal character of influence remains unspecified. Our approach also runs counter to accounts in anthropology, sociology, economics, and political science that seek to explain sociocultural macrophenomena in terms of the influences of other sociocultural macrophenomena (e.g., unemployment as a cause of political change; see also Bloch & Sperber, 2002, for a prior formulation of this point).

In sum, we have tried to illustrate a unified approach to culture and cognition that takes us from individuals' evolved cognitive aptitudes to historically contingent collective practices (e.g., managing a rainforest) in systematic and reliable ways. We have described the general character of the likely causal factors and linkages involved, although we have only set the stage for inquiry into the actual causal processes and occurrences at work. Nevertheless, we have found in this endeavor that the study of culture formation and cross-cultural relations requires careful attention to group dynamics as well as individual psychological processes. To causally understand cultural cognition and behavior, anthropology and psychology must be close companions.

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(*Appendix follows*)

Appendix

Rankings of Human Impact on Plants and Ecological Centrality for Itza', Ladinos, and Q'eqchi'

Itza'			Ladino			Q'eqchi'		
Impact	Centrality	Plant	Impact	Centrality	Plant	Impact	Centrality	Plant
1.00	**0.66**	Ramon	0.75	0.20	Ceiba	0.33	0.04	Guano
1.00	**0.64**	Chicle	0.58	0.15	Pacaya	0.25	0.09	Corozo
0.83	**0.10**	Cedar	0.58	0.10	Xate	0.08	0.07	Grasses
0.83	**0.49**	Ciricote	0.55	0.16	Allspice	0.00	0.17	Amapola
0.83	**0.11**	Mahogany	0.50	0.47	Ciricote	0.00	0.02	Cordage vine
0.75	**0.21**	Xate	0.42	0.61	Chicle	0.00	0.00	Chapay
0.67	**0.05**	Ceiba	**0.33**	**0.12**	Madrial	0.00	0.04	Ciricote
0.67	**0.42**	Guano	**0.33**	**0.64**	Ramon	0.00	0.08	Broom palm
0.67	**0.09**	Madrial	**0.17**	**0.14**	Cedar	0.00	0.01	Jabin
0.67	**0.38**	Allspice	**0.17**	**0.36**	Guano	0.00	0.00	Kanlol
0.58	**0.26**	Amapola	**0.17**	**0.25**	Grasses	0.00	0.07	Madrial
0.58	**0.13**	Chapay	**0.08**	**0.30**	Mahogany	0.00	0.02	Pacaya
0.58	**0.09**	Corozo	**0.00**	**0.29**	Amapola	0.00	0.00	Allspice
0.58	**0.32**	Broom palm	**0.00**	**0.17**	Water vine	0.00	0.01	Pukte
0.58	**0.21**	Pacaya	**0.00**	**0.22**	Corozo	0.00	0.21	Ramon
0.50	**0.35**	Grasses	**0.00**	**0.00**	Yaxnik	0.00	0.02	Santamaria
0.42	**0.07**	Chaltekok	**−0.13**	**0.14**	Pukte	0.00	0.20	Yaxnik
0.42	**0.17**	Jabin	**−0.14**	**0.01**	Chaltekok	0.00	0.05	Herbs
0.42	**0.06**	Manchich	**−0.18**	**0.11**	Santamaria	−0.08	0.15	Strangler fig
0.25	0.16	Santamaria	**−0.25**	**0.06**	Cordage vine	−0.08	0.03	Water vine
0.17	0.39	Herbs	**−0.25**	**0.25**	Herbs	−0.08	0.00	Chaltekok
0.08	0.48	Strangler fig	−0.33	0.09	Broom palm	−0.08	0.02	Killer vines
0.08	0.28	Yaxnik	−0.44	0.13	Jabin	−0.25	0.05	Ceiba
−0.25	0.15	Pukte	−0.50	0.20	Chapay	−0.25	0.01	Manchich
−0.33	0.07	Water vine	−0.60	0.00	Manchich	−0.25	0.04	Xate
−0.33	0.01	Cordage vine	−0.67	0.60	Strangler fig	**−0.58**	**0.14**	Chicle
−0.58	0.03	Kanlol	−0.67	0.24	Killer vines	**−0.67**	**0.12**	Cedar
−0.58	0.09	Killer vines	−0.75	0.06	Kanlol	**−0.75**	**0.09**	Mahogany

Note. Human impact was assessed on a scale from *negative* (−1) through *neutral* (0) to *positive* (1), with individual responses added and the sum then divided by the sample population size. Ecological centrality for a given plant is the proportion of plant–animal associations in the population's consensual ecological model for that plant. Latin names for plants are given in Table 2. Boldface type is used here to highlight the differences in rating preferences for the three populations. This Appendix is an updated and corrected version of a table that appeared in "Folkecology and Commons Management in the Maya Lowlands," by S. Atran et al., 1999, *Proceedings of the National Academy of Sciences, USA, 96,* p. 7601. Copyright 1999 by The National Academy of Sciences, USA.

Received April 20, 2004
Revision received January 24, 2005
Accepted January 31, 2005 ■

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