The cognitive foundations of cultural stability and diversity

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The existence and diversity of human cultures are made possible by our species-specific cognitive capacities. But how? Do cultures emerge and diverge as a result of the deployment, over generations and in different populations, of general abilities to learn, imitate and communicate? What role if any do domain-specific evolved cognitive abilities play in the emergence and evolution of cultures? These questions have been approached from different vantage points in different disciplines. Here we present a view that is currently developing out of the converging work of developmental psychologists, evolutionary psychologists and cognitive anthropologists.

A cultural group is held together by a constant flow of information, most of which is about local transient circumstances and not transmitted much beyond them. Some information, being of more general relevance, is repeatedly transmitted in an explicit or implicit manner and can end up being shared by many or even most members of the group. 'Culture' refers to this widely distributed information, its representation in people's minds, and its expressions in their behaviors and interactions.

Anthropologists have been justly fascinated by the richness and variety of human cultures, which they have documented and tried to explain. To do so, they have relied on a view of the mind, if not literally as a 'blank slate' [1], at least as an unbounded and unbiased learning machine, equally open to any kind of cultural content. This 'standard social science model' [2] of the relation between mind and culture has been more and more forcefully challenged both from inside and outside anthropology. It is in particular incompatible with much recent work in developmental psychology according to which the child's acquisition of knowledge is guided by domain specific cognitive dispositions [3]. The challenge that current research attempts to address is that of reconciling the evident diversity of culture with our best hypotheses about cognitive development, and in so doing to help lay down new foundations for anthropological theory.

Not just the diversity but also the stability of culture begs explanation. Cultural representations and practices must remain stable enough across the community through which they propagate for people to recognize themselves as performing, for instance, the same ritual, endorsing the same belief, or eating the same food. To maintain their stability while reaching a cultural level of distribution, cultural information has to be remembered and transmitted again and again with very little alteration, or else the accumulation of such alterations would compromise the very existence of culture. Anthropologists [4], and now also 'memeticists' [5,6], have assumed that human capacities for memory, imitation and communication are reliable enough to secure faithful reproduction of the contents they process across group and generations.

Yet, as has been known since Bartlett, content transmitted through a chain of individuals undergoes rapid distortion and decay [7]. Recent approaches to memory and to communication emphasize that both involve reconstruction rather than copying of the material remembered or communicated [8,9]. As for imitation, although remarkably developed among humans, it is not very reliable either, and is limited to the reproduction of perceptible behaviors [10]. One cannot for instance perceive, and hence imitate, mental states such as linguistic competence or cultural beliefs. In spite of the limitations of imitation, communication and memory, there is (and has been since well before the invention of writing) an abundance of stable cultural contents. What mental mechanisms contribute to making this stability possible? Two different but mutually compatible and possibly complementary approaches should be mentioned here. Boyd, Richerson and their collaborators have modelled the stabilizing role of psychological biases in transmission favoring for instance prestige or conformity [11–13]. Atran, Boyer, Hirschfeld, Sperber, and their collaborators have stressed the stabilizing role of the child's disposition to acquire knowledge structured in domain-specific ways [14–19]. Here, we report work related to this second approach.

Modules and their domains

In the case of non-human animals, the view that a cognitive system is an articulation of evolved domain- or task-specific autonomous devices or 'modules' is fairly uncontroversial [20]. Many of these modules, for instance the imprinting mechanism of geese or the food aversion mechanism in rats, involve some degree of learning. In the case of humans too, there is a growing body of evidence suggesting that, to an important extent, the cognitive system is comprised of modular devices, dedicated to specific tasks – for instance, to face recognition [21,22], language acquisition [23], or attribution of mental states [24]. Most of these devices (especially those organizing

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higher-level conceptual content) can be seen as 'learning instincts' fostering and guiding the acquisition of knowledge and skills in specific domains [25] (see Table 1).

Still, the view that the human mind might, like that of other animals, be to a large extent an articulation of modules is quite controversial. The terms of the debate were set by Jerry Fodor, who, in his 1983 *The Modularity of Mind*, proposed a definition of modules that is more appropriate for input modules, arguing that higher cognitive functions are not modular [26,27]. Our approach to mental modules is less rigid than Fodor's, and more in line with recent views of modularity found in comparative psychology, evolutionary psychology, evolutionary biology and artificial intelligence [28–30,20,2]. Here we don't review the arguments for the modularist view of the human mind [29,31]; we assume it and explore its implications for the cognition–culture interface.

An evolved cognitive module – for instance a snake detector, a face-recognition device, a language acquisition device – is an adaptation to a range of phenomena that presented problems or opportunities in the ancestral environment of the species [32]. Its function is to process a given type of stimuli or inputs – for instance snakes, human faces, or linguistic utterances. These inputs constitute the *proper domain* of the module [19]. To recognize items belonging to its proper domain, a module uses formal conditions that an input has to meet to be accepted and processed. All inputs meeting the input conditions of a module constitute its *actual domain*. These inputs conditions can never be perfectly adequate. Some items belonging to the proper domain of the module might fail to satisfy them – a snake can look like a piece of wood. Some items not belonging to the proper domain of a module might nevertheless satisfy its input conditions – a piece of wood can look like a snake. If only because cognition is a probabilistic activity, the actual and the proper domain of a module are unlikely ever to be strictly co-extensive. There will be false negatives – that is, items belonging to the proper domain but not to the actual domain; and false positives – items belonging to the actual but not to the proper domain (Figure 1a).

Mismatches between domains

The mismatch between the proper and the actual domain of a module can result in part from the exploitation of the module by other organisms, as in cases of camouflage (creating false negatives) and mimicry (creating false positives). Many insectivorous birds for instance have the ability to detect wasps, which are dangerous to eat. Hover flies, which are good food for these birds, have evolved black and yellow stripes on their abdomen that mimic the appearance of wasps and activates the birds' wasp detecting module. These hover flies have invaded, to their own benefit, the actual domain of the birds' wasp detector (Figure 1b).

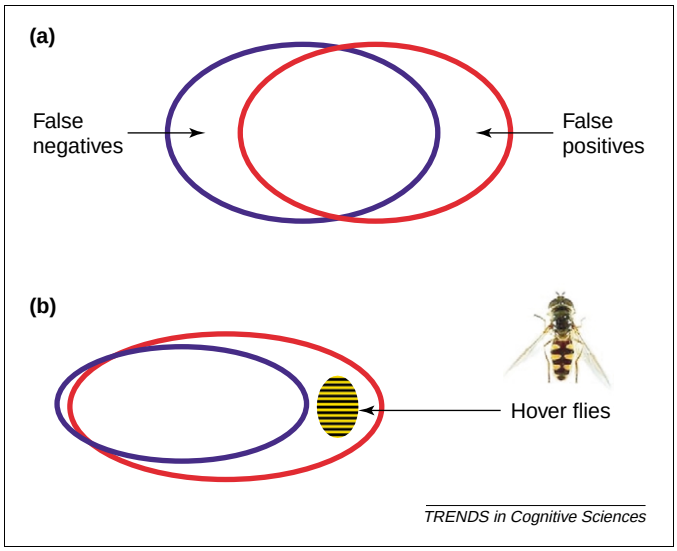

Figure 1. (a) The proper domain (blue) and the actual domain (red) of a cognitive module. In assigning items to a domain, it is likely that there will be some false negatives and some false positives. **(b)** The proper domain (blue) and the actual domain (red) of a wasp-detector module. An area of the actual domain (shown in black and yellow stripes) is occupied by hover flies mimicking wasps (false positives).

In general, systematic mismatch between the proper and actual domains of a module is likely to occur when the module is manipulated by other individuals, whether of the same or of different species. This takes place to a unique extent among humans. Humans seek to influence one another in many ways, and hence need to both attract and direct the attention of others. A reliable way to attract attention is to produce information that falls within the actual domain of modules, whether or not it also falls within their proper domain. Moreover, given the rigid patterns of modular processing, the direction in which such information is likely to be processed is relatively easy to predict.

A great variety of cultural artifacts are aimed at specific modules. For instance, face recognition modules found in primates accepts as input simple visual patterns that in a natural environment are almost exclusively produced by actual faces. In the human cultural environment, a great many artifacts are aimed at the face recognition module.

Table 1. Domains for which strong developmental, comparative and neurocognitive data exist

Theory of mind	Capacity to interpret behavior in terms of mental states like belief and desire	[57–61]
Folkbiology	Capacity to sort living things in terms of their morphology and reason about them in terms of biological principles like growth, inheritance, digestion, respiration, etc.	[34,37,38,53,62,63]
Number	Capacity to distinguish collections of objects according to the (small) number of elements in the collection	[64–66]
Face recognition	Capacity to distinguish conspecific faces from other similar stimuli and to identify individuals by the specificity of their faces	[21,22,67,68]
Naive mechanics	Capacity to form consistent predictions about the integrity and movements of inert objects	[69–71]
Folk sociology	Capacity to sort conspecifics into inductively rich categories, membership in which is based on (supposedly) shared intrinsic natures	[42,55,72]

They include portraits, caricatures, masks and made-up faces. The effectiveness of these cultural artifacts is in part explained by the fact that they rely on and exploit a natural disposition. Often, they exaggerate crucial features, as in caricature or in make up, and constitute what ethologists call 'superstimuli'. The effectiveness of these artifacts in turn helps explain their cultural recurrence. More generally, the actual domain of human mental modules is invaded and inflated by culturally produced information. When some specific type of information is culturally produced to activate a module, it can be described as a cultural domain of the module. For instance portraits, caricatures, masks and made-up faces are cultural domains within the actual domain of the face-recognition module (Figure 2). Cultural domains are likely to be outside of the proper domain of the module, as is the case with portraits, caricatures or masks. They might also fall within the proper domain as in the case of made-up faces: these are genuine faces and therefore it is the function of the face recognition module to analyze them; however they are faces that have been artificially transformed so as to interpreted for instance as younger or healthier than they really are.

The case of folk biology

All animals interact with a variety of other animals and plants and must organize knowledge about them to guide their own activities and interpret the properties and behaviors of other species (e.g. aggression from predators or sweet taste from ripe fruits). In the human case, categorization of living kinds is complex, comprehensive and cultural [33,34]. In different cultural traditions plants and animals play diverse roles (e.g. in activities ranging from foraging and agriculture to totemism). Nevertheless, folk taxonomies the world over are remarkable in the degree to which they structurally resemble each other and in the extent to which they match scientific taxonomies.

Sorting plants and animals into categories is largely guided by regularities in perceptual discontinuities in morphology in local ecologies [33,34]. However, reasoning about living things is not principally based on general inductive processes. Developmental findings provide evidence for a special-purpose module for folk or naive biology. Despite often fragmentary and limited experience, young children's inferences and expectations about the nature of living things are like adults': they are based on the fact that category membership supports very rich and varied inferences [35]. These inferences obey a naïve form of reasoning according to which each living kind has an unseen essence. These species-specific essences are thought to have causal effects on the appearance and behavior of members of the kind [36]. Young children, for example, privilege common folk category identity over similarity in appearance when inferring whether different living things share biologically-relevant properties. Young children also understand that a living thing's category membership is fixed, both with respect to developmental changes that organisms naturally undergo and with respect to the imperviousness of species-typical properties (even in the hypothetical case of an individual raised by members of another species; see Box 1). Cross-cultural

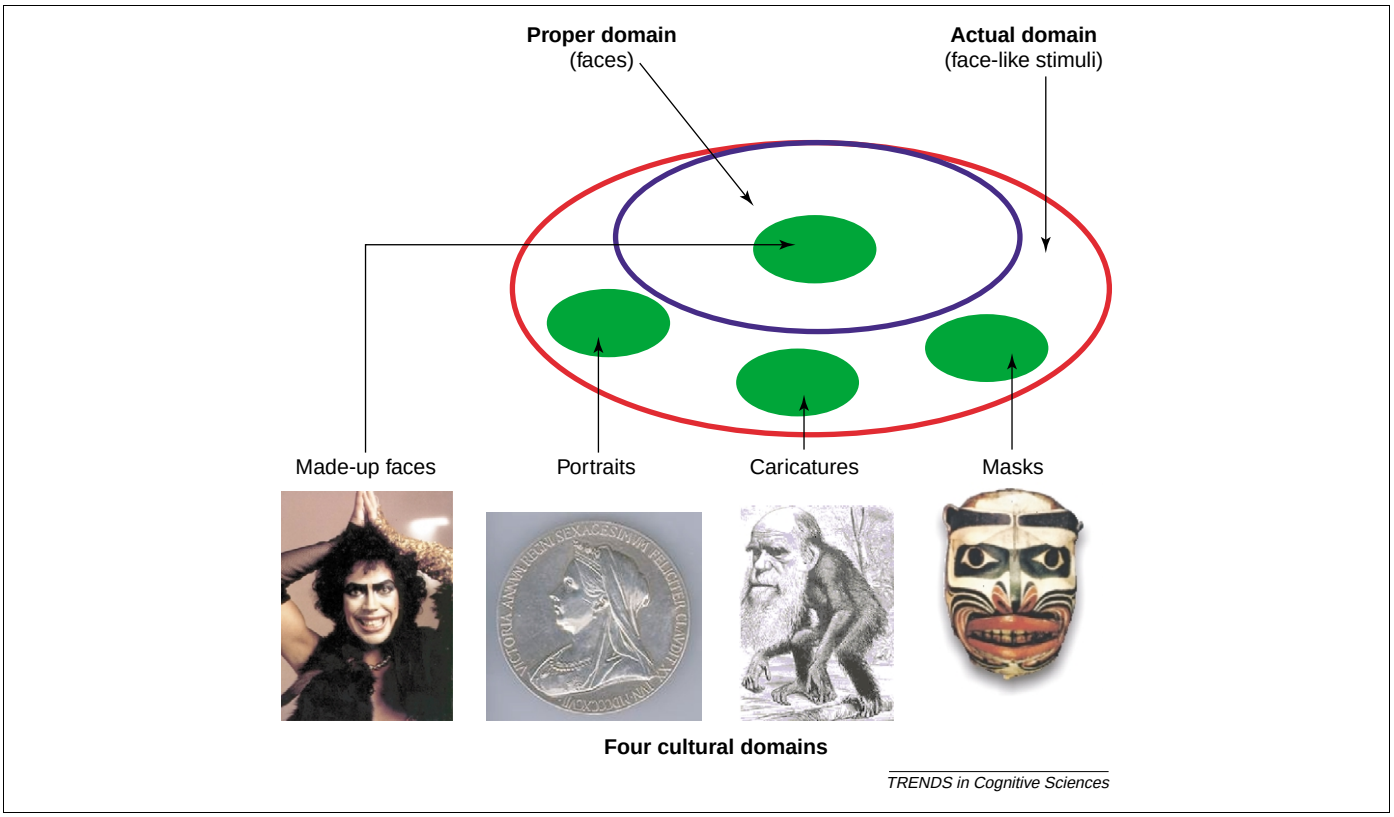

Figure 2. The face-recognition module, with its proper domain (i.e. genuine faces) shown by the blue ellipse, and its actual domain (i.e. face-like stimuli) shown by the red ellipse. In green are four cultural domains of the module: made-up faces (which are in the proper domain as they are genuine faces), portraits, caricatures and masks.

evidence is scant, but what little exists indicates that both expectations do not vary culturally [37,38].

The unique importance of animals and plants in ancestral environments and the fact that they afford domain-specific patterns of classification and inference suggest that a dedicated module might have evolved that governed the categorization of living kinds and reasoning about them. The similarities of folk taxonomies across cultures and the regularities in the acquisition and deployment of these taxonomies confirm this hypothesis [14]. The proper domain of the living-kinds module would have been the local plants and animals with which the individual had to interact. However, the fact that inputs to this module come not just from direct experience of the living creatures to be categorized but also, and crucially, from communication with other people allows expanding the actual domain of the module well beyond its proper domain and the limits of local ecology. Using verbal descriptions and pictures as inputs, the module might build representations of many species with whom the individual is unlikely ever to interact – including extinct species such as the dinosaurs, or imaginary species such as dragons.

The module can enrich its categories with information about both familiar and unfamiliar species, information the relevance of which is often cultural rather than practical. Indeed, folk biology strikingly illustrates how the existence of evolved modular dispositions to attend to and organize information in a domain-specific way lends itself to a massive cultural exploitation. For example, in modern societies, wolves are encountered, if at all, only in zoos. However a culturally transmitted representation of wolves as dangerous predators of humans (which they are not) is among children's earliest acquisitions. This representation is a strong attention catcher, a source of recurrent metaphors, and it plays an important role in folklore and children's literature [39]. Culturally reinterpreted wolves have become superstimuli. Modular processing of information about living kinds is similarly the basis for the variety of cultural exploitations lumped together in classical anthropological theory under the label of 'totemism' [40].

Box 1. Studying folk nativism with 'switched-at-birth' tasks

Adults in all cultures recognize that living things display a constancy in identity over time, even when they undergo dramatic changes in appearance and behavior (as when caterpillars become butterflies or cuddly tiger cubs turn into fierce adult tigers). Lay people the world over appear to explain this constancy in terms of unseen essences [47,33]. Each species is thought to have a unique essence that controls the development of species-typical attributes. Each organism's species' essence is thought to be fixed at birth and to remain impervious to variations in the environment in which the organism is reared (an apple seed grows into an apple tree even if planted in a pear orchard).

There are several proposals concerning the origins of these beliefs. Carey and her colleagues contend that genuine biological understanding emerges only through learning and conceptual change that accompany ever growing experience with living things in a cultural environment and that essentialist reasoning is a function of language, not a property of folk biology [48]. Atran and Gelman, among others, instead argue that nativist bias and commitment to unseen essences are expressions of a special-purpose cognitive mechanism that evolved to interpret a specific range of input (e.g. patterns of movement indicating animacy and underlying mental states [49] as well as patterns of morphology indicating discrete types [47]).

Findings from variants of a single experimental task, in which subjects are asked what happens when a newborn is raised by non-biological parents, have frequently figured in this controversy (much as performances on false-belief tasks have figured centrally in discussions of Theory of Mind). In these tasks, subjects are read vignettes about newborns who are switched at birth from the care of biological to non-biological parents. Subjects are asked to choose among alternative outcomes with respect to the species the newborn will become and the sorts of behaviors and physical features it will develop. Gelman and Wellman, the first to use the task [50], showed 4-year-olds drawings of a newborn animal (e.g. a cow) and a group animals of another species (e.g. pigs) and explained that the newborn was raised by parents of the other species [50]. They then asked children whether the cow would develop species-typical features (a curly versus straight tail) and whether it would develop species-typical behaviors (mooing verus oinking). They found that children overwhelmingly judged that the animal would develop the species-typical attributes and behaviors of its birth parents. Other researchers have obtained similar results [37,38,51–53]. This pattern of reasoning, however, is consistent with contemporary Euro-American lay and scientific biology; hence, these results might reflect cultural learning rather than a universal cognitive predisposition. In an effort to resolve the question, attention has turned to nonWestern children's performance on the switched-at-birth task. Atran, Medin and their colleagues tested children in several unrelated cultures and found that different cultural traditions and different experience with the natural environment did not affect performance on a switched-at-birth task using non-human animals [37,38,53], suggesting that it does reflect a universal predisposition.

Switched-at-birth tasks have been used also to investigate essentialist thinking in naïve sociology. Researchers have found that young American children appeal to unseen essences when reasoning about human reproduction, expecting that little girls grow up to be women even if raised in male-only environments [54] and that black children grow up to be black adults even if raised by a white family [18]. Slightly older South Asian children similarly expect that Brahmin children grow up to be Brahmin adults even if raised by Untouchables (R. Mahalingam, PhD thesis, University of Pittsburgh, 1999).

Some cultures, however, seem to reject social nativism. Astuti [55] has done ethnographic and experimental work among the Vezo of Madagascar, a culture that publicly endorses the belief that an individual's ethnicity is determined not by birth but by his or her life experiences. In spite of this public rejection of social nativism, Vezo adults presented with a switched-at-birth task reasoned as social nativists. What about Vezo children? If social nativism is learned from the public culture rather than from adults' private inferences, then, given that Vezo culture rejects social nativism, so should Vezo children. A switched-at-birth task with children revealed an interestingly mixed pattern. When the alternatives were Vezo birth parents and adoptive parents from a closely related neighboring group, Vezo children reasoned in accord with cultural tradition and rejected social nativism. In contrast, when the adoptive parents were from a more distant and more disimilar group, Vezo children, like adults, endorsed social nativism.

These switched-at-birth experiments show that people's inference patterns do not necessarily follow the cultural discourse even though they may be influenced by it. Together with other experiments on inference patterns across culture [56] they demonstrate that, to understand people's ways of thinking in different cultures, ethnographic observation should be complemented with experimental work, and in particular experiments with children.

The case of folk sociology

All social animals face the challenge of coordinating behavior with members of their own and other social groups. Among primates, the increasingly complex forms of group living have played an important role in the evolution of higher-order cognitive capacities such as deception and its detection, coalition formation, and social intelligence generally [41]. Primates (human and non-human) simultaneously belong to many social groupings (based on territory, intragroup status, sex, biological relatedness, and transient or opportunistic coalitions), membership in any of which provides a basis for predicting and interpreting the behavior of others [42]. The cognitive demands of such reasoning is sufficiently specific and complex to suggest the possibility of a special-purpose modular competence in naive or folk sociology.

Unlike the social lives of non-human primates, human social life is thoroughly cultural. All forms of social organization, from biological-sounding 'kinship' to such artificial groupings as monastic orders and political parties, vary culturally and rely on culturally transmitted, partly explicit institutional rules. The distinction we propose between the proper and actual domains of a cognitive module makes it possible to understand this cultural diversity as a function of the evolution of abilities found in other primates. The proper domain of primate and ancestral social intelligence modules consisted in the group affiliation of conspecifics. The actual domain of these modules was determined by whatever (in an individual's bodily appearance, behavior, or the reaction of others to them) provided evidence of their group memberships (e.g. chimpanzee strategies of facial phenotypic matching used in kin recognition) [43].

The culturalization of social groupings must initially have consisted in the elaboration of these cues of group membership. For instance, to natural sexual dimorphism was added a cultural gender dimorphism. Thus existing mechanisms for social cognition were presented with culturally contrived superstimuli (just as in the case of face recognition superstimulated with make-up, or the activation of notions of kin-solidarity to strengthen non-kin-based coalitions). Cognitively, groups are characterized by whatever cues makes it possible to identify their members and by the inferences this identification affords. In an ancestral environment these cues were natural, although there need not have been anything in the ancestral module that precluded the possibility of culturally enhanced or constructed cues.

Indeed, just as living kinds are categorized not only on the basis of direct experience, but also, and crucially, on the basis of communication, the recognition of social groups draws heavily on verbal labels and stereotypes and other expressions of attitude. The displacement of natural signs of group membership by more salient cultural signs together with communication about the consequences of group membership made possible the construction of novel social groupings [44]. If a culture recognizes, say, castes as genuine social categories with distinctive consequences for their members, then they are genuine social categories (although their actual sociological character may be misrepresented in the folk sociology). Whatever culturally constructed social groupings, at a given time and place, happen to fill the actual domain of a social competence module also falls within its proper domain.

The case of supernaturalism

Folk biology and folk sociology are cultural systems of representations that, we argued, might each be grounded in a specific evolved cognitive mechanism. However, not every system of cultural representations matches a distinct cognitive disposition. It is implausible for instance that representations of supernatural beings and events of the type found in all religions (and also in folklore, art and literature) are grounded in an ad hoc cognitive mechanism. After all, supernatural beings, unlike living kinds or social groups, were not part of the environment in which humans evolved. It has, nevertheless, often been argued that religion responds to a basic human need, be it a need for answers to fundamental questions, a need for transcendance, a need comfort and reassurance, or a need for superior authority. From a point of view informed both by cognitive science and evolutionary biology, the existence of such needs and the ability of religion to satisfy them are quite questionable. Typically religious beliefs raise more questions than they answer, and cause anxiety as much as they comfort (there is, say, a promise of eternal life after death, but it might be spent in Hell). Explaining religion by a religious disposition lacks insight and plausibility [45].

The ubiquity and salience of cultural representations of supernatural beings might be accounted for in terms of a modular cognitive architecture without assuming that there is a modular disposition to represent such beings or to look for supernatural explanations. Representations of supernatural beings do not just depart from what is taken to be natural or ordinary. A zebra with red and blue stripes or a person who, like Borges's character Funes, remembers everything, however out of the ordinary and in practice impossible, are unlikely ever to become culturally recognized supernatural beings. Supernatural beings are not just impossible in nature. They blatantly violate the kind of basic expectations that are delivered by domain-specific cognitive mechanisms. In direct clash with naive physics, some are able to be in several places at the same time or to pass through solid objects. In direct clash with naive biology, some belong to several species at the same time or can change from one species into another. In direct clash with naïve psychology, some can literally see all past and future events. Despite these striking departures from intuitive knowledge the appearance and behavior of supernatural beings is otherwise what intuition would expect of natural beings. That is, they have enough of the characteristic features of plants, animals, people, topographic entities or celestial bodies to fall squarely in the actual domain of cognitive modules. Supernatural animals have, apart from their supernatural features, a regular biology. Supernatural agents have a belief-desire psychology. As argued by Boyer, it is this combination of a few striking violation with otherwise conformity to ordinary expectations that makes supernatural beings attention arresting and memorable, and rich in inferential potential [46].

Representations of supernatural beings, we suggest, spread and stabilize in different cultures because they function for one or several cognitive modules as superstimuli. Unlike other superstimuli, which have some features exaggerated and essential features maintained, these cultural superstimuli typically combine not just exaggerated but also *paradoxical* features with ordinary and essential ones. One way in which they can be paradoxical is in falling simultaneously in the actual domain of two different modules. For instance, a sacred tree might have agency attributed to it: its appearance activates a naive botany module, whereas what is said of it and the way it is treated activates a ToM module. Representations belonging to a complex system such as a religion (which involves not only representations but also practices, artifacts and institutions) need not be all anchored in one and the same cognitive module. On the contrary, multiple anchoring in several cognitive mechanisms may contribute to the cultural system's stability [15].

Conclusion

The propagation, stabilization and evolution of cultural representations clearly have a variety of causes. They are helped or hindered by demographic and other ecological conditions, in particular by man-made features of the environment, and by religious, educational and political institutions. We agree with standard social science that culture is not human psychology writ large and that it would make little sense to seek a psychological reductionist explanation of culture. We believe, however, that psychological factors play an essential role in culture. Some of these psychological factors have to do with emotion more than with cognition. Here, we have reviewed some recent work suggesting that cognitive factors, in interaction with these other factors (ecological, sociological, emotional) can help explain cultural diversity and stability. In particular, a modular organization of human cognitive abilities favors the recurrence, cross-cultural variability, and cultural stability of a wide range of cultural representations. Future research in this perspective should explore other cultural domains – for instance numeracy, morality, kinship structures, folk epistemology, rhetoric, aesthetics – where the cognitive and the cultural sciences might prove ever more mutually relevant.

References

1 Pinker, S. (2002) *The Blank Slate: the Modern Denial of Human Nature*, Viking
2 Tooby, J. and Cosmides, L. (1992) The psychological foundations of culture. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture* (Barkow, J. *et al.*, eds), pp. 19–136, Oxford University Press
3 Hirschfeld, L.A. and Gelman, S.A. (1994) *Mapping the Mind: Domain Specificity in Cognition and Culture*, Cambridge University Press
4 Leach, E.R. (1976) *Culture and Communication: The Logic by Which Symbols Are Connected: An Introduction to the Use of Structuralist Analysis in Social Anthropology*, Cambridge University Press
5 Aunger, R. (2000) *Darwinizing Culture: The Status of Memetics as a Science*, Oxford University Press
6 Blackmore, S.J. (1999) *The Meme Machine*, Oxford University Press
7 Bartlett, F.C. (1932) *Remembering; a Study in Experimental and Social Psychology*, The University Press
8 Schacter, D.L. *et al.* (1995) *Memory Distortion: How Minds, Brains, and Societies Reconstruct the Past*, Harvard University Press
9 Sperber, D. and Wilson, D. (1986) *Relevance: Communication and Cognition*, Blackwell
10 Hurley, S. and Chater, N. *Perspectives On Imitation: From Cognitive Neuroscience to Social Science*. Cambridge University Press (in press)
11 Boyd, R. and Richerson, P.J. (1996) Why culture is common, but cultural evolution is rare. *Proc. Br. Acad.* 88, 77–93
12 Boyd, R. and Richerson, P.J. (1985) *Culture and the Evolutionary Process*, University of Chicago Press
13 Henrich, J. and Boyd, R. (2002) On modeling culture and cognition: why cultural evolution does not require replication of representations. *Culture Cogn.* 2, 87–112
14 Atran, S. (1990) *Cognitive Foundations of Natural History: Towards an Anthropology of Science*, Cambridge University Press
15 Atran, S. (2002) *In Gods We Trust: The Evolutionary Landscape of Religion*, Oxford University Press
16 Boyer, P. (1994) *The Naturalness of Religious Ideas: A Cognitive Theory of Religion*, University of California Press
17 Boyer, P. (2001) *Religion Explained: The Human Instincts that Fashion Gods, Spirits and Ancestors*, Heinemann
18 Hirschfeld, L.A. (1996) *Race in the Making: Cognition, Culture, and the Child's Construction of Human Kinds*, MIT Press
19 Sperber, D. (1996) *Explaining Culture: a Naturalistic Approach*, Blackwell
20 Gallistel, C.R. (1998) The replacement of general-purpose learning models with adaptively specialized learning modules. In *The Cognitive Neurosciences* (Gazzaniga, M.S., ed.), pp. 1179–1191, MIT Press
21 Bonatti, L. *et al.* (2002) The human first hypothesis: identification of conspecifics and individuation of objects in the young infant. *Cogn. Psychol.* 44, 388–426
22 Kanwisher, N. *et al.* (1997) The fusiform face area: a module in human extrastriate cortex specialized for face perception. *J. Neurosci.* 17, 4302–4311
23 Pinker, S. (1994) *The Language Instinct*, W. Morrow and Co
24 Scholl, B.J. and Leslie, A.M. (1999) Modularity, development and 'theory of mind'. *Mind & Language* 14, 131–153
25 Marler, P. (1991) The instinct to learn. In *The Epigenesis Of Mind: Essays on Biology and Cognition* (The Jean Piaget Symposium series) (Carey, S. and Gelman, R., eds), pp. 37–66, Erlbaum
26 Fodor, J.A. (1983) *Modularity of Mind: an Essay on Faculty Psychology*, MIT Press
27 Fodor, J.A. (2000) *The Mind Doesn't Work That Way: the Scope and Limits of Computational Psychology*, MIT Press
28 Wagner, G. and Altenberg, L. (1996) Complex adaptations and the evolution of evolvability. *Evolution* 50, 967–976
29 Carruthers, P. (2003) Is the mind a system of modules shaped by natural selection? In *Contemporary Debates in the Philosophy of Science* (Hitchcock, C., ed.), Blackwell
30 Calabretta, R. *et al.* (1998) A case study of the evolution of modularity: towards a bridge between evolutionary biology, artificial life, neuro- and cognitive science. In *Artificial Life VI: Proceedings of the Sixth International Conference on Artificial Life* (Adami, C., ed.), pp. 275–284, MIT Press
31 Sperber, D. (2001) In defense of massive modularity. In *Language, Brain and Cognitive Development: Essays in Honor of Jacques Mehler* (Dupoux, E., ed.), pp. 47–57, MIT Press
32 Cosmides, L. and Tooby, J. (2002) Unraveling the enigma of human intelligence: evolutionary psychology and the multimodular mind. In *The Evolution of Intelligence* (Sternberg, R.J. and Kaufman, J.C., eds), pp. 145–198, Erlbaum
33 Berlin, B. (1992) *Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies*, Princeton University Press
34 Atran, S. (2002) Modular and cultural factors in biological understanding: an experimental approach to the cognitive basis of science. In *The Cognitive Basis of Science* (Carruthers, P. *et al.*, eds), pp. 41–72, Cambridge University Press
35 Atran, S. (1995) Causal constraints on categories and categorical constraints on biological reasoning across cultures. In *Causal Cognition: A Multidisciplinary Debate (Symposia of the Fyssen Foundation)* (Sperber, D. *et al.*, eds), pp. 205–233, Clarendon Press/ Oxford University Press
36 Gelman, S.A. and Hirschfeld, L.A. (1999) How biological is

essentialism? In *Folkbiology* (Medin, D.L. and Atran, S., eds), pp. 403–446, MIT Press
37 Atran, S. *et al.* (2001) Folkbiology doesn't come from folkpsychology: evidence from Yukatek Maya in cross-cultural perspective. *J. Cogn. Cult.* 1, 2–42
38 Sousa, P. *et al.* (2002) Essentialism and folkbiology: evidence from Brazil. *J. Cogn. Cult.* 2, 195–223
39 Zipes, J. (1993) *The Trials and Tribulations of Little Red Riding Hood*, Routledge
40 Lévi-Strauss, C. (1963) *Totemism*, Beacon Press
41 Whiten, A. and Byrne, R.W. (1997) *Machiavellian Intelligence II: Extensions and Evaluations*, Cambridge University Press
42 Hirschfeld, L.A. (2001) On a folk theory of society: children, evolution, and mental representations of social groups. *Personality & Social Psychology Review* 5, 107–117
43 Parr, L.A. and de Waal, F.B.M. (1999) Visual kin recognition in chimpanzees. *Nature* 399, 647–648
44 Hacking, I. (1995) The looping effects of human kinds. In *Causal Cognition: A Multidisciplinary Debate* (Symposia of the Fyssen Foundation) (Sperber, D. *et al.*, eds), pp. 351–394, Clarendon Press/ Oxford University Press
45 Boyer, P. (2003) Religious thought and behaviour as by-product of brain function. *Trends Cogn. Sci.* 7, 119–124
46 Boyer, P. (2001) *Religion Explained: the Evolutionary Origins of Religious Thought*, Basic Books
47 Atran, S. (1998) Folk biology and the anthropology of science: cognitive universals and cultural particulars. *Behav. Brain Sci.* 21, 547–609
48 Carey, S. (1995) On the origin of causal understanding. In *Causal Cognition: A Multidisciplinary Debate* (Sperber, D. *et al.*, eds), pp. 268–302, Clarendon Press
49 Premack, D. (1991) The infant's theory of self-propelled objects. In *Children's Theories Of Mind: Mental States and Social Understanding* (Frye, D. and Moore, C., eds), pp. 39–48, Erlbaum
50 Gelman, S.A. and Wellman, H.M. (1991) Insides and essence: Early understandings of the non-obvious. *Cognition* 38, 213–244
51 Springer, K. (1996) Young children's understanding of a biological basis for parent-offspring relations. *Child Dev.* 67, 2841–2856
52 Hickling, A.K. and Gelman, S.A. (1995) How does your garden grow? Early conceptualization of seeds and their place in plant growth cycle. *Child Dev.* 66, 856–876
53 Ross, N. *et al.* (2003) Cultural and experimental differences in the development of folkbiological induction. *Cogn. Dev.* 18, 25–47
54 Taylor, M.G. and Gelman, S.A. (1993) Children's gender- and age-based categorization in similarity and induction tasks. *Social Development* 2, 104–121
55 Astuti, R. (2001) Are we all natural dualists: a cognitive developmental approach. *J. R. Anthropol. Inst.* 7, 429–447
56 Nisbett, R.E. (2003) *The Geography of Thought: How Asians and Westerners Think Differently, And Why*, The Free Press
57 Tomasello, M. *et al.* (2003) Chimpanzees understand psychological states – the question is which ones and to what extent. *Trends Cogn. Sci.* 7, 153–156
58 Gallese, V. (2001) The 'shared manifold' hypothesis: from mirror neurons to empathy In *Between Ourselves: Second-person Issues in the Study of Consciousness*, pp. 33–50, Imprint Academic
59 Leslie, A.M. (2000) How to acquire a 'representational theory of mind'. In *Metarepresentation: A Multidisciplinary Perspective* (Sperber, D., ed.), pp. 197–223, Oxford University Press
60 Frith, U. and Frith, C. (2001) The biological basis of social interaction. *Curr. Dir. Psychol. Sci.* 10, 151–155
61 Wellman, H.M. *et al.* (2001) Meta-analysis of theory-of-mind development: the truth about false belief. *Child Dev.* 72, 655–684
62 Inagaki, K. and Hatano, G. (2002) *Young Children's Naive Thinking About The Biological World*, Psychology Press
63 Gelman, S.A. (2003) *The Essential Child: Origins of Essentialism in Everyday Thought*, Oxford University Press
64 Feigenson, L. *et al.* (2002) Infants' discrimination of number vs. continuous extent. *Cogn. Psychol.* 44, 33–66
65 Wynn, K. (2000) Addition and subtraction by human infants. In *Infant Development: The Essential Readings* (Muir, D. and Slater, A., eds), pp. 185–191, Blackwell
66 Dehaene, S. (1997) *The Number Sense: How the Mind Creates Mathematics*, Oxford University Press
67 Gauthier, I. and Nelson, C.A. (2001) The development of face expertise. *Curr. Opin. Neurobiol.* 11, 219–224
68 de Haan, M. *et al.* (2002) Specialization of neural mechanisms underlying face recognition in human infants. *J. Cogn. Neurosci.* 14, 199–209
69 Hauser, M.D. (2003) Primate cognition. In *Handbook of Psychology: (Vol. 3) Biological Psychology* (Gallagher, M. *et al.*, eds), pp. 561–574, John Wiley
70 Baillargeon, R. (2002) The acquisition of physical knowledge in infancy: a summary in eight lessons. In *Blackwell Handbook of Childhood Cognitive Development* (Smith, P.K. and Hart, C.H., eds), pp. 47–83, Blackwell
71 Povinelli, D.J. (2003) Folk physics for apes: the chimpanzee's theory of how the world works. *Hum. Dev.* 46, 161–168
72 Bloom, P. and Veres, C. (1999) The perceived intentionality of groups. *Cognition* 71, B1–B9