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The role of intuitive ontologies in scientific understanding – the case of human evolution

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Abstract. Psychological evidence suggests that laypeople understand the world around them in terms of intuitive ontologies which describe broad categories of objects in the world, such as 'person', 'artefact' and 'animal'. However, because intuitive ontologies are the result of natural selection, they only need to be adaptive; this does not guarantee that the knowledge they provide is a genuine reflection of causal mechanisms in the world. As a result, science has parted ways with intuitive ontologies. Nevertheless, since the brain is evolved to understand objects in the world according to these categories, we can expect that they continue to play a role in scientific understanding. Taking the case of human evolution, we explore relationships between intuitive ontological and scientific understanding. We show that intuitive ontologies not only shape intuitions on human evolution, but also guide the direction and topics of interest in its research programmes. Elucidating the relationships between intuitive ontologies and science may help us gain a clearer insight into scientific understanding.

Introduction

Since the advent of modern biology, biologists have strived to give humans a place in their theories. Both Huxley (1863) and Darwin (1871) stressed that humans are subject to the same evolutionary pressures as other species. However, more than a century later, palaeoanthropology is still struggling to give man a place in nature. Palaeoanthropology as a science has set out to solve two important questions: are differences between humans and other animals ones in degree or ones in kind, and are humans unique – not just in the sense that any species is – but also uniquely different in the way they have acquired their characteristics? The wide disagreement among palaeoanthropologists on answers to these questions may seem puzzling given the sound theoretical background of evolutionary biology and the ever expanding archaeological and fossil record. We propose that much of these disagreements originate from clashing intuitions provided by our intuitive ontologies. We argue that intuitive ontologies structure our understanding of the world and that they continue to play a role in scientific understanding of human evolution.

This paper begins with an overview of the experimental literature in support of the proposal that the human mind can be at least partly decomposed into domain-specific subsystems. We discuss the development of intuitive ontologies in infants and young children, and review cross-cultural evidence for their central role in the development of folk theories. We further argue that intuitive ontologies, despite their value in everyday understanding, have clear epistemological limitations. Next, we examine the relationship between intuitive ontologies and science. We show that the influence of intuitive ontologies on scientific thinking but not on everyday thought has declined steadily since the rise of modern science in the 17th century. Taking models of human evolution as a case-study, we then examine whether scientists are still prone to fall back on intuitive ontologies in their understanding of their field. We demonstrate that theories on human evolution are influenced by tacit intuitive ontological notions. The persistence of these notions in spite of their incompatibility with science may provide tentative evidence that intuitive ontologies are an integral and stable part of human cognition.

What are intuitive ontologies?

In the course of only a few years, human children develop an impressive body of knowledge about the world, in fields as diverse as biology, physics, number and artefacts. A 4-year-old, for example, appreciates that internal mental states underlie actions, and realizes that the offspring of a particular animal or plant will grow up to belong to the same species as its parents, regardless of the circumstances in which it is reared. How do children perform these impressive computational achievements? There exists a burgeoning literature that favours the view that the mind is composed of several domain-specific learning mechanisms, here termed intuitive ontologies following Boyer (2000). In what follows, we review the experimental evidence in favour of intuitive ontologies in the domains of psychology, physics and biology.

Intuitive ontologies in ontogeny

Since the 1980s, a wealth of developmental psychological studies has suggested that the acquisition of intuitive ontologies is part of normal and spontaneous cognitive development during infancy and childhood. Intuitive ontologies describe categories of objects in the world, such as ‘person’, ‘artefact’, ‘plant’, or ‘animal’. While opinions are still divided on which domains constitute intuitive ontologies, the domains reviewed here have repeatedly turned up in the literature as plausible candidates.

Theory of Mind is an intuitive psychological theory by which we explain actions by attributing internal (unobservable) mental states, such as beliefs, desires and intentions. It emerges gradually in development from the second year of life, culminating in the ability to understand false beliefs between 4 and 5 years of age. By this age, children seem to realize that the mental representation of a situation may be different from the situation itself (Frith and Frith 1999). In one recent experimental condition (Onishi and Baillargeon 2005), this ability was even demonstrated in infants as young as 15 months.

Looking-time experiments suggest that intuitive physics is already robust in 3-month-old infants. They realise that objects are entities bounded in time and space, that two solid objects cannot occupy the same space at the same time, and that inanimate objects must make contact in order to influence each other's movements – an intuition they do not hold for animate beings (Spelke et al. 1995). By the time they are 3 years old, children have developed a more explicit naïve theory of physics by postulating unobservable mechanisms such as gravity, or the generative transmission of energy. They consistently appeal to external forces to explain motions of inanimate objects, even if these are not apparently visible (Gelman et al. 1994).

The first distinction between animate and inanimate objects arises in early infancy: 5-month-olds seem to realize that living beings are self-propelled, whereas inanimate things are not (Spelke et al. 1995). At around 4 years of age, children develop an intuitive biology, containing rich inferences on inheritance (offspring resembles its parents) and patterns of growth and development (members of the same species typically go through the same irreversible patterns of growth). One of the core intuitions underlying these rich inferences is that living kinds possess an unchangeable hidden essence, which causes their final form and behaviour (Medin and Ortony 1989). This psychological essentialism leads 4-year-olds to predict that an apple seed, planted in an orchard with pear trees will still grow to be an apple tree, or that a young kangaroo raised by goat foster parents, will hop rather than climb even if it never saw another kangaroo in its life (Gelman and Wellman 1991).

How intuitive ontologies are neurally subserved

Neuroscientists have contributed to the question to what extent mental functions can be decomposed, and whether these could be assigned to specific regions of the brain. Brain-lesions can selectively impair knowledge about a specific ontological domain, while leaving other domains intact. Some neuroscientists have interpreted these findings as an indication that evolutionary pressures have resulted in specialized and dissociable neural circuits dedicated to processing knowledge about different ontological categories. Consider the following striking example: EW, an elderly woman who suffered brain-damage, has extreme difficulties when reasoning about animals. She cannot tell real from imaginary animals, performs poorly on tasks involving recognition of animal sounds, and is at chance level on questions seemingly simple as 'do eagles lay eggs'. In contrast, her understanding of artefacts and plants has remained intact (Caramazza and Shelton 1998). A review of 79 cases of category-specific forms of semantic impairment revealed that ‘animal’, ‘plant’, ‘conspecific’, ‘artefact’ and ‘body part’ are categories that can be selectively impaired (Capitani et al. 2003). These categories are associated with computationally complex survival problems, including finding food and partners, and avoiding predators. If we assume on the basis of this that each of these evolved neural structures is specialized to deal with one specific domain, we may expect that damage to one such system cannot be recovered by others. This is exemplified by Adam who has a disproportionate impairment in the category of living things compared to artefacts. He suffered a cerebral artery infarction at one day of age, resulting in bilateral occipital and occipitotemporal lesions. Sixteen years later, he still performs poorly on visual recognition tasks and questions on animals and plants, e.g. confusing cherries with a Chinese yo-yo. In contrast, his knowledge of nonliving things is comparable to that of control subjects. This implies that prior to any experience with living or nonliving things, genes specify distinct neural systems for storing knowledge about them (Farah and Rabinowitz 2003).

Neuro-imaging studies provide clues on how intuitive ontologies may be neurally represented. They suggest that intuitive ontologies structure and guide perception, rather than the other way around: very scanty sensory input usually suffices to start a cascade of inference-mechanisms and expectations belonging to a specific intuitive ontological domain. In an elegant fMRI study (Martin and Weisberg 2003) subjects passively viewed simple geometric figures such as triangles moving about on a computer screen. In some conditions, movements suggested social interaction (e.g. playing, chasing), whereas others evoked mechanical actions (e.g. conveyor belt, pinball). The human brain apparently differentiates between these stimuli: social action activates the lateral fusiform gyrus and the superior temporal sulcus (both usually activated in Theory of Mind tasks); mechanical action preferentially activates the medial aspect of the fusiform gyrus and the left middle temporal gyrus (usually activated in tasks on artefact recognition and physics). Thus, the brain does not just passively construct abstract information from sensory cues, but actively constructs conceptual frameworks to interpret the sensory information.

Intuitive ontologies and folk theories

Cross-cultural evidence suggests that intuitive ontologies may play a crucial role in the development of everyday knowledge and folk theories. Many culturally transmitted ideas could be understood as cultural elaborations on preexisting intuitive ontologies. For example, intuitive biological knowledge in children develops similarly across cultures. It leads to similar folk taxonomies across the world, which enable people to reason about animals and plants in their environment based on their underlying species-typical essence (Atran 1998). Between 3 and 6 years of age, children adopt an essentialist stance when reasoning about animals and plants, and even social categories. Intriguingly, children are often more essentialist than adults. Five-year-olds believe that

French babies brought up by English-speaking parents will grow up to speak French; Indian children believe that a Brahmin child remains Brahmin, even when raised by untouchables (Gelman 2004).

A possible role for intuitive ontologies in the development of folk knowledge is that they are framework theories – they provide a skeletal structure to explain the world in terms of unobservable causal mechanisms. Hume (1739–1740: part III, section II) already noted that causality cannot be directly observed, but must be inferred. There seems to be no compelling reason to infer that a billiard ball sets another one in motion by colliding with it. Yet even 3-year-olds make such inferences based on an assumed generative transmission of energy (Shultz 1982). Children, laypeople and pre-scientific philosophers rely on framework theories, rather than on perceptual cues to explain a wide range of phenomena. First-graders, for example, initially adopt a geocentric (pre-Copernican) view to explain changes between day and night, even though this view is never taught (Vosniadou 1994). Such theories are preferred over perceptually based accounts, because they offer coherent and plausible explanations for a wide range of phenomena. Thus, it seems that science, with its criteria for coherence and scope, may derive some of its cognitive strategies from intuitive ontologies.

Epistemological limitations to intuitive ontologies

If humans view the world in terms of intuitive ontologies, it seems likely that there will be differences between intuitive and scientific understanding. Science typically requires rigorous, formalized explanations and sound empirical support, whereas intuitive ontologies are more implicit and less consistent. There is no overarching intuitive science that enables us to look at the world through a coherent intuitive lens. How reliable could intuitive ontologies be as a source of knowledge? It is evolutionarily quite implausible that they would be entirely off the mark. However, between usefulness and epistemological soundness lies an abyss of possible imperfect designs. Take a falling ball: intuitive physics assumes that a ball, carried by a running person falls in a straight line to the ground from its initial point of release since it is no longer directly propelled. Newtonian physics predicts a parabolic deviation in the course of the falling object. Yet, an overwhelming majority of college students predicts that the ball will fall in a path perpendicular to its point of release, an intuition which systematically distorts their empirical observations (McCloskey 1983). Although intuitive ontologies could be termed theories in the sense that they provide explanations, they are often surprisingly shallow. Intuitive psychology leads us to believe that our mental states cause our actions. If an intention is immediately followed by the appropriate action, we experience a sense of authorship over this. Yet experiments show that people can claim authorship over something they have not done: when subjects click on the image of a swan, after being primed the word 'swan', they will deny that their cursor had in fact been guided by an experimenter (Wegner 2003). Thus, our ideas on how the mind works are surprisingly shallow, an illusion created by the brain that seems to have been designed for making quick inferences about other people's behaviour rather than for self-reflection. There may be sound computational reasons why intuitive ontologies have these epistemological limitations. All too often, there are an almost infinite number of alternative solutions to any given problem. Examining each of them would place too much demands on our computational abilities. Evolution might have favoured fast, shallow inference mechanisms over epistemologically sound, but slow profound theories (Gigerenzer and Goldstein 1996).

Intuitive ontologies and scientific understanding

One way to look at early philosophical theories is that they made explicit the implicit modes of understanding that intuitive ontologies provide. Hellenistic and medieval theories on physics echo the object-centred naïve physics of modern college students (McCloskey 1983). Aristotle's biology, while introducing novel concepts such as an over-arching taxonomy, was still heavily imbued with intuitive notions of teleology and essentialism (Atran 1998). In some cases, specific cultural conditions can give rise to elaborations on intuitive ontologies, which nevertheless continue to be central to the theories. Initially, Aristotle's theory of motion stated that inanimate objects, in order to set each other in motion, need to make direct contact, a principle that is also held by 3-month-olds. From the Late Middle Ages on, however, this theory was felt to be inadequate. The increasing use of projectile weaponry in medieval warfare (such as longbows, crossbows and primitive cannons) made it necessary to formulate a new theory of physics, as is exemplified in the late medieval impetus theory. After all, once a projectile leaves its launcher, it becomes hard to pinpoint any external force operating through direct contact; therefore, the 14th century philosopher Jean Buridan stated that 'when a mover sets a body in motion, he implants into it a [...] certain force enabling the body [to keep on moving] into the direction in which the mover starts it' (McCloskey 1983: 114A). However, this impetus theory was but an elaboration of a pre-existing intuitive physics – as is evident in subjects without any training in physics restating it quite explicitly (McCloskey et al. 1980: 1140). Similarly, in biology, the view of a species essence as underlying causal mechanism for development and behaviour has dominated most, if not all pre-Darwinian biological thought. Eighteenth and early 19th century European taxonomies became increasingly elaborate as a result of the introduction of a dazzling array of new species of plants and animals by European explorers (Atran 1998). However, this proliferation of taxonomic hierarchic levels (family, order, phylum) did not result in a refutation of essentialist beliefs. Indeed, biologists could not forsake the intuitive belief that species have essences, which prevents them from evolving into different species (Stamos 2005: 84–88).

With the adoption of the experimental method in early modern Europe, and the gradual emergence of a scientific community, science began to part ways with intuitive ontologies, to the point that both became incompatible. Newtonian physics rejected the impetus; Darwinian evolutionary theory denied the notion of essences. Nowadays, scientists demonstrably abandon pre-scientific intuitions in their domain of expertise. In one study (Poling and Evans 2004), children, lay adults, medical students and evolutionary biologists were asked if extinction is inevitable for all species. Despite the ease with which they accept death as an inevitability for all living beings, all subjects, with the tell-tale exception of the evolutionary biologists, refused to accept that extinction is inevitable for every species; furthermore they were especially reluctant to foresee the extinction of *Homo sapiens*. Possibly death is not extrapolated on the species-level because essentialism in intuitive biology holds that species are unchanging and eternal. Professional evolutionary biologists, in contrast, endorsed extinction as inevitable, extending this belief to humans.

Nevertheless, scientists may not be able to eradicate intuitive ontological assumptions. Scientists exhibit the same cognitive biases and limitations as other human beings. To overcome these limitations, they exploit a vast array of cognitive tools (e.g. mathematical description) and cultural arrangements (e.g. storage of information outside of human memory, such as in books and scientific journals). Some scientific notions fit poorly with intuitive ontologies. Without intuitive notions to guide them, scientists often fail to agree on even the most basic foundations of their field. This may explain why there still is no single canonical version of evolutionary theory. Biologists disagree on the basic unit(s) of selection, on what a species may be, and on whether evolution takes place in a gradual or punctuated tempo. If intuitive ontologies continue to guide our everyday understanding, there remains the possibility that intuitive ontological ideas may slip unnoticed into scientific discourse.

Theories on human evolution

Over the past few decades, theories on human evolution have witnessed profound paradigmatic shifts, such as the crumbling of the model of multiregional continuity, or the archaeological evidence for the occurrence of hominids outside of Africa at 1.8 million years (myr) ago. These shifts were almost exclusively caused by finds of fossil evidence (e.g. Gabunia et al. 2000) and by new insights offered by other disciplines, especially molecular biology and geochronology (e.g. Swisher et al. 1994). Palaeoantropologists have always been consumers rather than producers of evolutionary theory; theirs is a discovery-driven rather than a theory-driven science (Tattersall 2000). For the most part, palaeoanthropology has been descriptive rather than explicitly theoretical; in other words, it describes the hominid fossil record, rather than providing novel theories on how these fossils connect in an evolutionary framework (Foley 2001). Therefore, studies of human evolution lack an explicit ontological framework, making them particularly susceptible to intrusion by tacit intuitive ontological notions. A possible way to distinguish cases where intuitive ontologies bias research and where they do not is to examine whether the basic assumptions of palaeoanthropologists depart from those of standard evolutionary theory. If these basic assumptions are more compatible with intuitive ontologies than with evolutionary theory (as we shall argue, for example, for the single species model of human evolution), there is reason to suspect that intuitive ontologies are at work.

How could intuitive ontologies influence scientific understanding of human evolution? In what follows, we explore some possible relationships between intuitive ontologies and scientific perspectives on human evolution. The case-studies below derive from two distinct intuitive ontologies: the human–nonhuman distinction and psychological essentialism, which have differing adaptive functions and therefore lead to distinct tacit assumptions. The human–nonhuman distinction is a psychological mechanism that enables us to distinguish conspecifics from nonconspecifics. This adaptation, which among other things helps us to recognize potential mates, is important in many species. As psychological evidence indicates that conspecifics (humans) constitute a distinct ontological category (Bonatti et al. 2002), it is not implausible that studies of human evolution are influenced by the ontological division between humans and other animals. This might strengthen the belief that human evolution is exceptional. Psychological essentialism, on the other hand, makes it possible to override perceptual differences. Its adaptive function is to facilitate inductive inferences about food, predators and other ecologically salient features. It enables us, for example, to realize that a tree currently without fruit will bear fruit in the right season, or that all predators of the same species are equally dangerous. Essentialism can come into play when a great genetic similarity between humans and apes is tacitly taken as evidence that they share the same essence. This can lead to the idea that apes have psychological abilities similar to those of humans.

Pruning and straightening the bushy tree of human evolution

Before Aristotle introduced humans as a genus alongside animals and plants, perhaps no culture ever included humans in their folk taxonomies. This may owe to the fact that humans belong to a distinct intuitive ontological domain. In effect, Western culture may be exceptional in its inclusion of humans in the category 'animals' due to this Aristotelian legacy. In many languages, the term which translates most closely as 'animal' excludes humans (Waxman 2005: 56). When Anggoro et al. (2005) asked Indonesian 5- to 10-year- olds whether humans can be categorized as animals, almost all children explicitly denied this. In contrast, more than half of their American subjects accepted this. Experimental evidence also suggests that 10-month-olds can distinguish humans from other animals, but fail to distinguish dissimilar looking artefacts, indicating that they make a fundamental human–nonhuman distinction (Bonatti et al. 2002). Modern evolutionary theory firmly rejects this ontological distinction between humans and other animals. From its earliest beginnings, evolutionary biology has taken pains to fit the human species into models of evolutionary theory, as is evident in Huxley's three essays on *Man's Place in Nature* (1863) and Darwin's *Descent of Man* (1871).

Even so, intuitive ontologies seem to influence scientific understanding on human evolution by compelling scientists to treat humans and their evolutionary history as exceptional. Hominid fossils are afforded an inordinate amount of scrutiny and speculation, yet the relatively scarce hominid fossil record pales in comparison to that of many other species, that are often far less studied. As White (1995: 369) sighs 'No suid [or other nonhominid] skulls grace the covers of *Nature* or garner headlines like 'new pig skull completely overturns all previous theories of pig evolution'.' Moreover, once we accept humans as a taxonomic group, next to species of plants and animals, it becomes possible to adopt an essentialist stance on humans as well. As late as the 1920s, for example, Raymond Dart (1925: 195) could appeal to the 'harmonious' proportions of the Taung skull as evidence for its proto-human status. The assignment of *type specimens*, i.e. representative fossils for given species of hominids, reflects a pre-Darwinian essentialist notion in that it builds on the assumption that for any given species an ideal type exists, and that variation occurs around this fixed point. If species are viewed as dynamic entities, subject to variations in space and time, there is no cogent reason to take a particular specimen as typical for the whole species. Nevertheless, assigning type specimens is still common practice among palaeoanthropologists, although it has declined in other branches of post-Darwinian taxonomy.

Tacit ontological notions that humans are unique may have resulted in the long-standing view that there is something special about humans that prevents them from speciating and evolving according to the laws of natural selection. Ever since Darwin, evolution has been conceived as a branching tree, in which one ancestral species can have several descendant species. However, for the greatest part of palaeoanthropology's history as a discipline, this was not the prevailing conceptual framework in which fossil hominid evidence was evaluated. The single species model, proposed by Weidenreich, and endorsed by Dobzhansky and Mayr had hardened into a unilineal and essentialist view on human evolution. In the first half of the 20th century, the gradual accumulation of fossil hominids had resulted in a plethora of taxonomic names. Dobzhansky (1944, 261–262), reviewing the hominid fossil record, concluded that 'no more than a single hominid species existed at any one time level'. Mayr (1950: 115–116) argued that all hominids could be grouped in a single lineage leading from the australopithecines, to *Homo erectus*, to *Homo sapiens*. To his credit, Mayr realized that his model of hominid evolution did not follow the usual branching pattern of evolution. His explanation for this exception was that hominids could not speciate because they occupied more ecological niches than any other known animal as they had developed culture. Because they occupy the cultural niche, humans were conceived of as a unique species, subject to unique evolutionary pressures. Left to themselves, ordinary (that is, nonhuman) species get on with speciating, but once the magic ingredient of culture is added, this process stops (Foley 2001). As Mayr (1950: 116–117) put it:

> There is one striking difference between man and most of the animals [...] Man, who has reached such a high degree of independence from the environment is less dependent on local adaptation, and a subspecies of man can quickly spread into many geographically distant areas [...] The authors who have claimed that man is unique in his evolutionary pattern are undoubtedly right.

In all probability, Mayr's reasoning was influenced by the importance of cultural anthropology – instead of biology, as is the case today – in the study of human evolution in the United States in the 1940s and 1950s. This resulted in a systematic overestimation of the role of culture in human evolution. It remains striking that Dobzhansky and Mayr, both key figures in the modern synthesis, proposed that speciation did not happen in human evolution. As Foley (2001: 7) points out, their main argument for proposing unilineal models of human evolution was informed by the tacit assumption that humans are unique, rather than by evolutionary theory. They reasoned in hindsight, not using culture as a primary causal mechanism, but as a justification for the alleged anomalies in human evolution. In contrast, their contemporary, the palaeontologist Simpson (1950), held the more informed view based on general principles of evolutionary theory, rejecting Weidenreich's application of orthogenesis on human evolution on theoretical grounds. Interestingly, Simpson (1950: 63) hinted at the possible role of psychological essentialism ('inherent tendency') in the popularity of orthogenesis during this period. Unfortunately, palaeoanthropologists chose to follow Mayr and Dobzhansky, rather than Simpson. The role of culture in human evolution can be easily overstated, as is illustrated by the recent find of *Homo floresiensis*, a small hominid with the brain size of an early australopithecine, dated at 18,000 BP (Brown et al. 2004). Despite their cultural niche, hominids were apparently subject to island dwarfism, just like other larger mammals that happen to strand upon remote islands. Morphological analysis of stone tools also calls the exaggerated role of culture in human evolution into question. It indicates that prior to the Upper Palaeolithic human culture evolved very slowly, with long periods of stasis. For instance, the earliest Oldowan stone tools, dated at around 2.5 myr ago, are morphologically indistinguishable from the youngest African specimens, which are 1 myr younger (Semaw et al. 1997). Culture undeniably played an important part in human evolution, but over-emphasizing its role may be less informed by sound archaeological and fossil evidence than by the intuition that humans are unique compared to other animals.

As a result, the palaeoanthropological community attempted to cram the entire hominid fossil record (then already quite diverse) into this single linear model (Tattersall 2000). The single species hypothesis finally collapsed with discoveries in the 1970s of fossils at the East-African Lake Turkana Basin, which unequivocally proved that at least two hominid species coexisted: the robust small-brained *Paranthropus boisei* and the large-brained gracile *Homo ergaster* (Leakey and Walker 1976). Since this time, palaeoantropologists have cautiously started to acknowledge that humans may be like other species after all, subject to the same evolutionary processes, as exemplified in Foley's *Another Unique Species* (1987), arguably the first book to make explicit use of evolutionary theory to interpret details of the human fossil record. A modern offshoot of the single species hypothesis is the model of multiregional continuity (see e.g. Wolpoff et al. 2000 for a recent overview). According to this model, all extant human populations descend directly from a single, highly variable species which arose about 1.5 myr ago, and which was divided into distinct ancestral African, Asian and European subpopulations. As they assume a rather unusual speciation pattern for humans, the multiregionalists too may be under the delusion of the human–nonhuman distinction. Pleistocene hominids lived in disparate ecological settings, and were therefore likely to be subject to different selective pressures. Yet they managed to avoid allopatric speciation, progressing steadily and in parallel towards the *Homo sapiens* that we are today! Gould (2002: 911–916) muses that multiregionalism only exists because it describes *human* evolution; no biologist would draw a similar scenario for another widespread species. Unsurprisingly, molecular biological studies have cast serious doubt on the multiregional hypothesis, since they indicate a very recent common ancestor for all current human populations (e.g. Ingman et al. 2000).

The intuitive human–nonhuman distinction may have contributed to the idea that human evolution is somehow exceptional. Palaeoantropologists chose to infer as few hominid species as possible from the fossil record, preferring a straightforward single evolutionary path to a bushy tree with many branches and dead ends. This is still apparent in mainstream palaeoanthropology: since 1994 important discoveries of late Miocene hominid fossils have given rise to four new genera within the hominid lineage: *Ardipithecus* (White et al. 1995), *Orrorin* (Senut et al. 2001), *Kenyanthropus* (Leakey et al. 2001) and *Sahelanthropus* (Brunet et al. 2002) – next to the three widely accepted genera *Australopithecus*, *Paranthropus* and *Homo*. Nonetheless, palaeoanthropologists (e.g. Haile-Selassie et al. 2004) and geneticists alike (e.g. Cela-Conde and Ayala 2003) argue that such a large number of genera is unacceptable, and that we should somehow prune the tree of hominid evolution.

Essentialism and humanized apes

One of the most crucial intuitions of psychological essentialism is that surface features of living kinds are caused and constrained by deeper properties: animals and plants have an underlying reality or true nature that one cannot observe directly, but which gives each living thing its identity and guides its development, as in the transformation from caterpillar to butterfly. As such, psychological essentialism assumes that a category has two distinct, although interrelated levels: the level of observable reality and the level of an underlying explanation and cause (Medin and Ortony 1989). This enables children and lay adults to override perceptual features when making judgements on category-membership. When 3-year-olds are shown a leaf, an insect and a leaf-insect, they believe that the leaf-insect will behave more like an insect than like a leaf, even though it looks more like a leaf (Gelman 2004). Children from such dissimilar cultures as Mesoamerican Mayas (Atran et al. 2004) and West-African Yoruba (Ahn et al. 2001) hold the belief that superficial changes do not alter a living thing's core identity. Lay adults too draw inferences based on taxonomic affiliation, rather than on superficial characteristics, e.g. most adults in the West believe that whales are mammals rather than fish (Dupré 1999), even though whales resemble fish in their morphological features. In the face of contrary evidence, psychological essentialism seems to guide inferences, that is, even if surface properties lead us to believe otherwise, we perceive underlying essences as fundamental causal mechanisms. Take Chris Darwin, Charles Darwin's great great grandson, who was assigned a tutor to help him pass his biology A-level. 'And he introduced himself and I introduced myself and he said, 'you're Darwin...I can't teach you anything about biology', which I thought was really sweet. And then I went off and failed.' (BBC report, 16 June 2005). Despite Chris Darwin's weak performance in biology, his tutor's essentialism compelled him to believe he had to be good in biology.

The implications of adopting essentialism on theories on human cognitive evolution may turn out to be far-reaching. During the second half of the 20th century, findings in palaeoanthropology and molecular biology have dramatically altered our conceptual framework on the relatedness between humans and other apes. It was generally believed that the split between hominids (the *Hominidae*) and the other apes (the paraphyletic clade *Pongidae*) occurred at least 15 myr ago. Sarich and Wilson's (1967) seminal molecular biological study demonstrated that humans and chimpanzees diverged only 5 myr ago. Thus, humans are no longer separated from other apes by a deep evolutionary chasm, but are part of the hominoid clade. Since King and Wilson (1975), molecular biological sequencing has shown that the human and chimpanzee genomes are highly similar, with estimates ranging between 97 and 99.9%. The close phylogenetic relationship between *Homo* and *Pan*, and the great similarities between their genomes can lead to the intuitively appealing but misleading conclusion that humans and chimpanzees are essentially the same. This intuition is strengthened by popular metaphors in which genes are often portrayed as the essence of an individual organism. Media coverage supports this essentialist image with headlines on genes for obesity, violence or alcoholism. At first it may seem unlikely that genes would trigger essentialist tendencies – although the causal role of essences has been proposed at least since Aristotle's writings on biology, the molecular structure of DNA has only been discovered in the second half of the 20th century. Genes, however, may be an ideal candidate for the indefinable essence to which children and adults intuitively appeal. Medin and Ortony (1989: 184–85) suggest that psychological essentialism is a *placeholder* notion: one can believe that a category possesses an essence without knowing what that essence is. For example, the tiger essence causes tiger offspring to develop into big, striped, roaring tiger adults, although circumstances might conspire to produce stripeless, dwarfed, mute individuals, which will nonetheless be categorized as tigers (Gelman and Wellman 1991: 216). Since its discovery, DNA appears to fulfill the role of the essence-placeholder in popular and perhaps also scientific discourse, because it is invisible, and presents a deeper level that is causally linked with appearance and development. This may explain the considerable media coverage of studies that link variations in DNA with health, behaviour and appearance.

Diamond (1992) rhetorically invokes an extraterrestrial observer, who would objectively classify humans as 'third chimpanzee', overlooking the blatant fact that only one of these species writes about the other two in fluent grammatical language. The blueprint or essence metaphor for genes is misleading. Genes do not have a one-to-one correspondence with the traits they build (Marcus 2004), hence the difficulties in finding 'genes for' homosexuality or mathematical talent. Instead, genes are concerned with the question in what sequence, and to what degree, proteins are built. One amino-acid substitution can dramatically alter a cascade of developmental events. Thus, the small genetic differences between humans and chimpanzees have huge effects. Conversely, it can be argued that we share at least 25% of our genes with any given species (since there are only four nucleotide types). Taking a conservative estimate that a human and a lily would share 35% of their genes, no-one would suppose that these species are 35% similar (Marks 2002). As early as 1975, King and Wilson have proposed that the differences between human and chimpanzee anatomy and behaviour may owe to differences in how genes are regulated, rather than in the proteins they code for. Given the short evolutionary time and relatively few genes involved, this may be the only possible way for natural selection to result in such considerable differences. Several recent micro-array studies that compared patterns of gene-expression in human, chimpanzee and other primate brains have indeed shown that genes have been upregulated in the human brain compared to that of the chimpanzee (e.g. Gu and Gu 2003). It may therefore be unnecessary to posit close psychological similarities between the two species.

Nevertheless, much of current research in comparative psychology is directed at finding similarities between our closest living relatives and us. One such research programme focuses on Theory of Mind in nonhuman primates. Controlled laboratory experiments have systematically failed to show genuine mentalizing in apes. Chimpanzees seem incapable to understand the connection between seeing and knowing: even after many trials they make obvious mistakes such as begging food from an experimenter who wears a bag over her head (see Povinelli 2000 for an extensive review). After many years, however, breakthrough experiments (Hare et al. 2001) seemed to provide evidence that chimpanzees do know what others can and cannot see if they are placed in a competitive situation. Subdominant chimpanzees consistently chose a piece of food only visible to themselves over a piece of food that was visible to a dominant conspecific as well, indicating a mentalistic understanding of visual access. These and similar competitive experiments were heralded as conclusive evidence that chimpanzees do have a Theory of Mind after all. Interestingly, once it was shown that rhesus monkeys (Flombaum and Santos 2005) succeeded in the same test, researchers of animal cognition began to doubt this rich interpretation. Burkart and Heschl (2005) demonstrated that marmosets, a small New World monkey about the size of a rat (and so perhaps also chimpanzees) could succeed in the test by applying the simple behavioural rule 'don't take the food the dominant one is looking at', rather than through a genuine understanding of the relationship between seeing and knowing. Chimpanzee minds may be 'suspiciously human' (Povinelli and Vonk 2003), a reflection of our own mental state attribution. The notion that chimpanzees are fundamentally like us has lead researchers to investigate chimpanzee cognition from an anthropocentric perspective, rather than as an end in itself. Psychological essentialism may compel researchers to believe that chimpanzees do share our cognitive abilities, even if evidence is lacking. Thus, it is conceivable that research programmes investigating this type of primate cognition will remain unabated by negative evidence as long as the intuitive notion (fed by the genetic similarity of an imposing 98%) that humans and chimpanzees are essentially the same persists.

Concluding remarks

Experimental evidence from developmental psychology and neuroscience supports the claim that young children and lay adults view the world in terms of intuitive ontologies. While these provide a shallow but fast framework to explain and understand salient features of the environment, they are epistemologically limited. In this paper, we have examined possible relationships between intuitive ontologies and science. Science and intuitive ontologies have gradually parted ways in their ontological and epistemological principles. However, because scientists are subject to the same cognitive limitations as other people, it is possible that intuitive ontologies still influence their understanding. Since each intuitive ontology results from specific evolutionary pressures, they are shallow and can therefore yield mutually inconsistent images of the world; they do not provide an overarching framework to understand the world. In our discussion of models of human evolution, we have proposed that these models can be influenced by intuitive tacit assumptions, especially when they depart from standard evolutionary theory. The assumption that humans are very different from other species may be based on an intuitive human–nonhuman distinction. This has resulted in the single species model, in which a single human species prevailed in disparate ecological settings over a long period of time. Psychological essentialism enables us to override perceptual features in specific conditions, where prior knowledge (of genes and phylogenetic proximity) can lead to the allegation that chimpanzees have cognitive abilities very similar to those of humans, an attitude that has influenced the direction and interests of research programmes in comparative psychology. Intuitive ontologies especially play a role in scientific understanding when it is not underpinned by an explicit theoretical framework. Scientists can therefore remain unaware of the fact that the questions they pose are more consistent with intuitive ontologies than with scientific theories. For example, de Waal's (1999: 635) remark that the cultural diversity observed in chimpanzees shows them to be 'inching closer to humanity' borders on the essentialist, as it presupposes culture as a human domain, rather than recognizing chimpanzee cultural behaviour within its own ecological and evolutionary context. However, scientists can become aware of intuitive ontological notions when they pit their ideas against existing scientific theories.

More theoretical and empirical work needs to be done in order to further clarify the role of intuitive ontologies in scientific and everyday understanding. However, it can be argued from the recent history of science that intuitive ontologies are not eradicated by scientific knowledge, even if they are in apparent contradiction to it. As such, the lingering role of intuitive ontologies in scientific understanding may help to elucidate how the human mind acquires knowledge. Our research tentatively suggests that intuitive ontologies are an integral and stable part of human cognition.

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