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Gewone geesten, buitengewone gedachten: een wijsgerig antropologisch onderzoek naar uniek menselijk gedrag, met nadruk op artistieke capaciteiten, religieuze reflectie en wetenschappelijke studie

Cover: The image on the cover is a photograph of the Emu in the sky, both an Australian aboriginal engraving (Ku-ring-gai Chase National Park) and the indigenous name for a cloud of interstellar dust close to the Southern Cross. Picture by Barnaby Norris, originally from `http://www.emuinthesky.com/`

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COMMON MINDS, UNCOMMON THOUGHTS

A philosophical anthropological investigation of uniquely human creative behavior, with an emphasis on artistic ability, religious reflection, and scientific study

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OVERVIEW

This dissertation is subdivided into four parts, each consisting of several chapters. Part I outlines the problem of human uniqueness. Chapter 1 contain mainly introductory material that provides background information that is presupposed in the other chapters. In this way, all readers will be on the same page with regard to the cognitive and evolutionary theories on which this thesis draws. Chapter 2 considers the human mental toolbox. It provides an overview of recent theories on how humans conceptualize the world, and what their mental tool box looks like. Chapter 3 approaches the problem of human uniqueness through an examination of language, indicating how a combination of modules can give rise to a uniquely human cognitive specialization without invoking a monolithic language faculty. Chapter 4 provides a detailed behavioral ecological analysis of the evolution of human social cognition during the late Pliocene and early Pleistocene.

With this background on human cognition set up, the next parts will examine products of human creativity. Part II discusses the evolutionary and cognitive origins of human artistic behavior. Chapter 5 evaluates recent cognitive neuropsychological and evolutionary psychological approaches to the appreciation and creation of art. Chapter 6 provides a cultural group selectionist model of artistic behavior, as exemplified in Magdalenian mobiliary art. Chapter 7 discusses how findings from developmental psychology, cognitive archeology, and ethnoarcheology, provide insights into the earliest art production, focusing on Late Middle Stone Age engraved objects from southern Africa and Aurignacian mobiliary art from Germany. Chapter 8 argues that some forms of art, especially incised bone and antler objects and rock art, were used to supplement internal mechanisms of mental time travel, greatly enhancing our ability to recognize cyclicity in the environment.

Part III focuses on the cognitive science of religion, especially on how it can be applied to the reasoning of theologians and philosophers of religion. Chapter 9 examines how the argument from design relies on intuitions about the purpose and design of artifacts and natural objects. Chapter 10 suggests that the cosmological argument relies on universal human intuitions about causation.

Part IV considers the cognitive basis of scientific practice. Chapter 11 discusses the limitations that our evolved cognitive capacities impose on scientific practice, focusing on paleoanthropology and comparative psychology. Chapter 12 demonstrates how individual researchers can overcome these cognitive biases by being part of a community of interacting scientists that exchange different inferences and hypotheses. The conclusion outlines implications of this evolutionary and cognitive approaches to uniquely human creative behavior for philosophical anthropological research, and indicates directions for future research.

Part I

Uniquely human behavior

CHAPTER 1

INTRODUCTION

1.1 *What is it like to be a human?*

Echolocation in bats is a paradigmatic example of an adaptive cognitive specialization. In *What is it like to be a bat?*, Thomas Nagel (1974) famously argued that echolocation, although clearly a form of perception, is not similar in its operation to any human sensory experience, so we can never know what it is like to be a bat. Three decades later, neuroscientist and primatologist Todd Preuss (2004) wrote a paper entitled *What is it like to be a human?* Remote as bat cognition may seem to us, we also seem to have little understanding of what cognitive capacities are typical for humans. What enables us to have complex and cumulative cultural traditions, fluent speech, symbolic storage of information, elaborate social and moral norms, and an inquisitiveness about the world that underlies our philosophical inquiry and scientific practice? Since the mid 1970s, molecular biologists (e.g., King & Wilson, 1975) have accumulated empirical evidence that humans share the bulk of their genetic material with their closest living relatives, the chimpanzee (*Pan troglodytes*). Comparing the draft of the complete chimpanzee genome with that of the human genome leads to an estimate of about 98 % genes common to both species (Mikkelsen et al., 2005). By taking into account insertions and deletions of genetic material, this figure drops to 95% (Gojobori, Tang, Akey, & Wu, 2007). Still, even with this more conservative estimate, we are left with a surprisingly small fraction of the genome to carry the burden of all behavioral and morphological differences between both species.

To get a sense of the behavioral differences between humans and other primates, let us compare the daily lives of humans with that of other great apes. First, there is a striking difference in geographical spread: whereas extant nonhuman great apes live preferentially in tropical rainforests (e.g., chimpanzees in West- and Central-Africa, orangutans in Southeast-Asia), humans occupy more ecological niches than any other species. No other species can maintain itself so successfully in the diverging conditions of tropical rain-forests, high-altitude plateaus, arid deserts, small coral atolls, or the desolate arctic tundra. Each of these environments requires different subsistence styles and technologies. The human capacity for cultural transmission enables us to find and transmit solutions to extreme ecological challenges. The main reason that Inuit can survive so well under the severe ecological conditions of the North Pole is not that they have physiological adaptations to the cold climate (which are quite modest compared to other large mammalian species that inhabit the same region, like polar bears), but that their technology and subsistence is well suited to these conditions.

Until well into the second half of the 20th century, humans were so impressed with their own cultural achievements, that they did not recognize the sophistication of socially transmitted skills in nonhuman animals. This has changed. Observations of chimpanzee behavior in the wild indicate at least 39 distinct cultural traditions (Whiten et al., 1999); orangutans have at least 24 culturally transmitted behaviors (Van Schaik et al., 2003). Nevertheless, there still seems to be a substantial difference between human culture and nonhuman cultural traditions. Since Jane Goodall started publishing her observations on chimpanzee groups in the 1960s, very little if anything has changed in chimpanzee material culture or social structures. There has been no *Pan* version of the Kyoto and Copenhagen climate summits, there have been no debates concerning simian gay marriages, nor did we witness anything analogous to the computer revolution in chimpanzee material culture. Whereas humans today are faced with challenges and technologies that would have been inconceivable in the 1960s, chimpanzees live basically the same lives as when Jane Goodall first observed them. Like 50 years ago, chimpanzee mothers today bring up their offspring alone, chimpanzee males form alliances and vie for power, and they have still have their traditional diet that consists mostly of picked fruit and young leaves (Kaplan, Hill, Lancaster, & Hurtado, 2000). By contrast, human culture is cumulative: we depend on socially transmitted behaviors that we further refine, mostly leading to a cumulative retention of innovations and improvements over the generations—exceptions like Tasmania, where there was a loss of cultural information, notwithstanding (see e.g., Henrich, 2004b, for an account of the steady loss of technology over the past millennia). Tomasello (1999a, 5) captures this with the metaphor of the *ratchett effect*: “faithful social transmission that can work as a ratchet to prevent slippage backward —so that the newly invented artifact or practice preserves its new and improved form at least somewhat faithfully until a further modication or improvement comes along.”

Some may argue that this comparison is unfair—what if there is indeed some form of cumulative cultural evolution in chimpanzees that has simply not been observed yet, since observations of chimpanzee behavior are only reliably recorded since the 1960s? The fast pace of human cultural evolution is not a recent phenomenon: we can see a marked increase in stone tool types in Europe since about 45,000 BP[1], and in Africa and the Middle East, evidence for this dates back even further, to the end of the Middle Pleistocene, ca. 130,000–125,000 BP (Conard, 2007, 2004–2008). By contrast, analyses of wear patterns on stone tools from Côte d'Ivoire (Mercader et al., 2007) that were used by chimpanzees about 4,300 years ago indicate that chimpanzees used unmodified stone tools as a form of percussive technology: these stones had traces of starch, indicating that they were used to crack open nuts. Present-day chimpanzees (*Pan troglodytes verus*) in the Taï forest do exactly the same: they crack nuts by hammering them with unmodified stones, as can be seen in Fig. 1.1. Even scholars who have argued in favor of the attribution of culture to chimpanzees (and other nonhuman animals) admit that evidence for anything like cumulative culture in chimpanzees is scant:

> To date, it appears that there is indeed little such evidence [for cumulative culture]. Given what we know of the learning powers of chimpanzees, most of the cultural behaviors identified to date appear to be ones that have not advanced beyond the achievement of their original inventors, rather than being the products of generations of complexification (Whiten, Horner, & Marshall-Pescini, 2003, 95).

Systematic attempts to replicate cumulative culture with chimpanzees have been largely unsuccessful. For example, Marshall-Pescini and Whiten (2008) first showed juvenile chimpanzees how to extract honey from a device using a simple dipping technique, where a stick could be placed in a rectangular box to obtain honey. The chimpanzees mastered this technique with ease. In a second stage, the human model demonstrated a more complex probing technique that incorporated the dipping technique to lever the lid off the box, which was a more effective way to get to the honey. None of the subjects was able to master this latter technique, even though they could perform the separate steps. It seemed as if the animals were 'stuck' on the simpler, suboptimal dipping technique that brought them some immediate reward.

Figure 1.1: Human cultural evolution and chimpanzee cultural stasis. 4,300 years ago, humans used adzes to work the land (bottom left) which exhibited a gradual evolution in shape (e.g., at first without hilt) and material (first stone, then copper, then bronze) only in the course of about one millennium. Current successors to these adzes are tractors and other agricultural vehicles (top left). Meanwhile, chimpanzee stone tools (top right) look the same as they did 4,300 years ago (bottom right). Images (counterclockwise) retrieved from `http://www.freefoto.com/images/`, `http://www.dot-domesday.me.uk/bronze.htm`, Mercader et al. (2007), Fig. 2, p. 3046., `http://news.softpedia.com/news/Humans-and-Chimpanzees-Learned-to-Use-Tools-From-a-Common-Ancestor-46941.shtml`

The most convincing example of cumulative culture in a nonhuman species is tool use in the New Caledonian crow (*Corvus moneduloides*). New Caledonian crows fashion two types of tools to catch invertebrates: one from twigs and similar material, and the other from barbed edges of pandanus leaves. These tool types each have a limited number of subtypes that differ in their modes of manufacture, and that can be found in distinct, largely non-overlapping geographical locations (so these probably represent local cultural traditions). Each of these locally distinct manufacturing styles consist of several steps, indicating to Hunt and Gray (2003) that cumulative cultural evolution may have been at work. The social transmission of song patterns in songbirds may also provide compelling examples of cumulative cultural evolution in nonhuman animals (Laland & Hoppitt, 2003). Although such examples suggest that cumulative culture is not uniquely human (in contrast to what authors like Galef (1992) have proposed), they do indicate that it is specific to humans within the primate lineage. Indeed, as Laland and Hoppitt (2003, 152) observe, there is more compelling evidence for cumulative cultural transmission in birds than in nonhuman primates, despite the disproportionate attention comparative psychologists accord to the latter. Thus, we are still left with the question how and why cumulative culture evolved in humans (for a discussion of this, see chapter 4).

Another striking feature of human culture is, as Margolis and Laurence (2007a, ix) put it, that we "live in a world that is, to an unprecedented extent, populated by our own creations." This is not only the case in urbanized areas. In almost all areas where humans live the landscape is altered to a significant extent to meet human needs (e.g., paddies, dykes and fences). Of course, constructing one's own environment is not uniquely human. In fact, nest building is far more pervasive across species than tool use. As Hansell and Ruxton (2008) observe, tool use and manufacture may have been studied so intensively because of their rarity in nonhuman traditions and their suggested importance in human evolution—after all, stone tools and the cut-marks they leave on bones are often the only tangible traces of Paleolithic human cultures. Animal constructive behavior, such as nest building in birds or insects often exhibits remarkable flexibility and complexity (e.g., birds have to take into account local topography and materials when deciding where and how to construct their nest). It is mainly the sheer extent to which humans construct their own environment that is remarkable. Although artifacts and buildings have utilitarian functions, they often also have substantial cultural and emotional value: our built environment and everyday man-made objects help to structure our social relationships and identities. For example, in her detailed anthropological study of artifacts as inalienable possessions, Annette Weiner (1992) has documented how valuable artifacts, such as the New-Zealand Maori woven cloaks that are transmitted through generations help to consolidate and justify the political power of Maori chieftains. In such cases, it is the uniqueness and irreplaceability of the objects that constitute their value. Even in functional objects, such as arrowheads, basketry or agricultural tools, the shape of the object is usually not solely dictated by its intended function. For example, Polly Wiessner (1983) has shown that Kalahari San (southern African hunter-gatherers) arrowheads have stylistic variations that are imbued with social information. Some variations reveal something about the owner's affiliation or group identity, not unlike the use of particular dress codes in western subcultures. Others are meant to assert the individual identity of their owner. As we shall see in more detail, this social import of artifacts can also be inferred from the archeological record, for example, in beads and figurines from the European Upper Paleolithic (see chapter 6), and perhaps even in older material culture dating to the Middle Stone Age in Africa (see chapter 7). There is no parallel for this social dimension of material culture in nonhuman animals.

Finally, humans, unlike other primates, devote considerable time and energy to activities that do not seem crucially related to survival and reproduction, but that involve creating, maintaining and enjoying objects and worldviews that are quite remote from mundane tasks like gathering food and caring for offspring. The arts, religions and scientific knowledge acquisition are perhaps the most striking examples of this. As Daniel Dennett (2006, 5) put it: "Hardly anybody would say that the most important thing in life is having more grandchildren than one's rivals do, but this is the default *summum bonum* of every wild animal." This is not to say that these forms of human behavior have no bearing on reproductive fitness. Geoffrey Miller (2000), for example, has attempted to explain cultural displays in terms of sexual selection, where they serve as an honest signal of fitness. We shall return to this hypothesis in chapter 5, which discusses adaptationist accounts of artistic behavior. To take another example, scientific knowledge (especially in the medical and technological spheres) has allowed for an increase in human longevity and a worldwide population expansion. However, even though they have a clear impact on human fitness, many scientific innovations start out without any clear practical purpose in mind. To give but one example, Einstein's general theory of relativity allows for the implementation of the GPS satellite system (Hawking & Mlodinow, 2010, 102)—obviously, Einstein did not have GPS in mind when he came up with this theory. A considerable part of scientific practice is concerned with learning for its own sake. Next to this, religious people do have a higher reproductive success compared to atheists and agnostics (Kaufmann, 2010), but it is still a matter of intense debate whether religion can be seen as an evolutionary adaptation or a byproduct of other adaptations (more on this in the introduction to part III).

1.2 The puzzle of human uniqueness

These observations of the peculiarities of human culture provide a starting point to set up the basic question of this dissertation: the problem of uniquely human cognition, especially in the domain of creativity. The question of the place of humans in the world, and especially of the role of human cognition in shaping that place has ancient roots in philosophy, going back at least to Aristotle, who saw humans as rational animals. This view remained popular into the Middle Ages, where all Christian writers up to Aquinas saw humankind's power of reasoning as the *imago Dei*, i.e., the view that humans are made in the image of God (Van Huyssteen, 2003, 167).

However, developments in philosophy, and later in evolutionary theory, as well as an increasing knowledge about the behavior and cognitive capacities of nonhuman animals have dramatically overturned this view. In the 18th century it became clear that nonhuman primates, especially great apes, have a striking resemblance to humans. Anecdotal observations of apes with humanlike behaviors (including tool-use) and similarities in their skeletal anatomy were too obvious to be overlooked. Carl Linnaeus was already compelled to fit humans and apes together in the order *Anthropomorpha*, or primates. Linnaeus' motivation was that naturalists should classify by physical resemblance alone. Georges-Louis Leclerc, Comte de Buffon, like Linnaeus, granted a physical resemblance between humans and apes in his *Histoire naturelle générale et particulière* (1766), but argued that humans were still set apart by their mental powers. These classifications, which effectively seemed to undermine the claim for human uniqueness, were not widely accepted. For example, the German biologist Johann Friedrich Blumenbach and the French naturalist George Cuvier divided humans from apes by placing them into two separate orders: *bimana* (two-handed creatures) and *quadrumana* (four-handed creatures) (Bowler, 2003, 50–57). The first to propose an evolutionary link between humans and apes was Jean-Baptiste Lamarck, who proposed chimpanzees as the ancestors of the human species in his *Philosophie zoologique* (1809). However, Lamarck's ideas on human evolution were less influential than those proposed by Darwin in the *Descent of Man* (1871), which fuel the debate on human uniqueness up to the present.

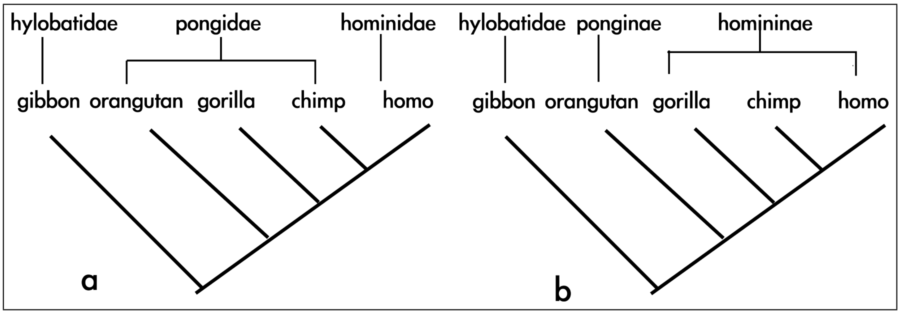

Figure 1.2: Cladistic relationships between humans and other apes. (a) shows the outdated view, with humans set apart from the other apes, which form a paraphyletic clade, the *Pongidae*; (b) shows the current view, with humans, chimpanzees and gorillas forming the *Homininae*.

Discussions on the relatedness between humans and other apes continued well into the 20th century. George Gaylord Simpson (1963), for example, classified hominids apart from the other apes: the nonhuman apes constituted the *Pongidae*, a separate lineage comprising all the nonhuman great apes which was believed to have diverged from the hominid lineage as early as 15 million years ago (see Fig. 1.2a). However, subsequent morphological and molecular biological analysis (e.g., Sarich & Wilson, 1967) indicated that humans and chimpanzees are in fact more closely related to each other than chimpanzees are to other great apes. Thus, the *Pongidae* became a paraphyletic (invalid) clade, because the clade is not based on evolutionary relationships, but only on the shared characteristic that its members are nonhuman apes. For the past 30 years, humans, chimpanzees and gorillas have been grouped into the *Homininae*, and orangutans have been placed into the *Ponginae*, as can be seen in Fig. 1.2b. The split between humans and chimpanzees is now believed to have occurred at a more recent period. Although Sarich and Wilson (1967) did not have the sophisticated molecular clock techniques that are used today, they came to a date of about 5 million years BP for the most recent common ancestor of humans and chimpanzees, a date that is still maintained today. The best current estimate is 5.4 million years BP, ± 1.1 million years (e.g., Stauffer, Walker, Ryder, Lyons-Weiler, & Hedges, 2001).

When the 19th-century British prime minister Benjamin Disraeli was asked whether humans were apes or angels, he answered without hesitation that he was on the side of the angels. Apes and angels can still be used as metaphors for two positions that paleoanthropologists, comparative psychologists and other scholars have held since the publication of the *Descent of man*, namely an emphasis on human uniqueness (angels) or a search for continuity between humans and other animals (apes). Robert Foley (1995, 32–34), for example, rightly indicates that paleoanthropologists like Glynn Isaac (e.g., 1978) have emphasized uniquely human aspects of social organization, such as sharing and division of labor, whereas others, like Lewis Binford (e.g., 1981), looked for animal characteristics, such as the prominence of scavenging in a large part of human prehistory. In paleoanthropology, this polarization is gradually giving way to a more balanced position, where humans are seen as just *Another unique species* (Foley, 1987). However, as we shall see in the next sections, this debate still continues in comparative psychology.

1.2.1 The mental continuity assumption

In the philosophical and psychological literature, there are four main types of strategies to deal with the puzzle of human uniqueness. Some authors, following Darwin (1871), propose that the difference between humans and other animals is a matter of degree, rather than kind. This position can be termed the *mental continuity assumption*; it is especially a popular position in contemporary comparative psychology, in particular with researchers who study nonhuman primates (e.g., Povinelli & Bering, 2002). Darwin's (1871) original statement captures the mental continuity assumption very well:

> Nevertheless the difference in mind between man and the higher animals, great as it is, is certainly one of degree and not

> of kind. We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention, curiosity, imitation, reason, &c., of which man boasts, may be found in an incipient, or even sometimes in a well-developed condition, in the lower animals. [...] If it be maintained that certain powers, such as self-consciousness, abstraction, &c., are peculiar to man, it may well be that these are the incidental results of other highly-advanced intellectual faculties; and these again are mainly the result of the continued use of a highly developed language. [...] The half-art, half-instinct of language still bears the stamp of its gradual evolution (Darwin, 1871, 105–106).

Many proponents of the mental continuity assumption are comparative psychologists, i.e., scholars who study cognition in nonhuman animals. For example, Susan Savage-Rumbaugh, 'mentor' of the bonobo Kanzi, has declared that her bonobo is "the ape at the brink of the human mind" (quoted in Povinelli & Bering, 2002, 115). The idea is that cognitive and behavioral differences between humans and other animals have been overstated. With appropriate experimental techniques, or sufficient hours of observations in the wild, any discontinuities between humans and other animals will disappear. Induction from past experience makes this idea less far-fetched than it might seem at first. For example, tool use was once thought to be uniquely human, but has since been observed in a variety of species, including most prominently nonhuman primates—at first, only great apes but more recently also monkeys, (e.g., Visalberghi et al., 2007)—next to, amongst others, birds and cetaceans (e.g., Krützen et al., 2005). Nonhuman animals are also selective in the tools they procure (e.g., Visalberghi et al., 2009). The ability for meta-tool use, i.e., the use of a tool to fashion another tool, a hallmark of human stone technology since the Late Pliocene, is also present in New Caledonian crows (A. H. Taylor, Hunt, Holzhaider, & Gray, 2007). Thus, there seems to be little in human tool-use of which there are no parallels in other species.

The mental continuity assumption implies that every human cognitive capacity can be found to a lesser degree in other animals—cognition distributed along an intellectual *scala naturae* with humans comfortably at the top, and other animals holding continuously lower positions. Darwin's (1871) legacy is reflected in current investigations of chimpanzee cognition which take human cognition as the point of reference: do chimpanzees seek causal explanations (e.g., Povinelli & Dunphy-Lelii, 2001), do they have cultures (e.g., Whiten et al., 1999), do they possess a theory of mind (e.g., Hare, Call, & Tomasello, 2001)? Leading neuroscientists (e.g., Finlay, Darlington, & Nicastro, 2001) likewise assume that the only difference between primate brains is their size. However, although the mental continuity assumption is a progressive research programme in the Lakatosian sense that it generates a wealth of empirical findings, it suffers from a major flaw, viz., it takes the human mind as the standard against which all other minds are measured. This attitude methodologically excludes the possibility of discovering cognitive specializations in nonhuman animals that would be less developed or nonexisting in humans. As mentioned earlier, echolocation in bats is a paradigmatic example of a cognitive specialization. Nagel (1974) famously argued that echolocation, although clearly a form of perception, is not similar in its operation to any human sensory experience, so we can never know what it is like to be a bat. Experimental studies (reviewed in Schwitzgebel & Gordon, 2000), however, indicate that humans possess a rudimentary capacity to use the sound-reflective properties of objects in the environment they navigate. Yet few would take these observations to mean that humans effectively possess the same cognitive capacity as bats, albeit to a lesser extent. In contrast, within mainstream comparative psychology, any cognitive similarity between humans and other apes is readily taken as evidence for a fundamental continuity between the structure and function of their brains.

The theory of natural selection compels us to see the history of life as a branching tree rather than a scale. Thus, it may be misleading to conceptualize human cognition as the pinnacle of intelligence, and to gauge animal cognition in terms of its resemblance with human cognition. We can expect that diverging selective pressures adapt animal minds to their unique ecological niches. It may therefore be more fruitful to approach cognitive evolution with Darwin (1859) in mind, rather than Darwin (1871). Take, for example, the case of language. As will be argued in more detail in chapter 3, it is fundamentally misleading to treat vocal imitation in dolphins and songbirds as ‘precursors’ to the human capacity for vocal imitation, which is an important part of our capacity for language acquisition. Since our closest living relatives, the nonhuman apes, do not have this capacity, vocal imitation in humans is a cognitive specialization that arose independently in the human lineage. Some similarities in the way young passerines acquire songs and humans acquire speech (for example, in the babbling stage (Doupe & Kuhl, 1999), where young birds and human infants produce song- and speechlike vocalizations) do not imply that language would not be uniquely human. In contrast to the mental continuity assumption, several scholars (see Shettleworth, 1998, for an overview) have taken an ecological approach. Rather than ask whether a given human cognitive capacity is present in particular species of animals, they take the following point of view: given the selective pressures in a species' environment, what kinds of cognitive capacities can we expect? Over the past decades, this behavioral ecological approach has led to a rethinking of claims that were initially anthropocentric (Shettleworth, 2009). For example, social cognition—including theory of mind, keeping track of third-party relationships, and self-awareness—was initially extensively studied in primates because of their close relatedness to humans. However, recently, researchers have also begun to probe social cognition in more distantly related clades such as hyenas (e.g., Engh, Siebert, Greenberg, & Holekamp, 2005) and corvids (e.g., Paz-y-Miño, Bond, Kamil, & Balda, 2004), non-primate species that have complex forms of social organization. These studies indicate that a good predictor of complex social cognition is whether animals live in stable, social groups with complex hierarchies and alliance-formation—and that this is a better predictor of complex social cognition than relatedness to humans.

We can distinguish three styles of research in comparative cognition: the anthropocentric approach (informed by the mental continuity assumption), the ecological approach (informed by behavioral ecology), and a more recent third approach, advocated by Lea, Goto, Osthaus, and Ryan (2006), that takes the ecological perspective, but also recognizes that humans are at present the best studied animal, which means that most experimental paradigms have been developed with human subjects in mind. It remains challenging to design tasks that are ecologically relevant to nonhuman animals, but doing so often gives surprising results. For example, as shall be unpacked in chapter 4, traditional tasks that investigated theory of mind in nonhuman animals relied extensively on the ability of the animals to guess cooperative intentional actions (something humans are very good at, such as following pointing gestures by human experimenters)—and, unsurprisingly, chimpanzees invariably perform poorly on such tasks (e.g., Bräuer, Kaminski, Riedel, Call, & Tomasello, 2006). But when tasks had to be performed within a competitive setting (i.e., guessing what a competitor can and cannot see), the performance of the apes improved markedly (Hare et al., 2001).

1.2.2 The genetic perspective

A second way to investigate the problem of human uniqueness is to focus on genetic differences between chimpanzees and humans. Why are two species that share about 98% of their DNA so divergent in their anatomy and behavior? One way to approach this problem has been to identify which regions of the human genome show the largest number of nucleotide substitutions compared to the chimpanzee genome. The region with the largest number of genetic mutations in humans is human accelerated region 1 (HAR1), which changed very little during vertebrate evolution (only two nucleotide substitutions between chicken and chimpanzee) but underwent 18 further nucleotide substitutions after the split between human and chimpanzee (K. Pollard, 2009). HAR1 is involved in the development of the neocortex, indicating positive selection on this gene during hominid evolution. The second most accelerated region in the human genome is HAR2. Specific base differences in this DNA sequence are involved in the development of the wrist and thumb during fetal development, indicating their importance in the evolution of the human-specific hand morphology (K. Pollard, 2009).

An important factor in human-chimpanzee differences are not only nucleotide substitutions, but differences in gene regulation. As early as 1975, King and Wilson already acknowledged that “the genetic distance between humans and the chimpanzee is probably too small to account for their substantial organismal differences” (King & Wilson, 1975, 107). They went on to suggest that “evolutionary changes in anatomy and way of life are more often based on changes in the mechanisms controlling the expression of genes than on sequence changes in proteins” (King & Wilson, 1975, 107). Using refined techniques that were not available at that time, more recent molecular biological studies have attempted to empirically test these predictions. Such studies typically study gene expression using micro arrays, which allows for the comparisons of mRNA levels in brain tissue of humans and other primates (see e.g., Preuss, Cáceres, Oldham, & Geschwind, 2004, for a review). Several of these studies indicate that gene expression has been upregulated in the human brain since the human-chimpanzee split, whereas no marked upregulations have occurred in other human tissues, such as the liver and the lungs (e.g., Gu & Gu, 2003; Uddin et al., 2004; Enard, Khaitovich, et al., 2002). A summary of data from three studies on Fig. 1.3 shows the increased upregulation of genes in the human brain compared to the chimpanzee brain. While elevated gene expression intuitively looks like more of the same, it can result in striking differences: it increases the probability that a particular protein will be built. Since many genes depend for their expression on the presence or absence of particular proteins (i.e., on the expression of other genes), the upregulation of a single gene can dramatically alter one or more cascades of developmental events, resulting in large phenotypic effects (Marcus, 2004). Genes that regulate synaptogenesis in the prefrontal and temporal cortices, two brain areas involved in social cognition, show more divergent expression patterns in humans and chimpanzees compared to those that regulate synaptogenesis in the cerebellum, involved in locomotion (Cáceres, Suwyn, Maddox, Thomas, & Preuss, 2007). Also, genes that are primarily expressed in the neocortex, the part of the brain involved in domains such as social interaction and conceptual thought, have been under stronger positive selection in both humans and chimpanzees (Oldham, Horvath, & Geschwind, 2006).

A problem with this view (at least in its current form) is its limited explanatory potential. Because there is no one-to-one correspondence between genes and behavior, the relationship between genes, cognitive function and environment remains largely unexplained. We know, for example, that HAR1 is involved in the development of the neocortex, but its exact function remains unknown (K. Pollard, 2009). Similarly, the fact that many genes involved in the development of the human brain have been upregulated should come as no surprise, but this does not give us any more insight into human cognition than we already have. An exception to the limitations of the genetic perspective seems to be *FoxP2*, a gene critically involved in language production (Enard, Przeworski, et al., 2002). We know that a disruption in this gene causes language-specific impairments, and the recent discovery of *FoxP2* in the Neanderthal genome (Krause et al., 2007) undoubtedly provides insights into the evolution of articulate speech. However, as will be argued in chapter 3, it seems that even this case has little explanatory power, as it remains unclear how *FoxP2* interacts with other genes to produce articulate speech.

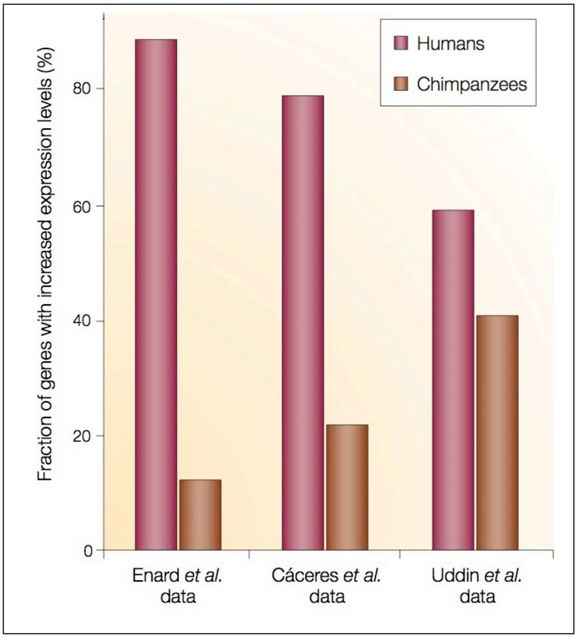

Figure 1.3: Patterns of gene expression changes in human and chimpanzee brains, from Preuss et al. (2004), Fig. 3, p. 854.

1.2.3 Silver bullet theories

Another group of scholars (e.g., Mithen, 1996; Deacon, 1997; Tattersall, 1998) have argued that one or a few key changes in human cognitive evolution can explain human-specific behavior and culture. Although they do not agree on which cognitive capacities are responsible for uniquely human behavior, these authors' views are similar in several respects. First, they claim, pace Darwin (1871), that human cognitive capacities are not only different in degree from those of other animals, but also in kind. For example, Tattersall (1998, 32) argues that humans are "not simply *more* intelligent [. . .] but *differently* intelligent, in a manner that allows us not only to view ourselves, but also to manipulate the environment, in a qualitatively unique way" (emphasis in original). Second, these authors claim that the purported cognitive change appeared relatively late in human evolution, long after the split between the human and chimpanzee lineages. For example, Steven Mithen (1996) situates the advent of ‘cognitive fluidity’ (the human capacity to draw on knowledge from distinct domains such as social cognition, natural history and technological insight, see below) at 60,000–30,000 BP; Tattersall (1998) places the development even later, during the Upper Paleolithic (between 45,000 and 10,000 BP). Third, many (but not all) of these models are committed to a form of punctuated equilibrium, in contrast to the gradualism that is characteristic of Darwin’s mental continuity assumption. Punctuated equilibrium, as developed by Eldredge and Gould (1972, 1988; Gould and Eldredge, 1993), proposes that evolution is punctuated by brief periods of rapid change, followed by longer periods of stasis. Dramatic changes in climate or geography are regarded as the primary causes for these brisk evolutionary changes. The paleoanthropologist Ian Tattersall (1998, 230–231), for example, has argued that the emergence of uniquely human behavior, especially our ability to use symbols in language and material culture, was achieved in one single punctuated event; he speculates that this was a relatively minor event in genetic terms, a small neural innovation that depended crucially on pre-existing adaptations that could be exapted (i.e., co-opted for a new adaptive function) by the symbolic mind.

Cognitive archeologist Steven Mithen (1996) has combined gradualism and puncturated equilibrium to explain the emergence of cognitive fluidity. Drawing extensively on a metaphor of the mind as a cathedral, he argues that the human mind is built from several specialized cognitive domains (in his terminology, intelligences), and that several phases of cognitive evolution can be discerned. In the first phase, which corresponds to the common ancestor of humans and chimpanzees, the mind is like a central nave (as in the simple one-room churches in late classical and early medieval times), without any specialized cognitive capacities. A second phase witnessed the building of multiple ‘chapels’ of specialized cognitive capacities around this nave, in close analogy to the building of chapels in Romanesque churches. These include domain-specific capacities for reasoning about social life, artifacts and natural history. Pursuing this analogy, Mithen argues that these domains did not influence each other:

> A critical design feature of these chapels is that their walls are thick and almost impenetrable to sound from elsewhere in the cathedral. There is no access between the chapels. In other words, knowledge about different behavioral domains cannot

> be combined together (Mithen, 1996, 69).

Hominids from this phase, such as *Homo ergaster*, could not reason across domains, which would explain why they did not make specialized tools, but rather general-purpose tools such as handaxes. To put it in another way, since the artifactual and biological domains could not communicate, these hominids could not develop specialized hunting tools. The third phase is marked by a partial demolition of the separating walls between the distinct cognitive domains, so that information from one domain can flow to others. Here, the metaphor draws on the transition from Romanesque to Gothic architecture, where the thick, heavy walls between the chapels were replaced by thinner columns. The differences between the minds of the second and the third phase are analogous to those between Romanesque and the succeeding Gothic cathedrals. In Gothic architecture sound and light emanating from different parts of the cathedral can freely flow around the building unimpeded by the thick heavy walls and low vaults one finds in Romanesque architecture. Similarly, in the Phase 3 mental architecture, thoughts and knowledge generated by specialized intelligences can now flow freely around the mind: "[T]he result is an almost limitless capacity for imagination. So we should refer to these Phase 3 minds as having a 'cognitive fluidity' " (Mithen, 1996, 71). Cognitive fluidity is exemplified in animism (endowing inanimate objects with a desire-belief psychology), totemism (merging social and biological domains by making animals ancestors to current human groups) and anthropomorphism (endowing animals with human properties). According to Mithen (1996), this third phase started about 60,000 years ago, when we see the first material evidence for across-domain reasoning, including specialized hunting tools which reveal a cross-fertilization of natural history knowledge and technology (e.g., harpoons for specialized fish capturing), and the emergence of therianthropes in art (half-human, half-animal creatures such as the 32,000-year-old 'lion man' from Hohlenstein Stadel, Germany, Fig. 7.5a, p. 192) which reveals a crosstalk between the social and biological domains. The result is an almost limitless capacity for imagination, which constitutes the roots of our ability to create art, invent scientific theories and imagine religious beings. Although Mithen's view is more gradualist, there is still a punctuated event needed to explain the emergence of cognitive fluidity. Even though it is a metaphor, the change from Romanesque to Gothic architecture is dramatic, and one may wonder what has prompted such a dramatic change in human cognitive evolution. Moreover, since 1996, substantial archeological evidence has come to light that questions this hypothesis, indicating an ability to make specialized tools well before 60,000 years ago, e.g., hunting spears from Schöningen, Germany, dating to 400,000 BP (Thieme, 1997) and bow and arrow hunting technology from Sibudu Cave, South Africa, dating to 64,000 BP (Lombard & Phillipson, 2010).

Several of the silver bullet theories propose language, or more broadly, symbolic thought, as the capacity that sets humans apart from other animals. Terrence Deacon (1997), for example, presents a picture of a co-evolution between brains and language. At some point in our ancestral past, some hominids developed the ability to communicate symbolically. The great selective advantage associated with this learned ability favored biological changes that facilitated linguistic skills, such as an enlargement of specific areas of the brain, especially within the frontal cortex. According to Deacon, the evolution of human-specific cognition, in particular our ability to manipulate symbols, can be seen as the product of a Baldwin effect, i.e., learning language changed the hominid selective environment in such a way that linguistic competence was selected for. Penn, Holyoak, and Povinelli (2008, 110) argue for an even more profound discontinuity between human and nonhuman minds, "which pervades almost every domain of cognition—from reasoning about spatial relations to deceiving conspecifics." They hypothesize that only humans are able to reason about higher-order relations in a structurally systematic way, which requires distinctive representational capacities that are not found in nonhuman animals. Humans, like other animals, have representational capacities, but unlike the latter, they can reinterpret their perceptually-based representations in terms of higher-order explicitly structured relations. To give but one example: animals can recognize when two physical stimuli are perceptually similar (e.g., two sounds of the same pitch, two pieces of fruit). Human children as young as two years (Gelman & Coley, 1990) tend to use causal-logical characteristics of relations, rather than simple perceptual features of their environment, such as that the relationship bird–nest is the same as dog–doghouse, despite the fact that there is no surface similarity between those stimuli; according to Penn et al. (2008) there is no evidence that animals can recognize structural similarities like these.

Other models place more emphasis on social cognition. The philosopher Peter Carruthers (2002a), for example, has argued that while all the capacities for human creativity were in place from the emergence of the first anatomically modern *Homo sapiens* (ca. 195,000 BP), the ability to engage in childhood pretend play only emerged about 40,000 BP. This ability, according to Carruthers (2002a), provides us with crucial practice to generate suppositions, and novel, relevant, fruitful and interesting ideas. Our habit to pretend as children is the basis of a consistent disposition to generate such ideas when we are adults. The comparative psychologist Michael Tomasello (e.g., 1999a) thinks that cognitive capacities involved in theory of mind and shared attention were the crucial element: in *The cultural origins of human cognition*, he proposes that cumulative culture requires a theory of mind (the ability to understand other people's mental states, including their goals and intentions). Social learning situations, such as teaching and imitation, require an understanding of the intentions and goals of the person who is being taught or whom one is imitating. Tomasello argued that chimpanzees and other primates do not take the intentions of others into account when they are learning any given behavior socially, but rather, that they focus on changes in the observable situation (e.g., the spatial configuration of objects) that are involved in the action. This could explain why social learning in chimpanzees is a long process. It takes for instance four to five years for young chimpanzees in the Taï forest to learn how to crack nuts using hammerstones and anvil (Tomasello, 1999b, 521). Moreover, experimental studies indicate that human children—unlike chimpanzees—selectively imitate relevant, intentional actions, but not accidental ones, even if the end result of both types of actions is the same (Boesch & Tomasello, 1998, 611).

However, subsequent studies in comparative psychology indicate that some nonhuman primates can discern the intentions of others. Chimpanzees, for example, can imitate intentional goal-directed actions, although they are more selective in what they imitate, i.e., they prefer to use their own methods if they find these easier or more efficient than those of the model, whereas human children almost always copy the model's method (Horner & Whiten, 2005). Other studies placed chimpanzees in a competitive situation, where they had to vie for food. Hare et al. (2001) showed that subdominant chimpanzees consistently chose a piece of food that was only visible to themselves over a piece of food that was also visible to a dominant conspecific. Similar experiments indicated that rhesus monkeys (Flombaum & Santos, 2005) also have some inkling about the relationship between seeing and knowing. These experimental results seemed to undermine Tomasello's earlier position that only humans have an understanding of goals and intentions, and that this was necessary and sufficient for the evolution of human culture. Consequently, in later publications (e.g., Tomasello & Rakoczy, 2003, 141), he has argued that while chimpanzees might understand something about simple intentions, they "seem not to understand communicative or cooperative intentions, and so they do not attempt to direct the attention of conspecifics by pointing, showing, offering, or any other intentional communicative signal". His current position (e.g., Tomasello & Carpenter, 2007) is that humans are unique in their ability for shared or joined attention. Shared attention is not only that two or more agents share information over the same thing, but crucially, that they also realize that they are doing so. Between the ages of nine to fourteen months, human infants spontaneously attempt to share attention, for example, by pointing and gesturing at objects that catch their attention. Whereas nonhuman apes gesture primarily to manipulate other agents' behavior (e.g., begging), human children also gesture to inform others, or to simply share experience with them (Tomasello & Carpenter, 2007, 122). Call and Tomasello (2008) speculate that the chimpanzee's theory of mind is primarily perception-based, concerned with the inference of observable goals and intentions, whereas human theory of mind is based on a belief-desire psychology that allows them to pay attention to unobservable beliefs and desires of others. There are many situations in which shared attention can make social learning faster and more efficient. It allows for explicit teaching, like when a teacher potter can see to what extent her student has mastered the technique of using the potter's wheel, whether she is paying attention, or whether she might have difficulties. Unsurprisingly, instances of deliberate teaching are extremely rare in nonhuman animals, and are limited to anecdotal, unsystematic observations (e.g., Boesch, 1991)—we will return to human teaching and nonhuman learning by observation in section 4.5.

These and other silver bullet theories point to interesting discontinuities between human and nonhuman animal cognition. What remains to be seen is whether one or a few key changes in human cognitive evolution (such as the emergence of language or cognitive fluidity) could account for the complete repertoire of uniquely human abilities we see today. As we shall see in the next chapters, the current empirical evidence is more in agreement with the idea that several cognitive innovations occurred during human evolution, including a fully developed language (see chapter 3), shared attention (see chapter 4), and symbol-mindedness (see chapter 7).

1.2.4 Dual inheritance models

This group of models emphasizes the interrelations between cognition and culture. Briefly stated, they view both culture and genes as providing separate, but interconnected systems of inheritance, each with its own forms of variation, selective retention and fitness effects (e.g., Henrich & McElreath, 2007). Culture and genes interact in various ways. For example, many cultural traits have been identified that clearly affect (i.e., increase of decrease) the fitness of those who possess them. Technology is a clear example of this, allowing humans to survive under conditions that they are not physiologically adapted to, including, for example, the complex technology of kayak-making, weaponry, and snow-house building that characterizes traditional Inuit societies. However, as Sterelny (2007) aptly points out, the Inuit also have a host of costly beliefs that decrease fitness, including belief in giant fish and birds that inhabit certain places —traditional Inuit adapted their foraging patterns to avoid these supposed dangers. Under extreme conditions, cultural practices are subject to a form of runaway selection that are so detrimental to fitness that they can cause the collapse of the entire cultural complex. Jared Diamond (2006) has convincingly argued that the collapse of the culture on Rapa Nui (Easter Island) was probably due to a depletion of the local resources, fueled by large prestige projects such as the construction and erection of *mo'ai* (giant stone anthropomorphic statues) by local competing political factions. Cultural practices sometimes encourage the selection of initially rare mutations. A well-known example is the spread of an initially rare allele of the LCT gene that produces lactase (an enzyme that is necessary to digest lactose, the sugar in milk). A majority of humans only express this gene during infancy and early childhood, but most members of dairy cattle keeping communities in Africa, Europe and northern America have an allele with a mutation that allows the expression of LCT into adulthood (Tishkoff et al., 2006). This mutation arose several times independently in Africa and Europe; it is a remarkable example of convergent evolution. Direct examples of gene-culture coevolution remain rare, however. To examine the interdependence of and relationships between cultural and biological evolution, dual inheritance models often rely on mathematical modeling, where individual characteristics (such as a given cultural trait) are linked to population-level processes (e.g., fitness outcomes of specific cultural traits). Examples of such models can be found in the compilation *The origin and evolution of culture* (Boyd & Richerson, 2005).

Dual inheritance models often explicitly provide a counterbalance to the recent emphasis on evolved, biological cognitive adaptations in evolutionary approaches to human behavior[2]. For example, Richerson and Boyd (2005) devote their entire second chapter to defend the claim that culture actually exists, citing several examples of cultural variation between human groups that cannot be solely explained in terms of varying environmental conditions or differing genetic backgrounds. However, unlike standard social scientists (such as anthropologists for a large part of the 20th century), who treated culture as a superorganic entity that was totally disconnected from human biology, proponents of dual inheritance models recognize the importance of evolutionary constraints, both in biological and in cultural evolutionary terms. Although these models provide explanations of how culture can increase human fitness, dual inheritance theory also allows for the possibility of maladaptive cultural traits. For example, an evolved prestige bias can explain why people tend to copy the behavior of more successful individuals (Henrich & Gil-White, 2001), which may be adaptive (e.g., emulating the best hunter), but which may also be maladaptive (e.g., taking up recreational drug use following famous actors and musicians). Some cultural traits evolve neutrally with respect to human fitness. Their propagation can thus be entirely driven by the fit they have with our evolved cognitive predispositions. Cultural traits that have a close fit with evolved human preferences have a higher chance of being remembered or transmitted. Sperber (1996) has termed this form of cultural evolution the epidemiology of representations. In section 5.4 we shall see how the evolution of abstract art toward more bold lines and brighter colors was driven by evolved preferences of the human visual system, and the evolution of toys like teddy bears and *My Little Pony*, as well as the evolution of the depiction of children in historical paintings from the Low Countries in the direction of more baby-like features was driven by a preference for neoteny. However, not all forms of neutral cultural evolution fit in the model of the epidemiology of representations. In some cases, the evolution of cultural traits is purely driven by a random and stochastic copying process, such as the shifts in popularity of specific dog breeds in the second half of the 20th century (Herzog, Bentley, & Hahn, 2004). Given that dogs today are kept mainly as companions and no longer as working animals, the shifts in dog breed popularity are no longer driven by practical concerns.

Dual inheritance models also recognize that cultural evolution can be subject to distinct evolutionary forces that are rarely encountered in biological evolution. For example, in order for group selection to occur, very specific conditions need to be met, including a high between-group variation and a low within-group variation. Such conditions are rare in nature, as in the case of colonies of eusocial insects. But these groups have a high measure of relatedness, making it difficult to distinguish the effects of group selection from those of kin selection (Wilson & Hölldobler, 2005). By contrast, human cultures do exhibit high between-group variation, and considerable within-culture homogeneity, even if there is some migration between cultures (Henrich, 2004a). This opens the possibility of cultural group selection, a topic that will be further explored in chapter 6.

Some authors working in the field of dual inheritance theory have examined human culture as a form of niche construction. Humans live in their own artifactual, created environment, and are surrounded by their own symbolically laden material culture. In this respect, humans are similar to other species that modify their environment to improve their climatic conditions and increase the viability of their offspring, such as beavers, termites and ants. Niche construction theory is a recent branch in theoretical evolutionary biology (see e.g., Laland, Odling-Smee, & Feldman, 2000; Sterelny, 2005, for reviews). It emphasizes the ability of organisms to modify the selective pressures in their environment (Laland & O'Brien, 2010). Niche construction is characterized as "the activities, choices, and metabolic processes of organisms, through which they define, choose, modify and partly create their own niches" (Laland et al., 2000, 132–133). The main difference between niche construction and mainstream evolutionary biology is that these modifications to the environment are seen as more than just a *consequence* of evolutionary change. Richard Dawkins (1989a) regarded them as extended phenotypes, i.e., as nothing more than an expression of genes in the environment. By contrast, according to niche construction theorists, these modifications influence the selective pressures to which organisms are subject. In this way, modifying the external environment can be seen as an evolutionary pressure in its own right. Take the example of human clothes. Molecular analysis of *Pediculus humanus*, the human body louse which lives on clothes, indicates that *Homo sapiens* has been wearing clothes since about 70,000 BP (Kittler, Kayser, & Stoneking, 2003). A clear consequence of habitual wearing of clothes is a decrease of natural selection on physiological adaptations to cold or heat. Although such adaptations do exist, they are quite modest compared to these in nonhuman species (compare, for instance, the physiological adaptations of a fennec (a desert fox) to those of a desert-dwelling nomad). Indeed, it turns out that physiological adaptations to cold or heat are much more extreme in human societies where very little clothes are worn. Tierra del Fuegans, for example, who traditionally wore almost no clothes, despite an annual mean temperature of about 7 °C, have extreme adaptations to cold, including the highest body mass index documented in nonwestern cultures, namely 25.7 $\text{kg}\backslash\text{m}^2$ (Steegmann Jr, Cerny, & Holliday, 2002). Sometimes our modification of the external environment results in an increase in natural selective pressures—the retention of the initially rare allele of LCT due to dairy farming is a case in point.

According to its proponents, niche construction is a pervasive phenomenon, not restricted to highly specialized constructions of termites and other eusocial insects. Nest-building, burrowing, web-making, pupal casings, and even fungi decomposing organic matter on the forest floor are considered to be clear examples. Thus, niche construction blurs the distinction between human culture and environment-altering behaviors present in most organisms, including plants and fungi. Sterelny (2005), however, is less convinced about this and rightly argues that niche construction should distinguish between organisms' ability to *control* the environment and the mere *effects* of their actions on the environment. While it seems plausible to categorize nest building and tool use as instances of niche construction, it is less clear why the ability of plants to change the chemical composition of their environment should be placed in the same category, as Laland et al. (2000) maintain. Also, cultural niche construction by humans is not only altering the physical environment (e.g., by constructing buildings), it can also consist of making the environment more cognitively congenial, as will be discussed in more detail in chapter 8.

A third strand of research that can be categorized under dual inheritance models is the work by authors who work on the extended mind thesis. These scholars are less mathematically inclined than those working on cultural group selection and niche construction theory, and usually study more qualitative observations on the role of artifacts in human cognition. Examples include Donald (1991), Mithen (2000) and Hutchins (1995). These authors see our increased reliance on material culture and our ability to make external symbolic representations not just as a result of human cognitive evolution, but as one of the driving forces behind it[3]. Cognitive neuroscientist Merlin Donald (1991), for example, distinguishes three stages of human cognitive evolution: mimetic culture (corresponding to the evolution of imitation, improvements in motor control, and the ability to produce memorized motor patterns on command), mythic culture (basically, the acquisition of speech), and the externalization of memory (corresponding to the invention of symbolic storage in the Upper Paleolithic, a process that continues up to this day). Mithen (2000) has similarly argued that the shift to behavioral modernity in the Upper Paleolithic, i.e., the shift to improved and specialized foraging techniques, specialized tools, long-distance exchange, and social differentiation is due to our ability to offload ideas that are difficult to conceptualize in the environment:

> The cultural and cognitive transformation that occurred between 60,000 and 30,000 years ago arose because humans learnt a clever trick. They learnt how to exploit material culture to extend their minds beyond the limits of their brains alone. By creating artifacts that represented ideas that could only have transient existence within the mind, it became possible to regenerate those ideas, communicate those ideas, and allow for cross-fertilization of ideas between individuals in such a way that completely new constructs could be developed (Mithen, 2000, 216).

The unanswered question remains why humans (and not other animals) have learnt “this clever trick”, and why they only did so in the past 60,000 years. This relationship between symbolically mediated culture and cognition will be discussed in chapters 7 and 8. In these chapters, it will become clear that material culture allows us to enhance our cognitive capacities, but that the ability to use material culture symbolically does depend on a suite of pre-existing cognitive adaptations, including the design stance and symbol-mindedness.

1.3 Approaching human uniqueness through multiple disciplines

This aim of this dissertation is to present a philosophical picture of the cognitive roots of human creativity, as manifest in capacities that are specific to our species. It focuses on the capacity to create and enjoy art, the ability for religious reflection and scientific practice. The basic question that motivated this research is: why is human creative behavior so distinct from that of all other animals? Why do humans, including those from small-scale societies with limited material culture living in harsh environments, invest disproportionate amounts of time and energy in the production and enjoyment of art, such as music, dance, body decoration, painting and sculpture? Why do we, but not other animals, believe in supernatural beings, and why do we go at such great lengths in representing such beings and worshipping them in religious rituals? Why are we alone in our ability to make models of reality in the form of scientific theories? At first blush, these questions seem to require widely diverging answers. For one thing, even if one takes a long chronology of science, where its emergence is situated in classical Greece, scientific practice is only a few thousand years old, whereas archeological evidence for religious practices stretches back to the late Pleistocene in the form of grave gifts (about 25,000 BP) and religious imagery (from about 32,000 BP onward). Evolutionary approaches to human cognition provide a potentially unifying framework to conceptualize these cultural elements as products of a universal human cognitive architecture.

The main title of this thesis *Common minds, uncommon thoughts* is meant to capture the idea that remarkable products of human cognition and culture (including art, theological reflection, and scientific theorizing) arise as the products of mundane cognitive capacities that have evolved in response to selective pressures in our ancestral past. To co-opt a beautiful metaphor by the philosopher of art Stephen Davies (2009), human culture is a *passacaglia*, and our universal human nature (specifically, universal human cognitive capacities) can be regarded as the *basso ostinato* that underlies it. In the next chapter, this *basso ostinato* will be characterized in more detail; how we see traces of it in human creative behavior will be considered in parts II (art), III (religion) and IV (science). However, unlike some early evolutionary psychological claims, I think that it is a mistake to regard variations in human culture as mere 'evoked culture'

(Tooby & Cosmides, 1992). According to that view, variations in culture can be regarded as different expressions of an evolved domain-specific psychology in response to various conditions (e.g., war, drought, abundance). In different environments, specific cognitive adaptations come flexibly into play, e.g., a preference for a low body mass index emerges in societies where food is plentiful and healthy food is a privilege for the rich, whereas people living under harsh conditions close to starvation will prefer more voluptuous body shapes. Although the concept of evoked culture allows for rich inferences and novel predictions, it nevertheless falls short of explaining the cultural achievements that will be discussed in the next chapters. *Common minds* specifically refers to the social nature of human cognition, i.e., the observation that human culture and evolved cognitive dispositions interact with each other. Human culture is more than a simple expression of evolved cognitive dispositions: rather, arises as the product of interacting human minds and their material culture. This emphasis on the communal aspect of human cognition will be explored in several chapters. In chapter 4, we will take a closer look at selective pressures that operated in hominid evolution during the late Pliocene–early Pleistocene and that gave rise to human social cognition, including the specific features that underlie human social learning. In chapter 6, I will discuss how material culture can serve as ethnic markers in the context of cultural group selection. Through interaction with our own material culture, we are able to surmount cognitive limitations, for example in the domain of mental time travel (chapter 8). In chapter 12, we will see how scientific progress critically depends on an interaction of creative individuals.

This dissertation will make use of an eclectic combination of theoretical and empirical findings of disparate disciplines. I will not tackle the question of whether human behavior can be best studied in terms of innate, psychological adaptations, or an interaction between psychology and culture, or ecological factors (see e.g., Smith, 2000, for such an endeavor), but will instead assume that all these approaches are valuable in the study of human behavior and cognition. This approach fits within the scope of a broad scientific naturalism (Quine, 1969a), which views philosophy not as privileged and independent, but as fundamentally continuous with science. My philosophical picture will draw on a variety of empirical sources, including developmental psychology, comparative psychology, experimental psychology, cognitive archeology, ethnoarcheology[4], cognitive anthropology and cognitive neuroscience. Why this reliance on so many disparate strands of evidence, rather than concentrating, say, only on developmental psychological studies? The most compelling reason for using many different theoretical frameworks to approach a complex problem is what Whewell (1840, chapter 5, §11) has termed *consilience of inductions*: when an induction obtained from one class of facts coincides with that obtained from another class of facts, this provides an epistemic justification of the induction, meaning it raises the probability that the induction is correct. Writing 55 years before Whewell, the commonsense philosopher Thomas Reid elegantly phrased this idea as follows:

> The strength of probable reasoning, for the most part, depends not upon any one argument, but upon many, which unite their force, and lead to the same conclusion. Any one of them by itself would be insufficient to convince; but the whole taken together may have a force that is irresistible [...] Such evidence may be compared to a rope made up of many slender filaments twisted together. The rope has strength more than sufficient to bear the stress laid upon it, though no one of the filaments of which it is composed would be sufficient for that purpose (Reid, 1785, 690).

One philosophical motivation behind consilience of inductions is the theory-ladenness of observation. Since Kuhn (1962), philosophers of science accept that our observations are always theory-laden: scientists who conduct experiments or rely on other forms of empirical observations start from a set of assumptions. These assumptions are not only based on pre-existing scientific models and hypotheses, but also on extra-scientific hopes, wishes and aspirations of individual scientists, next to the broadly shared cultural and cognitive biases. As Kuhn (1962) has argued extensively, this makes it very hard to falsify any scientific model. Nonetheless, proponents of a fallibilist version of falsification (e.g., Shadish, Cook, & Campbell, 2002, 16) argue that empirical observations can still improve our understanding of the world despite the theory-ladenness of observation, especially in those cases where the observations are repeated across different methods and disciplines, and where observations from diverse domains strengthen each other. Although in those cases empirical observations are still theory-laden, crucially, the background assumptions of different disciplines are not identical, and can indeed widely differ. If, despite this, observations are yet repeated across domains, they can attain a factlike status, even if they can never be fully justified as completely as theory-neutral facts (if the latter were to exist at all).

It is with this in mind that this thesis should be read and evaluated. Rather than a detailed comparison of naturalistic approaches to uniquely human behavior, and extensive critiques of each method, this work will draw on a consilience of inductions from different methodological outlooks to argue that normal, evolved cognitive abilities, operating in specific cultural and ecological environments are constitutive of what are traditionally regarded as exceptional cultural achievements, i.e., artistic expression, theological reflection and scientific practice. Some of these capacities are shared with other species, whereas others seem to have evolved somewhere after the split between humans and chimpanzees about 5 million years ago.

CHAPTER 2

THE HUMAN MENTAL TOOLBOX: EVOLUTIONARY, COGNITIVE PSYCHOLOGICAL AND DEVELOPMENTAL PERSPECTIVES ON HUMAN KNOWLEDGE ACQUISITION

To understand uniquely human cross-cultural traits it is important to obtain an insight into the human mental toolbox. This chapter addresses the following questions: What similarities and differences underlie human and nonhuman cognition? What is the relationship between cognition and language? What evolutionary forces can we discern behind the evolution of uniquely human cognitive skills? How do humans naturally conceptualize their world? These questions are quite wide, and answering each of them in detail would require a separate in-depth discussion. This chapter is structured as follows. In section 2.1, we will see to what extent conceptual thought differs between humans and nonhuman animals. Section 2.2 will examine the human cognitive architecture, focusing on theories of modularity. Section 2.3 introduces intuitive ontologies as cognitive mechanisms that underlie much of human intuitive reasoning and inference.

2.1 How humans see the world: Conditions for conceptual thought

2.1.1 Conceptual thought in humans and nonhuman animals

To examine continuities and differences between human and nonhuman cognition, it is useful to consider what is required for thinking. What does it take to think, or, to put it more precisely, what is required for conceptual thought? According to a standard dictionary definition (Webster's), concepts are abstract ideas, conceived in the mind. The concept HORSE[5] can be seen as an abstraction from individual horses. Throughout this dissertation, the term 'concept' will be used in a strictly psychological sense. Accordingly, concepts are mental representations; they are the constituents of propositional attitudes such as beliefs and desires (Margolis & Laurence, 2007b, 563)[6]. Concepts are the constituents of thought, or as Prinz (2002, 2) imaginatively put it "Without concepts, there would be no thoughts. Concepts are the basic timber of our mental lives." Philosophers have held two distinct, and it seems, mutually incompatible naturalistic positions on this front.

One philosophical tradition—going back to René Descartes—holds that conceptual thought requires language. Since humans are the only known species with a fully developed, articulate language, such a position draws a categorical divide between human and nonhuman cognition. According to Descartes (1637 [1988], part V), animals have no reason, but are mere complex organic machines, whose actions can be fully explained without any reference to the operation of a thinking mind, just like a watch can keep track of time without cognition:

> de façon que ce qu'ils font mieux que nous ne prouve pas qu'ils ont de l'esprit, car à ce compte ils en auraient plus qu'aucun de nous et feraient mieux en toute autre chose; mais plutôt qu'ils n'en ont point, et que c'est la nature qui agit en eux selon la disposition de leurs organes: ainsi qu'on voit qu'un horloge, qui n'est composée que de roues et de ressorts, peut compter les heures et mesurer le temps plus justement que nous avec toute notre prudence (Descartes, 1637 [1988], part V).

Descartes realized that human cognition, too, could be explained in such mechanistic terms, but insisted that two factors set us apart: humans are more flexible in their behavior than animals, and they use language in a creative and relevant manner. No machine or animal that would be taught to use language would be able to engage in a decent conversation (in this criterion, Descartes foreshadowed the Turing test):

> jamais elles [the machines] ne pourroient user de paroles ni d'autres signes en les composant, comme nous faisons pour déclarer aux autres nos pensées: car on peut bien concevoir

> qu'une machine soit tellement faite qu'elle profère des paroles, et même qu'elle en profère quelques unes à propos des actions corporelles qui causeront quelque changement en ses organes, comme, si on la touche en quelque endroit, qu'elle demande ce qu'on lui veut dire; si en un autre, qu'elle crie qu'on lui fait mal, et choses semblables; mais non pas qu'elle les arrange diversement pour repondre au sens de tout ce qui se dira en sa présence, ainsi que les hommes les plus hébétés peuvent faire (Descartes, 1637 [1988], part V).

Both criteria—language and flexibility—still play an important role in contemporary discussions on animal cognition (see e.g., the papers collected in Hurley & Nudds, 2006).

A second tradition—going back to John Locke—draws a closer connection between conceptual thought and experience. Locke (1689) argued that all knowledge derives from experience through the senses, and that this sets animals and humans apart from plants. He realized that animal cognition is adapted to the ecological niche in which the animals live:

> Perception, I believe, is, in some degree, in all sorts of animals; though in some possibly the avenues provided by nature for the reception of sensations are so few, and the perception they are received with so obscure and dull, that it comes extremely short of the quickness and variety of sensation which is in other animals; but yet it is sufficient for, and wisely adapted to, the state and condition of that sort of animals who are thus made (Locke, 1689, book 2, § xix).

This is an interesting precursor to cognitive ethologists like Konrad Lorenz and Niko Tinbergen, who likewise argued that animal perception is adapted to their environment. For Locke, the only qualitative difference between human and animal cognition is abstraction, the ability to make generalizations between different kinds of stimuli, i.e., to derive universals. WHITE, for example, is abstracted from the appearance of milk yesterday and the perception of snow or chalk today (Locke, 1689, book 2, § xi). Locke defends this claim by arguing that animals do not have words or other signs that denote abstract concepts.

> For it is evident we observe no footsteps in them of making use of general signs for universal ideas; from which we have reason

> to imagine that they have not the faculty of abstracting, or making general ideas, since they have no use of words, or any other general signs (Locke, 1689, book 2, § xi).

This Lockean position is also still present in contemporary philosophical arguments based on empirical and theoretical studies in cognitive ethology and psychology (e.g., Camp, 2009).

2.1.2 Intentionality

Theories of thought must explain how a cognitive system is able to represent aspects of the world. The absolute minimum for a cognizing system is that it has intentionality, i.e., it refers to states of the world. Intentionality by itself is not sufficient, of course; maps and abacuses represent aspects of the world (spatial and numerical, respectively), but few people would argue that these objects think. Therefore, most philosophical analyses of cognition require that a thinker has a belief-desire psychology, in other words, there needs to be a realistic distinction between perceptual states (e.g., seeing an apple) and conceptual (belief, desire) states (e.g., I wish I had an apple). Additionally, some authors (e.g., Carruthers, 2006) require that perception and conceptual thought must possess distinctive causal roles in guiding behavior. Carruthers' requirements may be demanding, but can even be met by nonhuman animals, including those with very small brains, like invertebrates. Bees, for example, can flexibly use directional information to navigate from a food source to the hive, and then use that information to produce an elaborate bee dance to inform others about the location of this food source. The bee that discovered the food has to move in an angle 90 ° away from the Sun to get back to the hive, but once inside, it needs to convey that the source is at an angle 90 ° toward the Sun. Foraging worker bees, on the other hand, will simply take the nectar back to the nest when reaching the location. In other words, the stimulus (a patch of flowers) does not always lead to the same response, but to a variety of responses (dance, foraging).

How do bees and other animals achieve this intentionality? Recent philosophical theories on mental content (teleosemantics) argue that intentionality is a product of evolution. According to these authors (e.g., Millikan, 1984; Rowlands, 1997), the proper function of our cognitive processes is to promote survival and reproduction. 'Proper function' is a normative concept that is ultimately relative to fitness. The heart, for example, does many things: amongst many other things, it pumps blood and produces lines on a electrocardiogram. From an evolutionary perspective, only the pumping of blood is relevant. Similarly, a brain does many things but its proper function is the production of beliefs that are fitness-enhancing. Intentionality is a property that mental states possess by virtue of their evolutionary history. In other words, bee dances are ‘about’ the location of nectar, because the ancestors of current bees were able to pass on the behavioral trait of dancing as a cue to the location of a food source to subsequent generations because of the selective advantage this conferred to them. If this evolutionary reasoning is correct, we can expect that many animals, including indeed invertebrates, may have intentional mental states.

2.1.3 Stimulus-independence

Additionally, genuine conceptual thought, as opposed to mere passive reaction, should also require some sort of distance or separation between the thinker and what it thinks about (Camp, 2009, 287). As Locke (1689) already noted, we not only recognize whiteness when we actually see it, but we can also reflect on whiteness in the absence of direct perceptual stimuli. Elisabeth Camp (2009, 288) formulates this criterion as follows: “Genuine thought involves a clear distinction between representation and represented, so that the former can occur even in the latter’s absence.” Although this condition seems demanding, there is good reason to suppose that many instances of nonhuman animal cognition would meet it. A hungry predator must have a concept of PREY when it goes hunting; many instances of operant conditioning, likewise, depend on an animal’s ability to anticipate a food reward following the completion of a specific action, such as pressing a lever. Indeed, Gallistel (1990) has shown that mere temporal association is not sufficient for operant conditioning.

Next to this, many animals can represent states of affairs independent of the state they are currently in. Western scrub jays, for example, are caching birds that store food for future use. In one experiment (Raby, Alexis, Dickinson, & Clayton, 2007), the animals were placed in a three-compartment room, which they could freely explore by day. The next days, they were alternatingly placed in two compartments, one in which food was served in the morning, and one in which no food was given. Once the birds had learned in which of the rooms they received breakfast, they started caching food in the compartment where they had previously not received anything, thus anticipating a future state (hunger) by storing food in advance. The scrub jays saved food even when they were currently hungry, indicating that they can discount current feelings of hunger to take future needs into account. In this respect, scrub jays are better than humans in discounting present feelings: the latter (Morewedge, Gilbert, & Wilson, 2005) are influenced by current feelings of satiation or hunger when they are shopping for food, buying more high-calorie snacks to eat in the future because they are hungry now. Tool-use in nonhuman animals is a further example of stimulus-independent reasoning. Animals like New Caledonian crows and chimpanzees can select and modify objects to retrieve food. For example, in the lab, New Caledonian crows can shape bits of wire into hooks to retrieve food from a narrow tube (Hunt & Gray, 2004). More impressively, these crows can use a short tool to obtain another, longer tool in order to retrieve a food reward that is out of reach, one of the few convincing examples of meta-tool use in nonhuman animals (A. H. Taylor et al., 2007). Taken together, these studies indicate that while stimulus-independence may be important for genuine conceptual thought, it is not distinctly human.

2.1.4 Cognitive fluidity

A further hallmark of conceptual thought may be combinatorial flexibility, or as Mithen (1996) calls it, cognitive fluidity. Humans can put their concepts to use in a variety of contexts, and draw connections between mental representations in unexpected ways. Domains where this flexibility is particularly evident are art, religion and science. As will be spelled out in more detail in chapter 5, art forms like music, visual art and dance rely on the co-optation of a variety of cognitive processes, as in a dancer who evokes a dying swan through bodily motions. Making visual art such as paintings or sculptures involves the use of tools like brushes or chisels. Whereas other animals mainly use tools to acquire food and for other basic-need purposes, artists use tools to achieve social goals. Religious concepts involve a combination of ideas from various domains. In many cultures, people believe that their ancestors are nonhuman animals, such as sharks or bears. Such totemic ideas involve a combination of knowledge from the social domain (kinship) with information about the natural environment (knowledge about animals). In theological thought, the design argument draws a connection between design of artifacts and design in the natural realm (see chapter 9). Scientific discovery often involves the combination of evidence and modes of reasoning from different domains, such as the use of mechanical metaphors by William Harvey and contemporaries in their description of the working of human bodily organs, such as the heart. Prior to them, physicians never thought about combining their knowledge of hydraulic mechanisms, like sluice gates, with their physiological knowledge about human anatomy. Medicine up to then did not even concentrate on organs, but involved the study of humors, fluids in the body, like blood and gall, that were believed to cause illnesses when they were in imbalance. However, once physicians started combining both domains, they began to think about human health and illness in terms of solid, bodily organs that are subject to the same mechanical principles as inanimate objects (De Cruz & De Smedt, 2010c).

Although no experimental paradigms have directly investigated cognitive fluidity in nonhuman animals, there is substantial indirect evidence to support Mithen's (1996) view that cognitive fluidity is uniquely human. Take the example of transitive inference. Transitivity is the ability to reason about properties of elements from a set by using relationships between these elements. For example, if you know that Jenny is taller than Ann, and Ann is taller than Beth, you know that Jenny is taller than Beth, even if you do not know the individual heights of these girls. Some experiments indicate that a small number of species can use transitive inference. Pinyon jays (*Gymnorhinus cyanocephalus*) can figure out dominance hierarchies between animals they did not directly interact with by use of transitive infernece. In a series of experiments (Paz-y-Miño et al., 2004), a test pinyon jay (A) was shown how an individual (B) it was familiar with interacted with an unfamiliar bird (C), fighting over a peanut. When A was subordinate to B, and witnessed B losing from C, A showed submissive behavior when confronted with C. However, when A was dominant to B, it would not show this submissive behavior when put in the same cage as C. Also, in control conditions where A did not know either B or C, it did not show submissive behavior toward whoever won the outcome of the peanut contest. However, as Penn et al. (2008) indicate, there is no evidence that nonhuman animals are able to transfer their transitive inferences to other domains. According to them, transitive reasoning in other animals is qualitatively different from that of humans, since the former cannot use this capacity in the systematic, logical way that the latter do. Humans, according to this view, would be able to abstract from any given situation and use deductive rules regardless of the context in which problems are presented.

However, cognitive fluidity seems to have its limits. Take, for example, the following implausible but logically valid argument:

(i) All things that are made of plants are good for one's health.

(ii) Cigarettes are things that are made of plants.

∴(iii) Conclusion: Cigarettes are good for one's health.

East Asian college students, such as Koreans and Chinese, are more likely to reject this argument than European and North American college students, even though the experimenters explicitly asked whether the conclusion follows logically from the premises (Norenzayan, Smith, Kim, & Nisbett, 2002). This ties in with a large body of experimental evidence (see Nisbett, 2003, for an overview) that indicates that East Asians reason more holistically and pay more attention to context than westerners. Such cross-cultural evidence indicates that context-sensitivity in deductive reasoning might be present in both humans and nonhuman animals, and that western college students may be atypical in their discounting of contextual information when presented with logical problems. In the contrived acronym of Henrich, Heine, and Norenzayan (2010), the latter may be WEIRD (from Western, Educated, Industrialized, Rich and Democratic societies).

Moreover, western subjects also have limits in their cognitive fluidity. Noam Chomsky's (1957, 15) famous example of a logically valid sentence "Colorless green ideas sleep furiously" is nonsensical, even though it is a combination of meaningful concepts. The cognitive anthropologist Pascal Boyer (2002, 98–100) has proposed that the combination of ideas from distinct ontological domains entails certain costs, such as in memory and processing—thus a minimally counterintuitive idea such as a talking tree is appealing, but a massively counterintuitive one, such as "a cat that can never die, has wings, is made of steel, experiences time backwards, lives underwater, and speaks Russian" (J. L. Barrett & Nyhof, 2001, 93) is simply unintelligible. In addition, an extensive literature on the boundedness of human rationality indicates that human cognition in many domains is context-specific, and that humans fail to generalize information from one situation to another, for example in the domains of probability theory and risk assessment (Kahneman, Slovic, & Tversky, 1982). This raises an important point that Susan Hurley (2003) also brought up: we should not overintellectualize the mind. She argued that nonhuman animals can occupy "islands of practical rationality," rather than a continuous space of reasons (Hurley, 2003, 231). In the case of pinyon jays, deductive reasoning is genuine, but it is limited to specific conditions, such as the evaluation of social interactions. Although the birds are not able to justify or make explicit the inferences they are drawing, they can still use them correctly to guide their behavior in taking a submissive or dominant attitude toward an unfamiliar bird.

Transitive inferences in the social realm may have evolved in species that live in stable, hierarchically organized social groups, without conferring additional cognitive capacities that allow these animals to transfer it to other domains, such as solving abstract tasks involving transitive reasoning in the laboratory. Indeed, nonhuman primates require extensive training, often comprising hundreds of trials, to solve transitive tasks in the nonsocial realm, such as relationships between objects in terms of size or other physical properties (Tomasello, 1999a, 18). To Hurley (2003, 251), such examples of context-sensitivity indicate that animal reasoning is context-bound, and fails to have full conceptual generality—what she terms "nonconceptual reasons in the practical sphere." But perhaps this picture should be resisted. It places high demands on conceptual abilities, since it seems to imply that context-bound human reasoning may not be fully conceptual either. Also, it seems to favor a linear scale or one-dimensional cognitive spectrum with humans at the pinnacle by virtue of their ability to integrate conceptual thoughts from distinct domains (Godfrey-Smith, 2003). Yet, one need but think about cognitive specializations in other species that are lacking in humans to realize that this scale-like view must be incorrect. Barn owls (*Tyto alba*), for example, can use auditory cues to make a topographic map of their surroundings, and use this auditory map to detect and capture prey—consequently, barn owls can hunt in pitch darkness, avoiding to fly into trees and other obstacles (Takahashi et al., 2003). There is no reason to prioritize cognitive fluidity as *the* cognitive specialization that puts us humans at the top, unless one can be persuaded to make many such scales, but what would be the scientific or philosophical relevance of this?

While cognitive fluidity is probably uniquely human, it still makes sense to term context-bound cognitive capacities of nonhuman species conceptual. Hurley (2003) and others have taken human cognitive capacities as a starting point to guide their reasoning about how nonhuman animals might think. As Sterelny (2003) remarks, they use their folk psychology (i.e., the way we think about other human minds in our daily interactions) to examine nonhuman animal cognition. Although folk psychology clearly works well as an interpretive tool to deal with our human social environment, using it to understand nonhuman animals like honeybees and pinyon jays may be a far stretch (Godfrey-Smith, 2003). Folk psychology has a clear heuristic value: we ascribe intentions, desires and beliefs to other agents, and motivate their actions based on these inferred mental states. However, it does not mean that folk psychology is accurate. Indeed, as we shall see in section 2.2, neuropsychological evidence indicates that human and other animal minds are more fine grained than folk psychology would have us believe.

2.1.5 Counterfactual and reflective reasoning

As we have seen, nonhuman species are able to think about states of affairs without requiring their actual proximity. This capacity is distinct from what may be termed ‘counterfactual reasoning’, the ability to reason about states of affairs that are manifestly untrue. Developmental psychologist Alan Leslie (e.g., 1987) argues that the ability of young children to pretend play is an early manifestation of this. A child who sees her mother talking to a banana (Fig. 2.1) is confronted with a puzzling sight: her mother talks to a banana, and the object obviously does not talk back. By attributing a propositional attitude (*pretend*) to her mother, even a two-year-old can understand her seemingly anomalous behavior. (This was especially the case in the late 1980s, when telephones still vaguely looked like bananas—it would likely be more puzzling to preschoolers today.) The propositional attitude *pretend* puts a given behavior or utterance (the proposition) as it were between scare quotes, shielding it from the everyday beliefs the child has. This enables her to understand that in the pretend situation, the banana is a phone, but that under normal circumstances, the banana is not a phone, but an edible piece of fruit. To Leslie (1994), this is an early manifestation of metarepresentation, the capacity that underlies our ability to pretend and to deal with false beliefs and counterfactual reasoning.

This is related to Peter Carruthers’ (2002a) proposition (see section

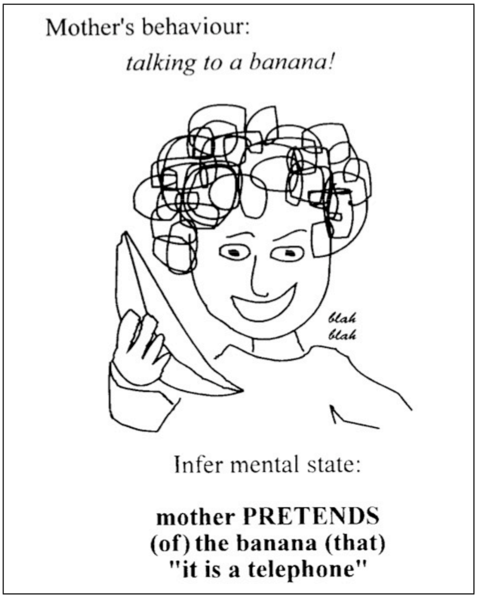

Figure 2.1: A pretend scenario that can be easily solved by a two-year-old by attributing a propositional attitude to mother, from Leslie (1994), Fig. 2, p. 213.

1.2.3) that argues that childhood pretense provides humans with the crucial practice in supposition-making and counterfactual reasoning. This makes pretense a critical contributing factor in the development of human creativity. Under specific circumstances, some nonhuman animals can be seen engaging in pretense. A cat that is chasing a ball may take this ball to be a real-life prey. Yet this capacity is typically limited to highly specific play situations: no cat has been observed that pretended that its empty plate really contained food, whereas young children regularly incorporate pretend food in their play. By contrast, humans use counterfactual reasoning in many domains. We can understand propositions such as 'If the present king of France were bald, he would not need a comb,' even though today France is a republic. Also, in logical reasoning, people are able to make valid deductive inferences, and can understand that an argument is valid even though it might be implausible.

Closely related to counterfactual reasoning is our ability to form reflective beliefs. The cognitive anthropologist Dan Sperber (1996, 1997) has compellingly argued that various credal attitudes do not constitute a natural kind. Within folk psychology we term them 'beliefs', but actually there are at least two basic categories of beliefs, which he labels 'intuitive beliefs' and 'reflective beliefs'. Consider the propositions 'This desk at which I sit is a solid object, made of wood' and 'This desk consists mostly of empty space, dotted with tiny particles that are too small for anyone to see with the naked eye, and that are held together by the strong nuclear force.' Like many western educated adults, I hold both beliefs, although they are actually incompatible. In Sperber's (1997) terminology, the first belief is an intuitive belief, which spontaneously emerges from my cognitive abilities and the way they interact with my environment. The human visual system, together with conceptual capacities involved in object representation, lead humans to hold an intuitive belief in solid objects (intuitive physics, see section 2.3.1). It is an intuitive belief that arises spontaneously, without reflection and deliberation, that guides my actions in relevant ways (e.g., I trust to put my laptop on this desk). Anything that were to violate this belief would be counterintuitive: if the desk suddenly disappeared, or if my laptop fell through its surface, I would be highly amazed. Not all beliefs that are intuitive are directly drawn from perception. Sperber (1997, 79) also allows for intuitive beliefs that are formed as a result of communication, as long as they are spontaneous, and according to intuitions that are furnished by our evolved cognitive capacities. I have never met a free-ranging wild tiger, but I have the intuitive belief (based on testimony) that tigers are dangerous. This belief accords very well with my evolved intuitive biological knowledge (see section 2.3.1) that includes a wariness for large, sharp-toothed predators.

The belief that the desk consists mostly of empty space is a reflective belief. According to Sperber (1996, 1997), humans have a specialized metarepresentational ability that allows them to make representations of representations. Thanks to this ability, one can assess the claim that 'Mary believes that homeopathic medicine works' as true, even though one evaluates the proposition 'homeopathic medicine works' as false. As we just saw, metarepresentation allows one to isolate propositions from one's own beliefs: one put them, as it were, between scare quotes. This allows humans to represent propositions that they do not understand. A person untrained in particle physics can accept the belief 'This desk consists mostly of empty space, dotted with tiny particles that are too small for anyone to see with the naked eye, and that are held together by the strong nuclear force' without really understanding it, based on his reliance on testimony by physicists. By extension, we can put any belief that is beyond the grasp of our evolved cognitive capacities between scare quotes, which greatly extends human cognitive capacities. Sperber (1997, 79) concedes that some people may have what he terms "reflective mastery" over their reflective beliefs. A trained particle physicist understands not just that a desk is mostly empty space, but also why this would be so. Her reflective concepts are based on explicit theories that specify these concepts, such as the standard model of particle physics. Yet she will not incorporate her reflective beliefs about desks into her intuitive beliefs—she will not, for example, have to deliberate whether it is safe to put her laptop on her desk. By contrast, when faced with a free-ranging tiger, she will attempt to run without having to deliberate. Thus, *pace* Sperber (1997), it seems unlikely that reflective beliefs can become intuitive beliefs.

If reflective beliefs keep on being put between scare quotes, how do they become part of our mental lives? How is it that a trained particle physicist can assess novel theories in her domain of expertise, and make qualitative predictions based on such theories, as De Regt and Dieks (2005) have argued? Several authors (e.g., Carruthers, 2006; Camp, 2009) argue that language lies at the basis of our ability to represent counterfactual and reflective ideas. Language allows us to represent ideas that have no bearing on the immediate present, allowing for stimulus-independent, cognitively fluid and counterfactual reasoning. As we have seen (section 2.1.1), the idea that language helps us think is well-established in philosophy. However, it may not be just language narrowly construed, but rather the human ability to store information symbolically that is crucial for maintaining reflective beliefs, both within individual minds and in a cultural environment. Take mathematical symbols, which can be seen as useful shorthands to denote difficult concepts (De Cruz & De Smedt, in press b). A consistent feature of western mathematics is that concepts that are difficult to grasp like $\sqrt{-1}$ were represented with symbols (in this case i). Taking an even root from a negative number is cognitively intractable: the result cannot be negative, since multiplying two numbers with the same sign is always positive; nor can it be positive, since multiplying two positives cannot yield a negative. Sixteenth-century mathematicians like Cardano and Bombelli allowed for calculations involving square roots of negative numbers in order to solve particular equations, especially cubic equations. In one problem, Cardano attempted to find a solution to the problem of dividing 10 into two parts, the product of which is 40. His solution was ingenious: first, divide 10 into two equal parts, we have five on each part. $5 \times 5 = 25$, which is still 15 short of 40. Dividing this remainder of -15 equally between the two parts, we have $\sqrt{-15}$. Thus the solution becomes $(5+\sqrt{-15})(5-\sqrt{-15})$. He remarked that this solution 'adeo est subtile, ut sit inutile' (it is as refined as it is useless) and considered the operation to be a 'mental torture'. Nevertheless, the formal correctness of the operations led Cardano to accept square roots of negative numbers (Ekert, 2008). However, real progress with even roots of negative numbers was only booked when Euler (18th century) introduced the symbol i. This symbol shielded a difficult concept from the corrosive effects of intuitive mathematical reasoning, namely that it is impossible to extract an even root from a negative number. Once introduced, mathematicians no longer needed to worry about square roots of negative numbers, because the symbolism effectively masks this cognitively intractable operation, for example $\sqrt{-15}$, which bothered Cardano, can be elegantly rewritten in Euler's notation as $i\sqrt{15}$, hence Cardano's equation would be written as $(5 - i\sqrt{15})(5 + i\sqrt{15}) = 40$. Once Euler introduced the symbol i, where $i^2 = -1$, mathematicians had a convenient shorthand to incorporate even roots of negative numbers. This allowed such numbers to be incorporated in number theory, allowing for the representation of complex numbers of the form $x + yi$, with x as the real component and yi as the imaginary one which vastly extended both number theory and algebra. It allowed, for example, for a proof of the fundamental theorem of algebra, for which real numbers do not suffice (De Cruz & De Smedt, in press b). Additionally, reflective beliefs have more chance of being transmitted and remembered unscathed if they are stored externally, by using material objects such as written documents (it is difficult to imagine particle physics without the storage of the information underlying it in textbooks and scientific papers), or visual imagery (think of the manifold depictions of the Trinity as a way to externally convey the difficult to grasp relationship of the Christian triune God to a lay audience). We will return to the role of external media in transmitting and remembering difficult beliefs in chapter 8.

2.2 Modularity in cognition

Until well into the 18th century, philosophy and psychology were not separate disciplines, but were both part of natural philosophy, the branch of philosophy dedicated to the study of nature and the physical universe prior to modern science. Within this broad domain, questions on the human mind and its structure held a prominent place. Natural philosophers interested in the human mind, like their intellectual contemporaries the philosophers of mind and philosophical anthropologists, relied primarily on conceptual analysis, induction from first principles, and thought experiments to examine human cognition. They attempted to answer questions like 'Of what parts is the mind composed?' As is well known, natural philosophy gradually transformed into diverse branches of modern science, with its emphasis on empirical testability and experiment. Nevertheless, current sciences still maintain an important aspect of natural philosophy: they are still aimed at a better understanding of the world (Dear, 2006). As we will see, current theories about human cognition are still informed and influenced by philosophical ideas, and conceptual analysis still plays a crucial role in them. This is especially the case for theories about modularity in cognition. As will be argued below, contemporary cognitive scientists, computer scientists, developmental psychologists and others often tacitly use a particular philosophical model of modularity to guide their research and interpret research findings.

At the outset of this discussion, it is important to note that modularity is a general concept, not restricted to mental phenomena, but often used in this context (Schlosser & Wagner, 2004). The concept of modularity is used in such widely diverging domains as education (e.g., a modular training program), engineering and design (e.g., modularity in architecture), and in many scientific domains outside of cognitive science (e.g., modularity in genetics, computer programming). In these disparate domains, we can characterize a modular system as follows:

- A system is modular if it is composed of separate units or modules. For example, in a modular training program, it is possible to follow individual courses within the program.

- Modules have a degree of autonomy from each other. For example, the individual units of a modular robot can function independently of what the others do.

- Each module has its own functional and structural integrity. For example, in modular architecture, each unit has a specific function and layout (e.g., bathroom, bedroom, office).

Scholars who study modularity in cognition add more characteristics (e.g., domain-specificity, informational encapsulation), often resulting in more restrictive definitions. Modularity as a hypothesis of how the mind works has been put forward in several disciplines, including neuroscience, philosophy, artificial intelligence, developmental psychology and evolutionary psychology. Across and even within these disciplines, there is no unified or generally agreed upon definition or set of criteria about what a modular cognitive system should look like. One reason for this is that there are actually at least four different modularity theses, each with its own specific methodology and assumptions. *Anatomical modularity* is the view that modules are cognitive faculties that correspond to specific anatomical locations in the brain. Historically, this was the earliest concept of cognitive modularity. It is mainly used in cognitive neuroscience. *Fodor modularity* is the concept of modules as proposed by the philosopher Jerry Fodor. To Fodor, modules are restricted to peripheral input systems (dealing with the processing of perceptual information) and language. This view of modularity has few actual supporters today, but remains very influential in debates on mental modularity. *Functional modularity* conceptualizes mental modules in terms of their functions. Evolutionary psychologists and behavioral biologists are the main proponents of this view. This position is often termed *massive modularity. Developmental modularity* conceptualizes modules in terms of their domains. This view, mainly endorsed by developmental psychologists, conceptualizes broad domains of ‘core knowledge’ that emerge early in cognitive development, and that gradually get enriched over time as children acquire more knowledge about the world.

2.2.1 Anatomical modularity

The idea that the human brain is composed of specialized processing units (modules) is not recent, but can be traced back to the 18th-century discipline phrenology (see Greenblatt, 1995, for a discussion). Well into the 18th century, human cognitive processes were regarded as distinct from the other functions of the human body. The Cartesian received view was that the mind was a unified entity (the soul) which could not be divided. The brain was not considered to be the seat of thought: physicians believed that the nerves were hollow, containing some kind of fluid which was the substance of the soul; the main function of the brain was its filtration and purification. This view accorded well with a Galenic medical paradigm, according to which illness and health were correlated to the balance between specific bodily fluids (the humors). However, in the course of the 18th century, a more 'solidist' view, in which the solid organs of the body became more important for diagnosis, was gaining currency, following the Harveyan view on the function of organs. In this intellectual climate, physicians and anatomists began to look for an organic centre in which all perceptual input would be processed. The Viennese anatomist Franz Joseph Gall and his German collaborator Johann Spurzheim argued that the brain is the seat of human cognitive processes, and that we can study individual cognitive faculties by the palpitation of bumps on the human skull. For Gall and Spurzheim, cognitive faculties were much akin to the propensities and mental faculties proposed by Scottish commonsense philosophers like Thomas Reid (1764); they included love of one's offspring, memory of facts, and the gift of music (Greenblatt, 1995, 790–793). The important legacy of phrenology is that it offered a monist (as opposed to the earlier dualist) view of the human mind—the quest for organic correlates for mental faculties still guides current cognitive neuroscience. The metaphysical assumption that all human cognitive processes have a material, organic origin, and the disappearance of all reference to an immaterial soul, is to a considerable extent due to phrenology. Phrenology's fatal mistake was to correlate the shape of the brain with the shape of the skull, and to use this as a proxy for mental faculties.

Ironically, phrenology's demise was caused by other theories of cognitive localization. The 19th-century French physician Paul Broca observed patients with serious language impairments, and noted damage to a specific area in the brain (what is now known as Broca's area, located in the inferior frontal gyrus) during autopsy. Likewise, the German neurologist Carl Wernicke found a different type of aphasia that corresponded with damage to another area of the brain, the posterior section of the superior temporal sulcus (now known as Wernicke's area). Neither of these locations was in agreement with the phrenological theory of where human speech was located. The studies by Broca and Wernicke were among the first lesion studies. Brain lesions are usually caused by external injury or a stroke (a blood-clot that momentarily deprives part of the brain of oxygen and nutrients), leading to specific patterns of cognitive impairment. Indirectly, one can infer from the correlation between damage to a given brain area X and loss of a certain cognitive function a that X and a are functionally correlated. Because lesions in humans are fortunately not the result of controlled experiments, they have some limitations. Lesions often damage multiple areas, and some areas are more likely to be damaged than others due to their proximity to major arteries. The fundamental idea that underlies all lesion studies, namely that discrete anatomical areas of the brain deal with specific cognitive functions, is to some extent an idealization. For example, neurons in the prefrontal cortex of rhesus monkeys have a response that is task-dependent, i.e., a given neuron might fire in response to a specific stimulus during one type of task (such as matching to sample), but show no activation when presented with an identical stimulus in a different task (e.g., visuo-spatial association), so the same neuron does not always respond to the same task (E. Miller, 2000).

Since the 1980s, advances in neuroimaging techniques have made it possible to examine the human brain in action. Functional neuroimaging techniques, such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), measure the consumption of oxygen or glucose by the brain using indirect signals. They typically have a very good spatial resolution: they can make maps of human brain activity that have an accuracy within a few millimeters. However, they have a relatively poor temporal resolution, which places limitations on experimental designs. Electrophysiological tools such as event related potential (ERP) measurement and magnetoencephalography (MEG) gauge the brain's electric activity. These tools have an excellent temporal resolution (within milliseconds), but poor spatial precision and limited depth. Neuroimaging studies can show that a given brain region is involved in a specific task, for example, that the bilateral intraparietal sulci are involved when a participant performs a subtraction or addition task (Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999). What is less clear, however, is whether the given brain areas are also *necessary* for those tasks. Some areas show increased activation during a task because they are connected to other areas that are involved in it. For example, it is possible that only one hemisphere is involved in exact numerical processing (as is suggested by e.g., Lemer, Dehaene, Spelke, & Cohen, 2003), but that the strong connections through the corpus callosum between the superior and inferior frontal gyri in both hemispheres yield a bilateral activation (O. Simon, Mangin, Cohen, Le Bihan, & Dehaene, 2002). Rorden and Karnath (2004) point out that lesion studies are still the only reliable method to find out whether a given brain area is truly involved in a given task. Even reversible induced lesion techniques like TMS (transcranial magnetic stimulation), where an area's functionality is briefly disrupted, cannot reliably say whether a particular brain area is necessary for a task, because the technique is as yet not fully understood. In some cases, repeatedly magnetically stimulating a brain area leads to a reduction of function in that area, but it sometimes also increases it.

fMRI is the most popular neuroimaging technique; most of the neuroimaging experiments cited in this dissertation make use of it. Therefore, it will be useful to look at this technique in more detail. fMRI captures the BOLD (blood oxygen level dependence) signal of bloodflow within the brain of a participant who is lying in a scanner. The basic assumption is that areas of the brain that are involved in a task need more oxygen, and that oxygenated blood has different magnetic properties compared to non-oxygenated blood. To gauge whether a brain area is involved in a task, its BOLD signal is compared to that of the brain at rest. The assumption here is that a statistically significant increase in blood oxygenation means that the area in question is functionally involved in the test. The brain during (wakeful) rest is taken as a baseline. Unfortunately, this assumption is highly idealized, for it turns out that the human brain during wakeful rest has a distinct pattern of activation termed the default network (see e.g., Buckner, Andrews-Hanna, & Schacter, 2008, for a review). Another problem with fMRI is that the technique requires the participant to lie as still as possible, since even minor head movements can disrupt the signal. Thus, the technique is ill equipped to examine the neural correlates of dance, playing a musical instrument, sports, and a variety of other tasks that require that the body be in motion.

As will be pointed out later (chapter 5), neuroscientists typically propose functionally specialized areas at a very fine grain, so-called 'psychological primitives' (Bechtel & Mundale, 1999). These are usually small and well-localized areas in the brain that have a narrow specific function, and that are often part of larger networks with a broader functional specialization. To give but example, our ability to infer mental states is described as a network of anatomically defined regions (C. D. Frith & Frith, 1999), each specialized in a specific subtask such as intentionality detection (superior temporal sulcus), explicit representation of states of the self (medial prefrontal cortex), and inferring emotions from facial expressions (anterior region of the superior temporal gyrus). The relationship between psychological primitives and the larger networks of which they are part often provide genuine insights into human cognition. Buckner and Carroll (2007), for example, note a large overlap between brain areas involved in remembering personal experiences, imagining future events, some forms of navigation and putting oneself into the perspective of someone else. In traditional psychology, these tasks were considered as distinct, but thanks to fMRI and other brain imaging techniques, one can plausibly argue that they rely on a common set of processes, in particular, they all rely on our ability to use past experiences to imagine perspectives and events beyond those that emerge from the immediate environment, including mental time-travel, navigating the environment and perspective-taking. It is hard to imagine how psychologists could have come up with this insight without functional neuroimaging.

2.2.2 Fodor modularity

Jerry Fodor (1983) introduced the concept of modularity in an attempt to unite two seemingly incompatible viewpoints of human cognition that were popular during that time. Behaviorism—a paradigm that was mainly motivated by studies of animal learning during the earlier decades of the 20th century—contended that cognitive processes are reflex-like, automatic, and primarily driven by the external environment, whereas cognitivism—an idea that arose during the cognitive revolution in the 1950s —maintained that cognitive processes are sophisticated, while underscoring the importance of internal, mental processes. Fodor (1983) argued that these concepts of human cognition could be united by making a distinction between two kinds of cognitive processes: input processes, such as perception and language, are modular, whereas central processes, such as memory, attention or conceptual thought, are nonmodular.

Fodor borrowed the concept of modularity from computer science. Since the 1950s, theorists from diverse disciplines became interested in cognitive processes, mainly driven by their attempts to implement artificial intelligence. Theorists like the economist Herbert Simon, the linguist Noam Chomsky and the computer scientist Alan Turing attempted to answer the question of how the brain, a material entity, is able to carry out cognitive processes and generate mental representations. They saw cognition as a set of computational processes. According to the *computational theory of mind* human cognitive processes are algorithmically specifiable processes defined over syntactically structured mental representations. In other words, when the appropriate input is there, the brain, or a part of it, performs a set of mindless computational processes, and then yields an appropriate output. Such a cognitive process is Turing computable, i.e., at some level, it is composed of mindless, algorithmic computational operations. If this were not the case, we would be faced with a problem of homunculi in the brain, a potentially infinite regress of minds within minds.

This cognitive perspective stood in sharp contrast to behaviorism, which was the dominant paradigm in psychology from the early 20th century until about 1960. Behaviorists assumed that the brain was a general processor that took stimuli from the outside world and converted them into appropriate outputs (behaviors). According to behaviorists, there was no way of knowing what went on inside, and since the brain was entirely dependent on the external environment, they treated cognition as a black box. Instead, they focused only on stimuli of the external environment and their effects on behavior, primarily in nonhuman animals —in fact, they overwhelmingly studies animals belonging to the white variant of the Norwegian rat—although they presumed this could be easily extended to human cognition as well (Lockard, 1971). Cognitivists doubted the view that cognitive processes were inherently reflex-like and completely dependent on the environment. Chomsky (1959), for example, argued that stimuli are often too poor and underspecified to explain the richness of some behaviors, such as language. Fodor (1983) proposed a way to unite these frameworks: although perception is reflex-like (automatic, involuntary), it is sophisticated (i.e., makes inferences). He dubbed such cognitive tools ‘modules’.

Fodor drew up a list of nine features he thought were typical of modular systems:

- *Domain specificity*, modules only operate on certain kinds of input —they are highly specialized in a particular domain.

- *Informational encapsulation*, information from other modules cannot influence the processing within a particular module.

- *Mandatory operation*, modules work automatically upon the right external stimulus, akin to a reflex. For example, you cannot choose to hear speech as senseless noise.
- *Speed*, modules are fast, because their function is mandatory.
- *Shallow outputs*, the output of a module is typically simple and limited to its own domain. For example, a module in the linguistic domain that is concerned with syntax will not process the semantics of utterances.
- *Characteristic ontogeny*, there is a regularity of development in a module, both in its pace and the sequencing of developmental stages.
- *Inaccessible to consciousness*, a module's working is not influenced by conscious processes; knowing that something is a visual illusion does not stop it from fooling us successfully
- *Associated with a fixed neural architecture.*
- *Subject to characteristic patterns of breakdown.*

As mentioned earlier, Fodor believed that central (also termed higher) cognitive processes, such as memory, attention, reasoning, or conceptual thought are nonmodular, they are subserved by a general cognitive processor. Fodor cites two reasons for this. First, there is his infamous "First Law of the Nonexistence of Cognitive Science" (Fodor, 1983, 107): central cognitive processes are too complex to be understood with our current empirical knowledge of how the brain works. He was indeed very pessimistic on cognitive science's ability to understand central cognitive processes: "the more global a cognitive process is, the less anybody understands it" (Fodor, 1983, 107). Second, Fodor thought that encapsulation is the most central feature of modularity, i.e., modules need to be isolated from each other. Indeed, in his follow up book *The mind doesn't work that way* (Fodor, 2000), he characterized modularity primarily in terms of informational encapsulation and domain-specificity. To Fodor, higher-order beliefs are typically holistic and isotropic, i.e., the degree of confirmation of any belief depends on its relation to any other belief; anything a person knows is relevant to determine whether to believe a given proposition.

Fodor's substantial influence on modularity theories can be explained by his careful listing of properties that mental modules should have. His nine characteristic features have thus become something of a diagnostic checklist against which empirical claims of modularity have to be pitted. The advantage of this approach is that it makes modularity a testable hypothesis, not a blanket term that can be adapted to fit almost any cognitive architecture. As Fodor (2000, 56) remarks, without the notion of informational encapsulation, "Probably everybody who thinks that mental states have any sort of structure that's specifiable in functional terms qualifies as a modularity theorist in this diluted sense." A potential problem, as Sperber (1996) and H. C. Barrett and Kurzban (2006) have pointed out, is that if modularity is indeed a natural property of cognition, it may not always reveal itself as conveniently and clear-cut as Fodor proposed it. In that case, its characteristics may be something to be discovered empirically instead of just ticked off. An analogy with physics might be useful here. Suppose that physicists who studied properties of the atom were guided by a particular model of the atom, for example, Dalton's model of atoms as hard, indivisible balls, which was very popular in the early 19th century. Suppose then that physicists subsequently discovered that the physical world did not in fact contain atoms as hard balls, but rather that atoms were composed of smaller particles such as electrons and neutrons. A possible response could have been: 'See, the theory of atomism is fundamentally flawed, since the stuff we find is not actually composed of hard, indivisible balls, so atoms do not exist!' This response is clearly less sensible than what actually happened, namely that physicists refined their concept of atomism to fit their experimental findings. It is thus conceivable that the modules that neuroscientists, evolutionary psychologists and developmental psychologists discover are not at all like Fodor's, but this does not imply that the thesis of modularity is fundamentally flawed. Indeed, even Fodor (1983, 37) himself has argued that the notion of modularity "ought to admit of degrees."

With this in mind, let us examine some of Fodor's central claims. Although Fodor outlined nine features, he thought that *informational encapsulation* was the most central feature: other cognitive domains (e.g., our beliefs) cannot influence a module's output. As an example of the of the cognitive impenetrability of modules, Fodor frequently (e.g., 1983, 66) mentions the Müller-Lyer illusion. However, McCauley and Henrich (2006) showed that people from some cultures are more susceptible to the Müller-Lyer illusion. In particular, it turns out that people from environments that have many straight lines (such as western cultures, with their angular buildings) are more susceptible to the Müller-Lyer illusion than people who inhabit circular dwellings, such as the San (hunter-gatherers that inhabit the Kalahari desert). This stands in sharp contrast to Fodor's claim that modules are impenetrable. To give but one more example, lower-level visual processes that are highly domain-specific, such as color perception and motion perception, can be influenced by higher-level thought processes. A good example is the influence of higher-level conceptual processes on motion detection. The medial temporal/medial superior temporal cortex is activated by the visual observation of motion. Interestingly, this module is also recruited when people watch still photographs of objects in which motion is implied, such as a running athlete or a crashing wave, compared to photographs of objects at rest, such as a resting athlete or a still lake (Kourtzi & Kanwisher, 2000). This effect is also shown when people look at drawings in which motion is implied, such as those in Hokusai's *Manga* (1814), which shows human figures in dynamical postures (Osaka, Matsuyoshi, Ikeda, & Osaka, 2010), see also sections 5.2 and 5.5. Since none of these objects are in actual motion, the best explanation of the differential activation of this brain region is that background information about the images (i.e., that they depict motion) can provide input to this module. In other words, in this case a high level belief influences the operation of a low-level module.

Most importantly, Fodor's idea that only perceptual and other peripheral input processes could be modularly organized is abandoned by most evolutionary psychologists and neuroscientists (H. C. Barrett & Kurzban, 2006). His claim that memory, for example, is not modular, has come under attack by cognitive psychological research that indicates that humans are equipped with at least three dissociable types of memory: semantic, episodic and procedural memory (Tulving, 1985). Semantic memory handles our factual memory of the world. It stores propositions like "The Parthenon is in Athens." Episodic memory contains the recollections of one's own, personal experienced past. It provides an autobiographical record of events like 'In 2007 I visited the Parthenon in Athens." Procedural memory stores how to do things, such as baking a cake, riding a bicycle or eating with chopsticks. Several studies indicate that these different types of memory can be selectively impaired, and that they operate independently from each other. For example, a study of three children who suffered brain damage shortly after birth shows that it is possible to store a wide variety of semantic facts and learn a range of skills without any episodic memories (Vargha-Khadem et al., 1997). These children were unable to remember anything about their personal lives, including what they had done the previous day, what movies they watched, or what classes they attended. Nonetheless, all attended mainstream schools, had normal levels of language competence, and a factual understanding of the world.

As we will see in the next section (2.2.3), many types of modularity are logically possible next to Fodor's. As it is, Fodor modularity is very influential—perhaps too influential, because debates on modularity too often center on whether particular modular systems correspond to all of Fodor's criteria. As we have seen, some of Fodor's claims are dubious on evidential grounds. Others are dubious on epistemic grounds: per definition Fodor modularity cannot provide an explanation for higher cognitive processes, so it has a limited explanatory scope compared to other functional modular approaches. Still, for modularity to be an interesting notion, it is crucial for modular theories to outline non-trivial properties that would be characteristic of modular cognitive architectures. We will now look at two such theoretical frameworks, massive modularity and developmental modularity.

2.2.3 Massive modularity

In the midst of debates on the applicability of Fodor's modularity concept, evolutionary psychologists (e.g., Cosmides & Tooby, 1994b) began to develop a very different notion of modularity, which has been often dubbed 'massive modularity' (e.g., Carruthers, 2006; Sperber, 1994). The key difference with Fodor modularity is that a massively modular mind not only contains peripheral, perceptual modules, but also modules involved in domains of central cognitive processing, including memory, decision-making and social cognition. Over the past decades, evolutionary psychologists have gathered considerable evidence to support cognitive specializations involved in social exchange, including the detection of kin and the avoidance of incest (e.g., Lieberman, Tooby, & Cosmides, 2003), the presence of cross-culturally stable mating strategies that differ markedly between men and women (e.g., Buss & Schmitt, 1993), and a heightened sensitivity to animal-like stimuli (New, Cosmides, & Tooby, 2007). Massive modularity has attracted widespread criticism (e.g., Panksepp & Panksepp, 2000; Bechtel, 2003). Unfortunately, many of these criticisms take Fodor modularity as the standard against which evolutionary psychological claims are to be gauged. Evolutionary psychologists do not necessarily subscribe to Fodor's nine criteria. For instance, they do not consider informational encapsulation to be a central or even an important feature of modularity (e.g., H. C. Barrett, 2005; Pinker, 1997). Instead, as we shall see, according to them the crucial property appears to be *functional specialization*. The next sections will examine the case for evolutionary psychological views of modularity. They will outline the main arguments in support for massive modularity, and look at some criticisms that have been raised against it.

2.2.3.1 Functional specialization

The basic starting point of massive modularity is the notion of *functional specialization* (H. C. Barrett & Kurzban, 2006). Human minds (and those of other animals) exhibit a considerable degree of functional specialization. Evolutionary psychologists assume that natural selection has resulted in the evolution of several cognitive structures that are tuned to solving specific adaptive problems (e.g., acquiring food, finding mates, raising offspring), and that a better insight into these problems can help us unravel the architecture of the human mind (Frankenhuis & Ploeger, 2007). Although chance events, such as drift or founder effects, may have played a role in the evolution of the human brain, evolutionary psychologists argue that its complex functional design can best be explained through natural selection. Therefore, we can expect that "the design or functional organization of the mechanisms present in our cognitive architecture reflects the principles and logic of natural selection" (Cosmides & Tooby, 1994b, 86). To explain functional cognitive specialization, evolutionary psychologists can look at two levels (roughly corresponding to two of Tinbergen's (1963) four questions). First, there are proximate explanations pertaining to the immediate function of a given trait. For example, most diurnal primates have brain areas that process information about the color of objects in the environment (in humans these are parts of areas V1, V2 and V4). Second, there are ultimate explanations that have to do with the adaptive value of that trait. Trichromatic color vision in diurnal primates enables a better detection of ripe fruit (the main diet of these animals), and was naturally selected.

In their early writings, evolutionary psychologists frequently appealed to machine analogies to capture the functional specialization of mental modules. The Swiss army knife analogy is probably the best known example of this:

> The mind is probably more like a Swiss army knife than an all-purpose blade: competent in so many situations because it has a large number of components—bottle opener, cork-screw, knife, toothpick, scissors—each of which is well designed for solving a different problem (Cosmides & Tooby, 1994a, 60).

There are sound evolutionary reasons to expect the human mind to be made up of several dedicated domain-specific cognitive systems, as specialized systems are better at solving distinct problems than a single processor: "We have both cork-screws and cups because each solves a particular problem better than the other. It would be extremely difficult to open a bottle of wine with a cup or to drink from a cork-screw" (Cosmides & Tooby, 1994a, 58). Some authors (e.g., Nesse, 2000) have objected to this use of machine metaphors, because machines are products of intelligent (human) design, whereas minds are a product of natural selection. Indeed, it may be argued that machine metaphors should be avoided altogether when we talk about evolved structures (Pigliucci & Boudry, in press). However, the use of machine metaphors in early evolutionary psychological writings can also be seen in a more positive epistemic context. In De Cruz and De Smedt (2010c), my co-author and I have argued that scientists often use distant analogies (i.e., analogies where source and target domain diverge widely) in areas of research that possess an as yet underexplored conceptual structure. Despite important advances in our understanding of how the human brain evolved, its evolutionary origins remain as yet poorly understood. Distant analogies play a role in the scientific creative process, especially in periods of intense conceptual change. However, once this initial creative phase is past, distant analogies are often abandoned. One can think of the use of the solar system as a model for the atom by Niels Bohr and Ernest Rutherford in early 20th-century theories on the structure of the atom; although it was useful at the time, physicists today no longer think about atoms in these terms. We can thus expect that as evolutionary psychology matures, its ideas about modularity should be less informed by machine metaphors and more by real-life examples of neural specialization in humans and other animals, that is if massive modularity is to become a successful research program. But why should we expect that natural selection would favor a massively modular cognitive architecture? The main arguments in defense of functional specialization are engineering constraints, functional incompatibility and computational tractability.

2.2.3.2 Engineering constraints

Engineering constraints for massive modularity were already proposed by Herbert Simon (1962), who drew an analogy of two watchmakers. Tempus makes watches in a holistic way, so that if he is interrupted because the phone rings in his workshop, he is forced to start anew each time. Hora makes smaller subassemblies that he then puts together; thus he does not need to start from scratch each time he has to put down his work. The modular watchmaker, although initially slower, ends up making more watches, even if the number of interrupting phone calls is quite low. The neuroscientist David Marr (1982), in his seminal work on visual cognition, invoked a similar engineering argument to explain why human vision has modular properties.

> [I]f a process is not designed in this [modular] way, a small change in one place has consequences in many other places. As a result, the process as a whole is extremely difficult to debug or to improve, whether by a human designer or in the course of natural evolution, because a small change to improve one part has to be accomplished by many simultaneous, compensatory changes elsewhere (Marr, 1982, 102).

Marr argued that vision has evolved in a modular way, hypothesizing that biological subsystems evolve in such a way that adding extra components does not change the performance of the overall system. Evolutionary psychologists (e.g., Cosmides & Tooby, 1994b) developed this engineering argument for human cognition:

> Speed, reliability and efficiency can be engineered into specialized mechanisms because there is no need to engineer a compromise between different task demands. [...] [A] jack of all trades is necessarily a master of none because generality

> can be achieved only by sacrificing effectiveness (Cosmides & Tooby, 1994b, 89).

The engineering argument relies on the notion of *adaptive problem*: when distinct adaptive problems arise, a modular architecture is the most efficient solution. This notion of adaptive problem is not specific to evolutionary psychology, but is a central part of the adaptationist program in biology in general (Frankenhuis & Ploeger, 2007, 694). However, evolutionary psychologists do not have an articulate notion of what an adaptive problem might be. Cosmides and Tooby (1994b, 90), for example, simply define it by providing specific examples, including foraging for food, navigating, selecting a mate, parenting, engaging in social exchange, dealing with aggressive threats, and avoiding predators. They argue that the statistical occurrence of such adaptive problems in our (Pleistocene) ancestors was sufficient to promote a modular cognitive architecture through natural selection. A more recent theoretical paper (H. C. Barrett & Kurzban, 2006) does not define 'adaptive problem' at all, but only suggests that the wide scope of adaptive problems that animals face has resulted in the evolution of multimodular cognitive architectures. Although the notion is intuitively appealing, it remains conceptually underdeveloped. Is mate selection an adaptive problem that is out there in the world, or do we impose it upon the world? Women use different criteria when they select short-term or extra-pair mates (good genes) than when they select long-term mates (providers) (Scheib, 2001). Does this mean that mate selection for women actually consists of two adaptive problems—i.e., father-selection and provider-selection? This example illustrates that adaptive problems may be more fine-grained than would be intuitively assumed.

Some authors have made more fundamental criticisms of adaptive problems. Sterelny and Griffiths (1999), for example, have argued that there are in fact no stable, pre-existing problems that natural selection can provide a solution to, since adaptive problems arise as an interaction between an organism's environment, its needs and its cognitive resources.

> The evolution of language, of tool use, and of indirect reciprocity are not solutions to pre-existing problems posed to the organism. There are no stable problems in these domains to which natural selection can grind out a solution. The "adaptive problem" is always being transformed in an arms race

> (Sterelny & Griffiths, 1999, 331).

This objection, however, fails to take into account that evolution always entails an interaction between an organism and its environment. Frankenhuis and Ploeger (2007) provide the following illustration: detecting emotions in human faces is not an adaptive problem for octopuses, since it is not a stable feature from their environment, and even if it were, they would not gain anything by developing a cognitive mechanism for this. For humans, detecting emotions in human faces is relevant. Indeed, they are confronted with facial expressions that show some stability across cultures (Ekman et al., 1987). A fly or mosquito might benefit from learning how to detect anger or irritation in humans, and thus avoid being killed. However, insects do not have the cognitive resources to detect facial expressions, so for them detecting emotions in human faces is not an adaptive problem. To return to the example of mate selection, it turns out that people are not only driven by what they want in a partner, but also by how they perceive their own quality as mates (Regan, 1998). It would seem that adaptive problems do exist, and that, as many other useful theoretical biological concepts (e.g., fitness), they critically depend on an interaction between organisms and environment. Incidentally, it is interesting to note that empirical evolutionary psychological research seems to favor quite fine-grained adaptive problems, more fine-grained than their theoretical work seems to suggest. For example, *prima facie* the detection of dangerous animals seems to constitute an adaptive problem. Yet, empirical research (e.g., Öhman & Mineka, 2003) supports the existence of a fine-grained highly specialized system for the detection of snakes.

Whether this myriad of adaptive problems also gives rise to a densely modular mind is another matter. Evolutionary psychologists seem to appeal to some notion of adaptationism to argue that it does. Tooby and Cosmides assert that

> Detailed theories of adaptive function can tell what modules are likely to exist, what adaptive information-processing problems they must be capable of solving, and—since form follows function—what kind of design features they can therefore be expected to have (Tooby & Cosmides, 1995, xv).

However, this reasoning relies on the adaptationist assumption that the most efficient cognitive architecture is effectively realized (Samuels, 2000).

Also, as Samir Okasha (2003) has argued, even if adaptationism is true, modularity does not automatically follow. At best, we can conclude that the mind is probably equipped with a lot of *innate mental content*. It is theoretically possible to have a nonmodular mind that is stocked with innate mental content. Therefore, we would need stronger engineering constraints than efficiency to infer that a mind furnished with modular innate mental content is more plausible than a mind that has a large holistic processor stocked with innate ideas (e.g., “go for good genes when in short term relationships”).

2.2.3.3 Functional incompatibility

Cosmides and Tooby have argued that

> different adaptive problems often require different solutions, and different solutions can, in most cases, only be implemented by different, functionally distinct mechanisms [...] As a rule, when two adaptive problems have solutions that are incompatible or simply different, a single general solution will be inferior to two specialized solutions. This is the argument from functional incompatibility (Cosmides & Tooby, 1994b, 89).

Sherry and Schacter (1987) provided a persuasive case of how functional incompatibility would work in practice by examining two kinds of memory systems in birds. Some species of bird, such as marsh tits (*Parus palustris*), sing songs and retrieve previously cached food items. Both abilities draw critically on memory, but the type of memory that is required is quite different in each case. Song learning takes place in a critical learning period, usually when the male bird is a fledgling, with the songs of adult males of the same species as models. Once the bird has acquired a song, it will keep this throughout life, as it is a way to signal its presence to (potential) mates and competitors. By contrast, food caching requires that a bird updates its memory each year with the new locations of caching sites. Sometimes cached food needs to be relocated to prevent pilferage by other birds. Remembering caching sites does not rely on a critical learning period, and requires continuous updating. The functional requirements of song learning and food caching are thus not compatible, so we can infer that bird species that have both behaviors evolved two separate memory systems to deal with these mutually incompatible tasks.

Note that the functional incompatibility argument is in some respects stronger than the engineering argument, because it does not presuppose adaptationism, and it can provide a solution to Okasha's (2003) question of why we should expect modular rather than nonmodular innate knowledge. It is thus not that natural selection favors modular cognitive architectures because it would be the *best* solution, but because it would be the *only* solution. If correct, the functional incompatibility argument has considerable power and would provide a serious challenge to nonmodularists. Unfortunately, functional incompatibility of cognitive tasks has not been actively researched. An exception is the domain of artificial intelligence, where neural networks are trained to solve a highly specialized problem. This sometimes prevents the network from solving tasks that require distinct computational operations. There are two possible ways to deal with this: either continuously retrain the previously learned examples (a very cumbersome and time-consuming way), or design a modular learning system. It turns out that modular learning systems are more robust, and better at generalizing than nonmodular ones (Jacobs, Jordan, & Barto, 1991).

How can this be translated to natural cognitive systems? A possible example of two functional incompatible systems could be the prediction of motion performed by animate and inanimate objects. The task demands are probably functionally incompatible: predicting the motion of an agent requires attribution of goals and intentions, whereas predicting the movement of an inanimate object requires only the ability to understand its velocity, trajectory and momentum. Humans do this quite successfully, and it turns out that even infants have widely differing expectations about how an animate or an inanimate object should behave (e.g., Kuhlmeier, Bloom, & Wynn, 2004; Spelke, Phillips, & Woodward, 1995). Indeed, it turns out that the detection of animate versus inanimate motion activates quite different areas in the human brain (Martin & Weisberg, 2003). Given that functional incompatibility has not been explicitly researched as a property of natural cognitive systems, it remains as yet unclear to what extent our cognitive architecture is filled with functionally incompatible structures.

2.2.3.4 Computational tractability

Computational tractability is an important concept in artificial intelligence, and in cognitive science in general. When presented with an appropriate input a cognitive system must be able to provide an appropriate output (behavior) through mindless and algorithmic processes. How does the cognitive system do this? According to evolutionary psychology, we can expect the brain to be modular because what counts as fit (appropriate) behavior differs markedly from domain to domain. Cosmides and Tooby (1994b) provide the following example: sex with close kin should be avoided because the resulting offspring has a higher probability of congenital disorders. Yet, helping close kin (e.g., sharing food) increases inclusive fitness. To make interactions with kin computationally tractable, we need modules (e.g., incest avoidance, nepotism). However, this argument may be conflating cognitive processes with their tasks. As Shapiro and Epstein (1998, 175) observe: tightening screws requires a turn to the right and loosening them requires a turn to the left—we do not need two different types of screwdrivers to perform these different tasks. It is not that a cognitive system needs a new module each time it is confronted with a new cognitive task. Indeed, it is quite possible that extant cognitive capacities are co-opted for solving novel tasks. This point will be developed in more detail in chapter 3 where we examine how language depends on a host of older auditory and conceptual cognitive modules.

Cosmides and Tooby (1994b) point out another problem for computation: some problems are too difficult to learn through trial-and-error learning within the lifetime of the individual organism. Sometimes this is because individual learning is too costly (e.g., learning to avoid predators); sometimes an organism can simply not foresee the long-term fitness consequences of its actions. Consider some male member of a species of bird which has the option to either help its mate build the nest and feed the offspring, or do nothing of the sort. Because of the mechanics of internal insemination, it does not know whether it is the father of the nestlings. If it helps, and it is the father, it increases its fitness (since it increases the probability that the offspring survives), but if it has not fathered the brood, it decreases its inclusive fitness since it wastes time and energy that could have been invested in other mating opportunities. For an individual bird with a life expectancy of only a few mating seasons, there is no way to find out which is the most adaptive strategy. By contrast, natural selection can detect statistical regularities in behavior—do female members of this particular species of bird frequently engage in extra-pair copulations? How successful are these females in rearing their offspring all by themselves?—and this can shape the nurturing behavior of the males accordingly. The computational tractability argument is a strong argument in favor of innate knowledge. But again, the argument does not necessarily favor a cognitive architecture that is composed of massively many modules.

2.2.4 Developmental modularity

While evolutionary psychologists developed computational and functionalist models of modularity, developmental psychologists (e.g., Spelke et al., 1995; Carey & Spelke, 1996; Gelman, 2004) put forward a very different notion of modularity: that of *core knowledge*. Core knowledge domains arise early in ontogeny; most are phylogenetically old, as many are shared with other animals. They deal with distinctive ontological categories such as inanimate objects, numerosities and spatial properties of the environment. During development, these core knowledge systems are not fundamentally altered; rather, they become enriched over time (see also chapter 10 for a discussion of core knowledge and an illustration of how it develops in specific cultural environments). Because of core knowledge emphasizes links between humans and other animals, it shares an evolutionary perspective with massive modularity. An important difference with the latter is that core knowledge is a hypothesis on innate mental content, i.e., innate *knowledge*, rather than innately specified information-processing units.

It is useful at this point to distinguish between two conceptions of modularity, namely intentional and computational modularity (Segal, 1996). Intentional modules ('intentional' used in the philosophical sense of 'aboutness') are primarily characterized in terms of their content, i.e., what they represent, rather than how they function. Chomsky's universal grammar, for example, is a hypothesis about what the human mind represents about grammatical structure. Computational modularity, on the other hand, is mainly characterized in terms of what it does, i.e., how it functions. Examples include the massive modularity hypothesis and the fine-grained model of psychological primitives in cognitive neuroscience. Core knowledge clearly falls in the first category, as the theory proposes that human conceptual thought falls into a limited number of conceptual systems, including knowledge about inanimate objects, conspecifics, animals, plants, geometry and number (Spelke & Kinzler, 2007). These core systems arise early in development and remain stable throughout a person's life. In other words, they continue to contribute to our conceptual reasoning as adults: "some of the cognitive achievements of children and adults do not result from processes of theory change [...]: they depend on core cognitive systems that emerge early in development and remain constant thereafter" (Carey & Spelke, 1996, 516). Core knowledge domains have a theory-like structure. Spelke et al. (1995) argue that the core knowledge domain of intuitive physics allows infants as well as lay adults to predict the behavior of inanimate objects. Infants as young as three months look longer, taken as an indication of surprise and violation of expectation, when they see a solid object spontaneously disintegrate, hover unsupported above the ground, or disappear. They propose that three principles regulate infants' cognition about objects: continuity (i.e., objects that are out of sight continue to exist), contact (i.e., inanimate objects must be in direct contact to influence each other's behavior; there is no action at a distance), and cohesion (i.e., inanimate objects do not fall apart without external cause).

A second difference between massive modularity and core knowledge is the number of proposed modules. Developmental psychologists typically posit fewer of them. Spelke and Kinzler (2007, 89), for example, explicitly say "both these views are false: humans are endowed neither with a single, general-purpose learning system nor with myriad special purpose systems [...] Instead, we believe that humans are endowed with a small number of separable systems of core knowledge." However, there is no universal agreement in this research program as to which systems count as core knowledge. For example, Carey (1995) includes number, intuitive psychology and intuitive physics as innate domains of knowledge, but is skeptical about intuitive biology. Spelke and Kinzler (2007) allow for intuitive geometry, number, the representation of agents, physics and perhaps reasoning about social partners.

2.3 Intuitive ontologies

2.3.1 What are intuitive ontologies?

The previous sections discussed several models of modularity. In most of this dissertation, I will use an eclectic notion of modularity termed *intuitive ontologies*. Helen De Cruz and I (De Cruz & De Smedt, 2007) derived this term from Pascal Boyer's (2000) 'intuitive ontology'. However, whereas Boyer used this term only in the singular, we put it in the plural to indicate that different inference systems are at work. Intuitive ontologies describe categories of objects in the world, such as person, artifact, plant, or animal. According to this view, the way humans parse the world is not arbitrary or even solely governed by external reality. Rather, our inductive inferences rely on intuitive ontologies—a limited set of category-based evolved expectations that emerge early in development and that guide our reasoning about physical, psychological and biological phenomena. Ontology is the philosophical study of what is, i.e., what kinds of entities there are in the world, and how different categories of entities are related to each other. The question of how particular objects relate to universal properties is an ontological question (e.g., a particular cat and cats as a species). Human category-based inference mechanisms are ontologies in the sense that they provide a set of expectations of how specific kinds of objects will behave. They are termed intuitive because they are not the product of deliberate reflection or scientific investigation (see also Sperber's (1996, 1997) distinction between intuitive and reflective beliefs, discussed in section 2.1.5). Examples of intuitive ontologies include folk psychology (how do agents behave), folk physics (how do inanimate objects move) and intuitive biology (how do livings things develop and behave).

The concept of intuitive ontologies combines elements of modularity from cognitive neuroscience, evolutionary psychology, and developmental psychology. It draws on neuroscience in the view that intuitive ontologies are subserved by a stable neural architecture, thus diverging from evolutionary psychology, which does not equate functional specialization with anatomical localizability (e.g., H. C. Barrett & Kurzban, 2006). It borrows the idea of functional specialization from evolutionary psychology in that intuitive ontologies are associated with computationally complex survival problems, including finding food, avoiding predators and handling tools. Rapid and efficient identification of and reasoning about these have significant survival and reproductive advantages. For example, humans make an early intuitive distinction between animate and inanimate objects: animate objects can be self-propelled and are driven by goals, desires and intentions, whereas inanimate objects need to be set in motion externally, and do not have internal mental states. This animate/inanimate distinction has been shown in five-month-olds, (Kuhlmeier et al., 2004), as will be expounded in the introduction to part III; it guides explicit reasoning in preschoolers, who believe, for example, that an unfamiliar animal (such as an echidna) can move itself uphill, whereas an animal-shaped statuette cannot (Massey & Gelman, 1988). As a result of this, we can quickly and without deliberation infer that a person running toward us does so out of his own accord and for a specific reason, but that a ball approaching at great speed is propelled by something other than itself. In both cases, we can react appropriately. The concept of intuitive ontologies also incorporates the notion of core knowledge, in that they emerge early in development without instruction, and remain stable throughout life. Intuitive ontologies continue to play a role in folk knowledge and in scientific understanding (see chapter 11). Based on the existing literature, to date the best candidates for intuitive ontologies include animal, plant, artifact, person and body parts (e.g., Capitani, Laiacona, Mahon, & Caramazza, 2003; Caramazza & Mahon, 2003). Each of these domains contains a distinct set of assumptions, which means that inductive inferences made in one domain cannot be transferred to another. Here are some examples of intuitive ontologies:

Intuitive physics Humans rely on folk physics to predict and understand the behavior of inanimate objects. It is based on principles like contact (objects need to be in direct contact to set each other in motion), cohesion (bounded objects normally do not fall apart) and continuity (an object continues to exist when out of sight). Looking time experiments (e.g., Spelke et al., 1995) indicate that infants as young as four months reason about inanimate objects in this way. They are surprised when a solid-looking object suddenly falls into pieces without any apparent external cause, or when an inanimate object apparently causes the motion of another one without direct contact (no action at a distance). Some principles of folk physics are shared with other animals. For example, Povinelli (2000a) found that chimpanzees, like humans, understand the principles of contact and continuity. However, humans may be unique in their ability to understand physical phenomena in terms of invisible generative causes, such as gravity or momentum (Vonk & Povinelli, 2006) (see also section 10.2).

Intuitive psychology Humans have an intuitive psychological theory (also termed theory of mind) by which they explain actions by attributing internal (unobservable) mental states, such as beliefs, desires and intentions. It develops already during the first year of life, culminating in the ability to verbally solve false belief tasks between four and five years of age. By this age, children seem to realize that the mental representation of a situation may be different from the situation itself (C. D. Frith & Frith, 1999). Their understanding of false beliefs is gauged by tasks that involve deception, such as the so-called Sally–Anne task, during which child has to predict where an agent will look for a previously hidden object based on her false beliefs. It is a cross-culturally robust phenomenon (Callaghan et al., 2005) that children routinely fail such verbal false belief tasks at age three, but can solve them by about five years of age. However, some experiments suggest that an implicit understanding of false beliefs appears earlier in life. Fifteen-month-old infants look longer when an agent looks for an object in a container where the object was moved to when the agent did not see this, and expect her to look for the object where she originally hid it (Onishi & Baillargeon, 2005). Surian, Caldi, and Sperber (2007) found a similar result with 13-month-olds. A recently published looking-time experiment (Kovács, Téglás, & Endress, 2010) pushes this further back to seven month of age. The latter experiment indicates that infants are influenced by the inferred beliefs of other agents, even if this conflicts with the infants' own beliefs. It seems likely that the ability to infer beliefs, especially false ones, is a uniquely human capacity, as nonhuman apes to date have failed all nonverbal false belief tasks (Call & Tomasello, 1999). It is important to note, however, that intuitive psychology (like all intuitive ontologies) consists of several, more fine-grained capacities; it cannot be reduced to an ability to infer beliefs. Cognitive scientists also include the detection of eye gaze and the inference of goals as parts of our intuitive psychology. In many cases of day-to-day interactions these less computationally demanding actions likely play an important role. For instance, the detection of eye gaze enables us to infer someone's intentional state without having to attribute explicit beliefs to this person. Infants are able to detect from birth whether someone makes eye contact with them (Farroni, Csibra, Simion, & Johnson, 2002). The widespread occurrence of eye spots in animal mimicry indicates that the ability to infer eye contact is phylogenetically ancient. Next to eye contact, the direction of the gaze can be used to infer the attention of an agent to things other than itself. Experimental studies indicate that not only apes, but also a variety of domesticated animals (e.g., horses, goats, dogs) are proficient in this (see Itakura, 2004, for an overview). The ability to infer goals is present in nine-month-olds, who can predict, for example, which path an agent (in this experiment, represented by an animated circle, see Fig. 2.2) will take if it wants to reach a specific location (Gergely, Nádasdy, Csibra, & Bíró, 1995). A growing number of empirical studies also indicates that chimpanzees can infer goals (e.g., Hare et al., 2001; Uller, 2004), even if they fall short of representing full belief states. Focquaert, Braeckman, and Platek (2008), for example, argue that a crucial difference between human and chimpanzee intuitive psychology is that only the former have an ability to engage in introspection, which they see as a necessary component of human mindreading abilities.

Intuitive biology At around four years of age (Ahn et al., 2001), 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). Neuroscientific evidence (e.g., Caramazza & Shelton, 1998) indicates that intuitive biological knowledge is dissociable into knowledge about animals and knowledge about plants. Nevertheless, inferences about heredity and development are common for both categories. One of the core intuitions underlying these rich inferences is *psychological essentialism*, the belief that living kinds possess an unchangeable hidden essence, which causes their final form and behavior (Medin & Ortony, 1989). Young children believe that surgically altering a dog to look like a

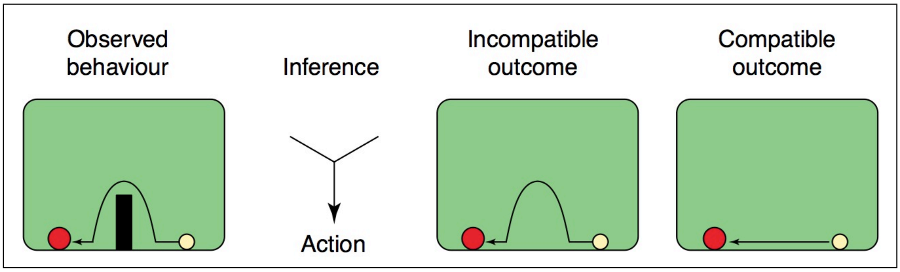

Figure 2.2: Looking-time experiment on the ability to infer goals. Nine-month-olds are shown a little white ball that jumps over a wall (observed behavior). During the test, they see either the ball jump over a wall that is no longer there (incompatible outcome), or go straight to the red ball (compatible outcome). Infants look longer when they see the ball jump, indicating that they expect the ball to take the shortest route to its goal. From Gergely and Csibra (2003, p. 288, Fig. 1).

raccoon does not actually transform this dog into a raccoon (Keil, 1989): it is the inside essence that matters, not the outside superficial appearance. Four-year-olds 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 & Wellman, 1991). One recent study (Phillips, Shankar, & Santos, 2010) suggests that essentialism may not be uniquely human. In this study, rhesus monkeys were shown how an exterior of one type of fruit (e.g., shell of a coconut) was placed around a different type of fruit (e.g., an apple). Then, a piece of the inside of the composite object was placed inside a box. The monkeys searched longer in the box when the piece of fruit they found was inconsistent with the inside of the original fruit—so in this example, if they found a piece of coconut instead of a piece of apple, they would continue searching longer in the box as if they were expecting to find a piece of apple. This study indicates that monkeys, like humans, expect the inside of a living thing to remain unchanged when its exterior undergoes a change. Another important element of intuitive biology is *teleology*, the tendency to think about the parts of living things (and even about living things in their entirety) in terms of purposes. The developmental psychologist Jean Piaget (1929 [2007]) was the first to propose that children tend to view objects, including natural ones, as designed for a purpose:

> [T]he child conceives every object, including the natural bodies, as, to use his own terms, "made for" a purpose. Now for a natural object, such as the sun, the lake or the mountain, to be considered as "made for" warmth, for boating, or for climbing implies that it is conceived as made "for man" and consequently closely allied to him (Piaget, 1929 [2007], 356).

People intuitively assume that animals and plants have parts that serve purposes that are beneficial for their owners, such as claws in cats for climbing or defense, or thorns in plants so that they do not get eaten. This kind of reasoning is termed teleology—it is an explanatory strategy that sees the purpose of a given structure as a necessary and sufficient explanation for why that structure exists. Teleology enables children to learn useful facts about organisms. Even three-year-olds can infer the diet of an unfamiliar animal based on the shape of its beak, and they can predict that an unfamiliar mammal with webbed feet lives in the water (Kelemen, Widdowson, Posner, Brown, & Casler, 2003), as illustrated on Fig. 2.3. Preliminary crosscultural studies indicate that this intuition is not only deeply engrained in people from western cultures, but also appears in other cultures such as the Shuar, Native Americans from the Andes. The Shuar, like westerners, classify animals and plants according to their functional parts, and think about these in terms of goal-directedness (H. C. Barrett, 2004).

Intuitive engineering A growing number of developmental psychologists (e.g., Kelemen & Carey, 2007) are convinced that artifacts constitute a distinct domain of intuitive knowledge, with its own set of inductive inferences and assumptions. As we shall see in more detail (see e.g., sections 7.2.1 and 9.2.1), humans have an intuitive *design stance*, by which they infer the function and identity of artifacts by the (inferred) intention of the designer. In other words, when considering an artifact, we tend to keep the intended

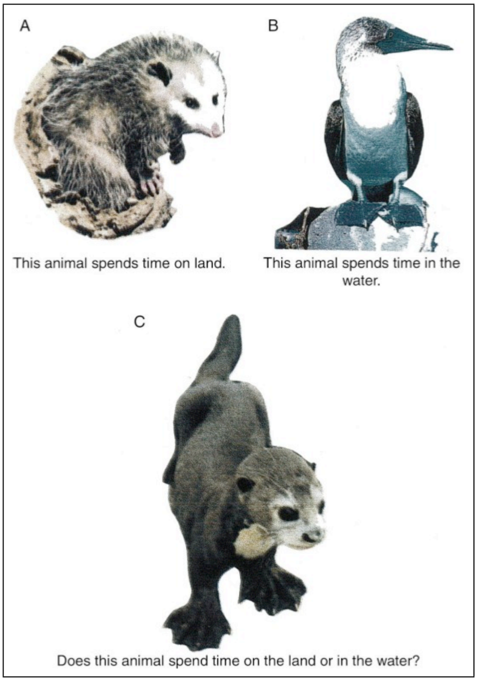

Figure 2.3: Young children can infer that the unfamiliar mammal (c) spends most of its time in the water due to its webbed feet, despite its greater superficial resemblance to a mammal that lives on land (a). From Kelemen (1999, Fig. 2, p. 464).

identity or use of the object in mind. Humans find the original function of an artifact more important than its current function. For example, adults judge that an object designed for exercising back muscles is still a training instrument, even if it is currently exclusively used for stretching clothes (German & Johnson, 2002). Children also have the intuition that the intention of the maker of an artifact is crucial for its identity: a spoon-shaped object is a key if the maker intended it to be a key—even if it looks more like a spoon (Jaswal, 2006). The design stance develops gradually between the ages of about nine months to six years (Casler & Kelemen, 2007). Two-year-olds who are exposed to a novel artifact that is used for a specific purpose will continue to use that artifact for that purpose, even if they only saw it demonstrated once, a phenomenon known as fast mapping. Moreover, they will avoid using the artifact for other, equally feasible purposes (Casler & Kelemen, 2005). In this respect, young children treat artifacts in a manner that is very distinct from other tool-using species. The key signature of a fully developed design stance is *functional fixedness*: subjects become *fixed* upon the intended design and function of an object, and are thus hindered to use objects flexibly in an atypical way to solve problems. A classic example is the following task designed by Duncker (1945): participants were given a book of matches, a candle, and a box of thumbtacks, and were asked to attach the candle to the wall in such a way that it would not drip onto the floor when being lighted. Many participants attempted to solve this problem by trying to glue the candle to the wall with hot candlewax, or even tried to attach the candle with the thumbtacks directly. Very few actually thought of emptying the box, putting a tack through one of its sides, attaching it to the wall, and finally putting the candle in the box. Adamson (1952, 289) argued that the prior use of the box as a container for the thumbtacks inhibited participants from using it as a candle stand. German and Barrett (2005) found that the Shuar, who have little material culture, are also hindered by functional fixedness. This is especially intriguing given that the Shuar often recycle their artifacts for other purposes. Yet, Shuar participants will insist that an object that was originally made for catching fish is a net, even if it is currently exclusively used as a hammock (H. C. Barrett, Laurence, & Margolis, 2008). Our intuitive ontological assumptions about artifacts may constitute a human-specific cognitive adaptation, possible evolved as a result of hominids' extensive reliance on tools for at least 2.6 million years (Semaw et al., 1997). Indeed, chimpanzees are more efficient than children at finding solutions to artifact-related problems because they disregard the suboptimal solution shown by an experimenter (Horner & Whiten, 2005).

2.3.2 Neural underpinnings of intuitive ontologies

Neuroimaging studies 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 & 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, both underlying intuitive psychology); mechanical action preferentially activates the medial aspect of the fusiform gyrus and the left middle temporal gyrus (usually activated in artifact recognition and physics, parts of intuitive physics). Thus, the brain does not just passively construct abstract information from sensory cues, but actively constructs conceptual frameworks to interpret the sensory information.

A useful theoretical framework in cognitive neuroscience is the domain-specific hypothesis, developed by Alfonso Caramazza and coworkers (e.g., Caramazza & Shelton, 1998; Caramazza & Mahon, 2003). According to this hypothesis, evolutionary pressures have resulted in specialized and dissociable neural circuits dedicated to different categories of objects. The categories of objects predicted by this hypothesis are those whose identification and reasoning would have conferred significant fitness advantages. Plausible categories include conspecifics (subserved by intuitive psychology), animals, fruits and vegetables (forming intuitive biology), tools (intuitive engineering), and body parts. To test the domain-specific hypothesis, neuroscientists (e.g., Caramazza & Shelton, 1998) have relied extensively on lesion studies. Brain lesions can selectively impair knowledge about a specific ontological domain, while leaving other domains intact, leading to the interpretation that evolutionary pressures have resulted in specialized and dissociable neural circuits dedicated to processing knowledge about different ontological categories. A review of 79 case-studies of patients with category-specific forms of semantic impairment revealed that animal, plant, conspecific (human), artifact and body parts are categories that can be selectively impaired (Capitani et al., 2003). Consider the following striking example: EW, an elderly woman who suffered brain-damage, has extreme diffculties 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?” By contrast, her understanding of artifacts and plants has remained intact (Caramazza & Shelton, 1998).

Neuroimaging studies (e.g., Caramazza & Mahon, 2003) suggest that some parts of the temporal and occipital cortex are exclusively dedicated to perceiving and thinking about animals. Interestingly, the neural correlates that correspond to the perception of animals are similar in sighted people as in congenitally blind subjects (Mahon, Anzellotti, Schwarzbach, Zampini, & Caramazza, 2009), indicating that this neural organization is not the result of perceptual features of animals, but rather of selective pressures that have formed specialized areas within the human brain that deal with semantic knowledge about animals. If we assume that each of the evolved neural structures that subserves intuitive ontologies 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 artifacts. 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 artifacts is comparable to that of control subjects (Farah & Rabinowitz, 2003). This implies that prior to any experience with living or nonliving things, genes specify distinct neural systems for storing knowledge about them.

2.4 Conclusion

We know a lot more about the human mental toolbox than we did a generation ago, thanks to advances in developmental and evolutionary psychology and cognitive neuroscience. Taken together, results from these disciplines strongly indicate that the human brain is not a holistic, undifferentiated processor, but rather, that human minds consist of several specialized domains of knowledge. At present, it remains unclear whether a limited number of cognitive specializations (as in core knowledge) or rather a multitude of modules (as in massive modularity) can account for the human cognitive architecture. This is partly because the current empirical evidence is consistent with both massive and more modest forms of modularity, although it is in principle possible to design empirical studies that would differentiate between the two (e.g., the extent to which different cognitive functions are functionally incompatible with each other has not been investigated). I have defended a hybrid position, which does not regard massive modularity and core knowledge as opposing positions, but as concepts that can be integrated. Neuroscientific and developmental psychological evidence is consistent with the view that intuitive ontologies are subserved by more elementary modules, each specialized in a narrow domain of inference. As we shall see in the next chapter, the language faculty likewise is composed of a number of elementary conceptual and perceptual modules, each with its own evolutionary and developmental trajectory.

As we have seen in this and the preceding chapter, the human brain does not present a radical new type of cognitive architecture that is unlike that of other animal species. And, as we shall see in the next chapter, this is even not the case for a uniquely human capacity such as language. However, this does not imply that all human cognitive faculties can be found to some extent in other species. The mental continuity assumption thus construed is misguided, since humans (like other animals) possess a mixture of plesiomorphic[7] and apomorphic[8] cognitive capacities. For example, as we have seen, human intuitive psychology relies amongst others on the abilities to detect eye gaze and goals which are phylogenetically widespread, but also on the ability to infer internal mental states, a capacity hitherto unattested in nonhuman animals.

CHAPTER 3

THE CASE OF LANGUAGE

This chapter is a revised and expanded version of De Smedt, J. (2009). Cognitive modularity in the light of the language faculty, *Logique & Analyse*, *208*, 373–387.

In this chapter, we shall examine what is perhaps the most salient example of an evolved, specialized, human capacity: the language faculty. Ever since Noam Chomsky, language has become the paradigmatic example of an innate capacity. Infants of only a few months old are aware of the phonetic structure of their mother tongue, such as stress-patterns and phonemes. They can already discriminate words from non-words and acquire a feel for the grammatical structure months before they voice their first word (Hespos, 2007). Language reliably develops not only in the face of poor linguistic input, but even without it. For instance, within a community of Israeli Bedouins, a group of people with hereditary deafness have developed their own sign language which has a grammatical structure that does not resemble that of the surrounding speaking community (Sandler, Meir, Padden, & Aronoff, 2005). Over the past few decades, several scholars (e.g., Pinker & Bloom, 1990) have extended this uncontroversial view on language into the stronger claim that natural language is a human-specific cognitive adaptation. As will be pointed out, this position is more problematic because of a lack of conceptual clarity over what human-specific cognitive adaptations are, and how they relate to modularity, the notion that mental phenomena arise from several domain-specific cognitive structures (see section 2.2). The main aim of this chapter is not to discuss whether or not language is an adaptation, an issue which has already been amply discussed, notably by Steven Pinker (1994), but rather, to examine the concept of modularity with respect to the evolution and development of natural language. This chapter will develop a parsimonious account of language: according to the model developed here, the human language faculty does not depend on a silver bullet theory, but rather on the co-optation of several modules, many of which (although not necessarily all) are shared with nonhuman animals. This is a recurrent theme throughout this dissertation, as later the same approach will be adopted for artistic expression, religious reflection and scientific practice.

3.1 Which cognitive capacities are specific to language?

The scientific study of cognitive modularity and of natural language as a specialized human capacity share common roots. As we saw in section 2.2.1, during the later decades of the 19th century, the physicians Paul Broca and Carl Wernicke noticed that a selective impairment of a cortical area in the left hemisphere could lead to a specific kind of language impairment. Patients with damage to the inferior frontal gyrus —Broca's area—suffered from an inability to understand and formulate grammatical sentences, whereas those with damage to the posterior part of the superior temporal gyrus—Wernicke's area—suffered from an inability to understand the meaning of words. It seemed a perfect dissociation: grammar processed by one area of the brain, vocabulary by another (Fig. 3.1a).

However, a growing body of evidence from neuroimaging studies, developmental psychology and neuropsychology indicates that this classical model of the neural correlates of language is fundamentally wrong (see Poeppel & Hickok, 2004, for a review). Most neuroscientists today agree that Broca's and Wernicke's areas are involved in a larger and as yet poorly understood neural network that also involves other temporoparietal prefrontal areas, as well as subcortical areas, such as striatum, basal ganglia, thalamus and cerebellum (Fig. 3.1b). Moreover, Broca's area is not uniquely involved in grammar, but also plays a role in nonvocal imitation (Heiser, Iacoboni, Maeda, Marcus, & Mazziotta, 2003) and the comprehension of musical structure (Maess, Koelsch, Gunter, & Friederici, 2001). Indeed, as we shall see in more detail in section 5.2, understanding grammar and musical harmony and rhythm are subserved by the same brain areas—violations in musical structure give the same neural signal in Broca's area as violations in grammatical structure (Maess et al., 2001). The functional specialization of Broca's area has precursors in nonhuman animals: a recent neuroimaging study (Taglialatela, Russell, Schaeffer, & Hopkins, 2008) indicates that a homolog of Broca's area is active when chimpanzees produce communicative gestures and vocal signals. Similarly, anatomical observations (Gannon, Holloway, Broadfield, & Braun, 1998) and an MRI study (Hopkins, Marino, Rilling, & MacGregor, 1998) indicate that the left planum temporale, a portion of Wernicke's area that serves linguistic functions in humans, is also enlarged in nonhuman great apes.

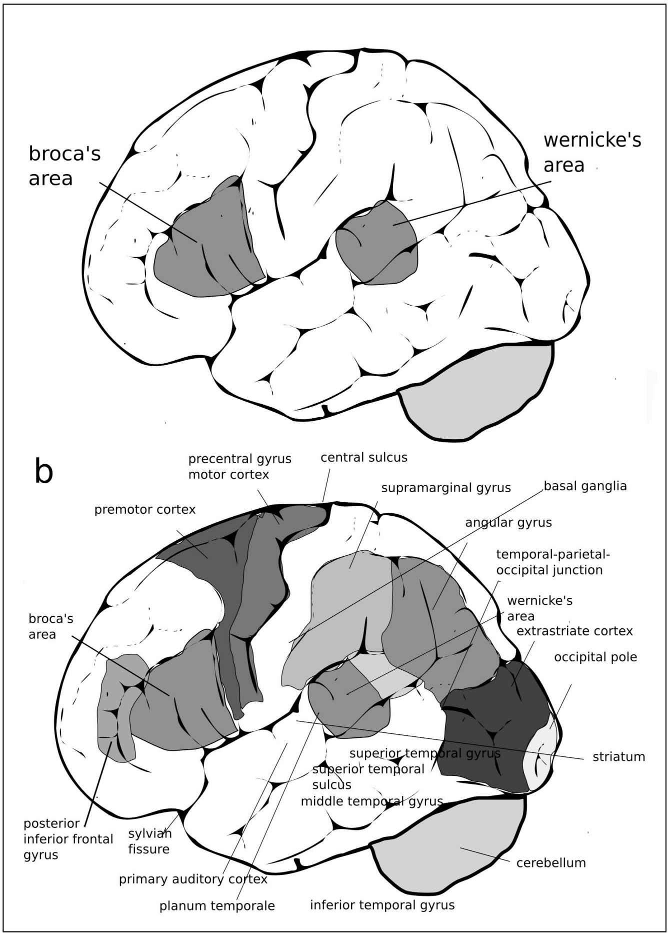

Figure 3.1: (a) Location of Broca's and Wernicke's areas in the human brain; (b) brain areas currently known to be involved in language processing.

To add to the confusion, language relies on cognitive capacities that are not specialized for language and that are not uniquely human either. Consider word learning. A necessary condition for word learning is the capacity to isolate words within a stream of continuous speech. Saffran, Aslin, and Newport (1996) demonstrated that eight-month-old infants rely on probabilistic information to detect words: they discern strings of syllables that occur with greater statistical frequency (e.g., 'bida' in the string bidakupagodibidaku. . .) as words. Since many animals can detect statistical regularities in their environment, it is perhaps unsurprising that this capacity is also found in nonhuman animals, including rats (Toro & Trobalón, 2005)[9]. Fast mapping, the ability of children to learn a word after just hearing it once, was first proposed as a capacity specific to word learning, but it turns out to be a more domain-general cognitive capacity. Markson and Bloom (1997) found that three-year-olds can also fast map facts (e.g., this object is called 'feb' versus this object was given to the experimenter by her uncle). Moreover, domestic dogs are also able to learn words through fast mapping. In a series of experiments (Kaminski, Call, & Fischer, 2004), a border collie was presented with an array of objects, all of which he knew by name except one. When requested to fetch x (with x the name of the unknown object), Rico correctly learned this word by exclusion, and still remembered it four weeks later. The arbitrary linking of vocal calls with concepts has been found in several nonhuman species, such as vervet monkeys, which have three distinct alarm calls for three kinds of predators, leopard, eagle and snake (Seyfarth, Cheney, & Marler, 1980), or dolphins (Janik, Sayigh, & Wells, 2006), that rely on signature whistles to discriminate between conspecifics. Even the fine discrimination of speech sounds (such as /b/ and /p/ or /d/ and /t/), once thought to be a hallmark of the human language faculty, is present in a variety of species, including chinchillas (Kuhl & Miller, 1975).

It turns out that many features of human cognition are necessary for the production and comprehension of grammatical language. Language exhibits intentionality—linguistic expressions are 'about something'. In order to have its semantic content, language relies on a pre-linguistic conceptual capacity, i.e., the capacity to make mental representations of objects such as DOG or WATER, and more abstract objects like SOLITUDE and HUNGER. As we have seen in section 2.3.2, selective impairment of brain areas involved in specific domains of semantic knowledge leads to impairments in the ability to learn the meanings of the corresponding words, e.g., some patients cannot answer simple questions about animals or plants, like 'Does a whale fly?', but do fine in other domains of knowledge, such as artifacts (Caramazza & Mahon, 2003). Some features of language, although stable across human cultures, may not even be innate at all. Because languages are limited by extrinsic factors like intelligibility, these features probably come about through the dynamics of group interactions rather than innate tendencies. Linguistic categories usually have a small number of members—for instance, although humans can discriminate about 10 million different colors, all known natural languages have fewer than 15 basic color terms.

3.2 Language and modularity

The past years have witnessed a lively debate on the question of whether language is a byproduct (e.g., Hauser, Chomsky, & Fitch, 2002) or an adaptation (e.g., Pinker & Jackendoff, 2005). One way to approach this question is to examine language from the perspective of cognitive modularity. Although not all cognitive modules are evolutionary adaptations (e.g., reading), there is a growing tendency to see modularity as a necessary condition for evolvability, i.e., the ability of a system (biological or artificial) to evolve. The evolvability argument (e.g., Sterelny, 2004) holds that unless cognition is to some important extent modular, it is incapable of evolving away from its current organization: a change in one component will be connected to many other changes, and even the slightest modication can have disastrous effects on the organism. The importance of modularity for evolvability has been demonstrated in disparate disciplines, including evolutionary artificial life (Nilsson & Pelger, 1994) and evolutionary biology (Lewontin, 1978). In evolutionary computer science, too, modular systems prove to be far more robust and flexible, and can be taught to learn something with more efficiency and ease than holistic systems (Jacobs et al., 1991; Wagner & Altenberg, 1996).

As we saw in section 2.2.3, the view that there are good evolutionary reasons to expect some degree of modularity in human and other animal brains has been taken up by evolutionary psychologists. Indeed, they argue that brains must be modular because they perform a variety of tasks that are better achieved by separate systems than by one holistic processor (e.g., Cosmides & Tooby, 1994b). Mind, since natural selection is a tinkerer, not an engineer (Jacob, 1977), it is not inconceivable that it would shape suboptimal non-modular brains. Nevertheless, even without invoking optimality, modularity remains plausible because any reasonably complex nervous system is faced with multiple tasks that are functionally incompatible. For instance, marsh tits and chickadees sing and cache food, activities that require distinct memory systems (Sherry & Schacter, 1987). Food-caching requires a memory that is flexible and can be updated regularly as the birds cache food at different locations each year, and must sometimes relocate food from caches that have been pilfered, whereas song-learning relies on a critical learning period in which the birds learn a particular repertoire that will not change during their lifetime. Since both types of memory are functionally incompatible, marsh tits and chickadees should have at least two distinct memory systems.

If we take a relatively broad, neurologically informed definition of modularity which specifies that modules are domain-specific computational devices, dedicated to solving specific tasks, and associated with specific brain structures, then language is non-modular. Given that most aspects of human cognition are involved in language, and given that brain structures most commonly associated with language do not appear to be uniquely specialized for language, it is difficult to term language modular without eroding the very concept of modularity. As we have seen (section 2.2.3.1), there are also good reasons to argue that modularity should be grounded in *functional specialization*, i.e., modules should be defined by their function, both from a proximate and an ultimate point of view. Whereas the proximate function of language is uncontroversial (it is used for communication), there is much disagreement over the question why ultimately language evolved. Explanations range widely: amongst others kin selection, communication during hunting, facilitating cultural transmission, enhancing social bonds through gossip (see Számadó & Szathmáry, 2006, for an overview). In sum, evolutionary accounts of language face several problems: there is no well-defined language module, many disparate domains of cognition are important to it, and its ultimate function remains unclear.

3.3 How did language evolve?

3.3.1 The FLB/FLN distinction

Hauser, Chomsky, and Fitch (2002) argue that language is modular, but that it is not an adaptation. They differentiate between two aspects of language. The faculty of language in the broad sense (FLB) consists of capacities that are necessary for language, but that are not restricted to it. The faculty of language in the narrow sense (FLN) comprises capacities that are unique to language. If FLN is sufficiently small, it is not inconceivable that language evolved through non-selective processes, such as genetic drift. In this scenario, human language depends on a host of cognitive capacities that are present in nonhuman animals and one very specific silver bullet, that emerged through a nonselective evolutionary process. Hauser, Chomsky, and Fitch (2002) identify recursion as the only thing that is specific to language and that is uniquely human—two properties that are logically independent, but that they systematically conflate. A recursion specifies a class of objects by defining a few simple base cases or methods, and defining rules to break down complex cases into simpler ones, e.g., my parents are my ancestors, my parents' parents are also my ancestors and so on. In language, recursion allows one to generate an infinite number of expressions from a finite vocabulary and a limited set of rules. Thus, expressions like 'to thine own self be true' can be embedded into larger frames like 'Shakespeare first coined "to thine own self be true" and many other expressions'. According to Hauser et al. (2002), if recursion were indeed the only evolutionary novel aspect of natural language, its emergence through nonselective processes seems parsimonious.

However, recursion is not unique to language, as exemplified by three agrammatic patients who were able to solve mathematical tasks that require recursion (Varley, Klessinger, Romanowski, & Siegal, 2005). All three had suffered severe damage in the left hemisphere and were incapable of producing and understanding grammatical speech. Still, they were able to work out complex bracket operations that can only be solved if recursive rules are adopted, and they could even come up with numbers bigger than 1 but smaller than 2, using a simple recursive rule (1.9, 1.99, 1.999, . . .). Moreover, recursion does not occur in all natural languages. Based on more than 20 years of fieldwork, the linguist Dan Everett (2005) has argued that the language of the Pirahã, a Native American culture from Brazil, is not recursive: it does not have self-embedded structures that can be expanded at will. Recursion is not a uniquely human capacity either. T. Q. Gentner, Fenn, Margoliash, and Nusbaum (2006) successfully taught starlings to recognize recursive strings of sounds. So FLN does not do the conceptual work it is supposed to do: it is not unique to language, and it is not even necessary for it.

A more fundamental problem with the FLB/FLN distinction is that it is not biologically relevant. Hauser, Chomsky, and Fitch (2002) take all traits that can be found in at least one nonhuman species as FLB, i.e., as not uniquely human traits. This confuses the notion of uniquely human and derived traits. A plesiomorphic or ancestral trait is present in an ancestral species (or clade) and its descendants. For example, the spinal chord is plesiomorphic with respect to goldfish and cats, because both species have inherited this trait from a common ancestral vertebrate species. A derived trait is a specialization found in one species (or clade), but not in closely related others. For example, the elephant trunk is a derived trait for elephants compared to other mammals, since no other extant species of mammal has this trait. For the same reason, wings of bats are derived with respect to other mammal clades, even though wings are not unique to bats. Hauser, Chomsky, and Fitch (2002), however, mistakenly claim that all capacities that are not uniquely human are plesiomorphic. For example, they argue that the ability for vocal imitation is not a uniquely human trait because cetaceans and some species of bird also possess this capacity—this view is mistaken because our closest living relatives (the great apes) are not able to imitate vocalizations, as is aptly illustrated by decades of experiments in which chimpanzees were in vain taught to speak. Hence, human speech and a parrot's ability to imitate a wide range of sounds are similar, but not because they share a recent common ancestor. Humans only imitate human language and a limited array of other sounds, finches only imitate conspecifics, and mynahs and parrots imitate a wide range of sounds, including all sorts of natural (streaming water, barking dogs) and artificial (telephone ringing, creaking doors) sounds. In everyday loose parlance all these phenomena are deceptively referred to as vocal imitation, but actually they are three distinct biological phenomena. The fact that humans are relatively poor at imitating nonvocal sounds such as whinnying horses or flying helicopters, whereas mynahs and parrots are good at it, bears testimony to this fact.

3.3.2 The evolution of traits specific to language

Pinker and Jackendoff (2005) rightly remark that traits that are special to language need not be uniquely human, and conversely, that not all uniquely human traits are specific to language. Nevertheless, they do accept the FLB/FLN distinction as a useful way to look at language. Using inference to the best explanation, they claim that some anatomical and cognitive adaptations have arisen to meet the demands of vocal communication. Enhanced human hearing due to upregulations (mutations that indicate positive selection) in auditory genes can be plausibly explained as a result of selective pressures brought about by the elaborate vocal communication in humans; the lowering of the human larynx can likewise be interpreted as an adaptation that facilitates the production of speech sounds—although both also serve other adaptive functions (e.g., voice timbre in males as a sexually selected trait). If a distinction between traits 'specific to language' and those 'not special to language' can be made, then it is not difficult to envisage that natural selection honed human anatomical and cognitive traits in such a way as to facilitate vocal communication. However, the inference from current function to adaptive origin cannot be made thus: it is not because the human auditory system, larynx and other traits have adapted to language, that language itself started as an adaptation in the past.

The distinction between what is special to language and what is not sometimes looks arbitrary. Pinker and Jackendoff (2005) argue that some capacities for conceptual thought are uniquely human, but not specific to language. For example, they write that humans are able to represent false beliefs, whereas chimpanzees and other great apes are not. It remains equivocal, however, whether the capacity for reasoning about false beliefs is language-specific or not. Newton and de Villiers (2007) asked adults to solve a simple false belief task while concurrently either shadowing (repeat with some delay) a pre-recorded dialogue or tapping along with a rhythmic soundtrack. The dialogue, but not the tapping, resulted in a serious disruption in the false belief reasoning. Might one not be tempted to conclude that false belief reasoning is language-dependent, and hence specific to language, especially since the ability is seriously compromised in those who cannot speak, and delayed in deaf children raised by hearing parents (these children also experience a delay in language development). A similar argument could be made for natural numbers, which can only be accurately represented by humans. Whereas infants and nonhuman animals can only distinguish very small numbers up to three precisely, and larger numerosities only when the difference between them is large enough (e.g., 6 and 12, but not 10 and 12), more educated children and adults can discriminate large numbers accurately (see De Cruz, 2006; De Cruz & De Smedt, 2010a, for an overview). Speakers of languages with very few number words represent numerosities as imprecisely as infants. Although it needs much more support to claim that this difference is caused by language, maybe in its use as a cognitive tool to guide exact representations (M. C. Frank, Everett, Fedorenko, & Gibson, 2008), such uniquely human concepts might turn out to be language-specific.

Proponents of language as a modular adaptation argue that our linguistic capacities can be selectively impaired or spared. Williams syndrome (WS), a rare genetic disorder due to a deletion of about 25 genes in the 7q11.23 region (on the long arm of chromosome 7), affects many domains of cognition, especially social abilities and visuospatial skills. People affected by WS find it difficult to infer other people's mental states; they also have difficulties finding their way and performing mundane motor-tasks such as tying their shoes. In comparison to this, their linguistic skills seem to remain relatively spared. Some authors (e.g., Pinker, 1995, 274) even suggest that WS patients are "hyperlinguistic": in their spontaneous speech, they choose markedly more unusual and sophisticated words, like 'mince', 'sauté' and 'alleviate'. When asked to name a number of animals, a normal eight-year-old will come up with prototypical barnyard and pet animals like 'cat', 'dog', and 'sheep'; WS children typically respond with more exotic examples like 'unicorn', 'yak' and 'chihuahua'. This has led several researchers (e.g., Pinker, 1994, 44–46) to claim that the language faculty can be considered as a modular computational system, which can be selectively impaired or spared. Yet, the atypical word choice reveals that at the semantic level, the language capacity of WS patients is disrupted. Their word-learning relies more on the phonological properties of words than on their meanings (Bellugi, Lichtenberger, Jones, Lai, & St. George, 2000). This may explain why vocabulary learning is severely delayed in young children with WS: only at about 28 months they reach the lexicon of a typical one-year-old. Older children and adults with WS have difficulties with placing words into different categories, e.g., both Spiderman and Mozart are 'not alive', but WS subjects fail to see that in this case 'not alive' belongs to two different categories, i.e., fictional character and dead person (Bellugi et al., 2000). They also perform worse when they have to sort a homonym with its more common associate, e.g., to pair 'bank' with either 'money' or 'river', normal subjects spontaneously choose 'money', but WS subjects show no preference (Brock, 2007). Semantics is indisputably one of the core features of language—language has intentionality, it refers to concepts or things in the world. The disrupted semantics of WS patients speaks against the claim that their language faculty as a whole would be selectively spared. Of course, this does not provide definite evidence against the modularity of language, but it does show that a phenomenon that is often cited as a very strong case of selectively spared linguistic skills is not in fact as clear-cut. Double dissociation requires that a faculty can be selectively impaired or spared. While there are well-documented cases of language-specific impairment (see below), to my knowledge, there are no convincing cases for the selective retention of language.

3.3.3 Deep homologies and FoxP2

Over the past decade, the discovery of *FoxP2*, a gene critically involved in the development of language, has given an exciting new perspective on the evolution and modularity of language. People with mutations in this gene have serious impairments in many areas of speech, including effortful, slow speech, problems with phonology, and difficulties in grammar comprehension. This was first observed in members of a single family, and has since been extended for a large sample of patients with language specific impairments (Feuk et al., 2006). *FoxP2* expression is not specific to the human brain; it is also expressed in the lungs, gut and heart. It is also not unique to humans, as it occurs in clades as divergent as mice, nematodes, and yeast (Marcus & Fisher, 2003). Enard, Przeworski, et al. (2002) noted that there were only three amino-acid substitutions separating human and mouse *FoxP2*, two of which were evolutionary very recent, occurring after the human-chimpanzee divergence, and therefore human-specific, as shown in Fig. 3.2a. Interestingly, the derived *FoxP2* variant of modern humans has also been found in fossil neanderthal DNA (Krause et al., 2007).

Remarkably, *FoxP2* also plays a key role in vocal communication in nonhuman species. Inhibiting *FoxP2* expression in the basal ganglia (a brain area critical to the development of song repertoire) in young songbirds hampers their capacity to learn songs (Haesler et al., 2007). A disruption in one copy of the *FoxP2* gene in mice pups yields a substantial reduction in ultrasonic vocalizations that are normally elicited when they are separated from their mothers (Shu et al., 2005). Given the extreme specialization of the auditory system in bats as a means of echolocation, it is perhaps not surprising that bats species have very diverse versions of the *FoxP2* gene. The diversity of *FoxP2* is larger within bats than in any other mammalian lineage (Li, Wang, Rossiter, Jones, & Zhang, 2007), as can be seen on Fig. 3.2b.

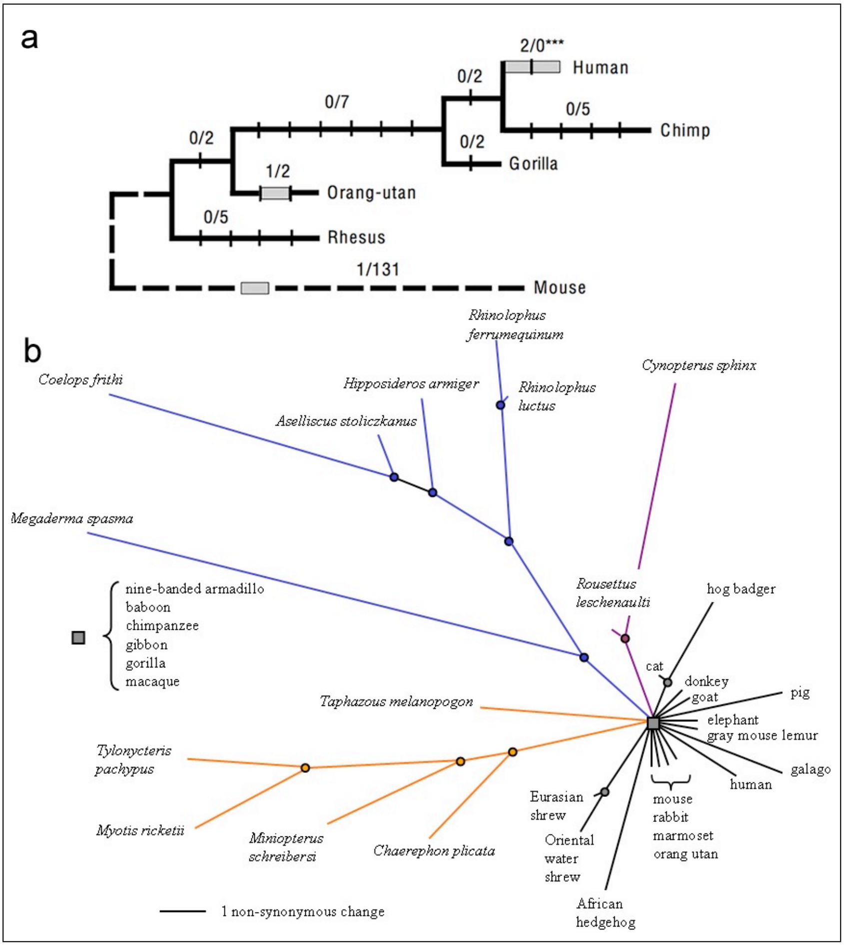

Figure 3.2: Two views on the evolution of the *FoxP2* gene in mammals (a) nucleotide substitutions indicated by grey boxes, from Enard, Przeworski, et al. (2002), Fig. 2, p. 871; (b) the branch lengths on this figure indicate the number of non-synonymous nucleotide substitutions that occurred in each species; species of bats are indicated in italics. Note that the bats (colored lines) show the widest variation in *FoxP2*, from Li et al. (2007), Fig. 1, p. 3.

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Language, birdsong and mouse vocalizations may be examples of deep homologies, traits that look like examples of convergent evolution, but that nevertheless share a deep genetic ancestry. A homology, classically defined, refers to a historical continuity: morphological features in different clades look similar, because they are inherited from a common ancestor. Deep homology also points to a historical continuity, but one that is less anatomically obvious: the similarity in function is due to commonly inherited regulatory genes (Shubin, Tabin, & Carroll, 2009). The paradigmatic example of this is *Pax-6*, a gene that stands at the top of a developmental cascade involved in eye-development (it can even generate an eye on the antenna of a fruit fly if it is artificially expressed there). Eyes in different organisms exhibit such divergent anatomical structures that biologists used to think that eyes had evolved independently dozens of times. However, studies of gene expression in a variety of species, including fruit flies and mice, indicate that *Pax-6* is involved in the building of light-sensitive cells. In all sighted animals, the development of eyes depends on a cascade that involves the production of opsin proteins, which is triggered by the *Pax-6* gene. The best explanation for this is that all animals that have eyes inherited *Pax-6* from a common ancestor, but that each lineage developed different cell types for the detection of light (Shubin et al., 2009). Thus, the cellular circuitry that underlies eye development is a deep homology that predates the evolution of eyes in vertebrates and invertrebrates. Apparently, *Pax-6* can be easily modified to produce light-sensitive cells, and natural selection has hit upon this solution several times independently. If *FoxP2* acts as a 'master control gene' for language development, one can see how slight evolutionary changes in this gene might have shaped the evolution of human language (and bat echolocation, bird song and mouse vocalizations). As Marcus and Fisher (2003) argue

> The genetic mechanisms involved in speech and language development are likely to involve recruitment and modification of pre-existing genetic cascades, much in the way that the development of the wing began with the development of the basic design of a vertebrate forelimb (Marcus & Fisher, 2003, 261).

Deep homologies show that natural selection often recycles ancient structures. Although birdsong and human speech evolved independently due to different kinds of evolutionary pressures, *FoxP2* is critically involved in the development of both kinds of communication, because across species the gene seems to be co-opted for tasks involving complex facial muscular motions and vocal communication. Unfortunately, the causal role of genes in shaping cognition is still poorly understood. As a mutation in *FoxP2* does not altogether abolish the ability to speak, but merely compromises it, more genes must be at work in the development of language. Similarly, inhibiting the expression of the gene in songbirds does not eliminate their capacity for song learning entirely (Haesler et al., 2007).

3.4 Toward a more fundamental solution

The view of natural selection as a tinkerer is not just useful for looking at language evolution at the molecular level, it can also be applied to the anatomical level. An advantage of this is that we have a much better (albeit still fragmentary) understanding of language from the anatomical than from the genetic-developmental point of view. To understand how something as highly specialized as the language faculty emerged, evolutionary thinkers might have to reconsider their notion of modularity. Evolutionary psychologists have a relatively coarse-grained view of modularity: to them, modules are domain-specific units, dealing with evolutionarily salient tasks like inferring mental states or vocal communication. On the other hand, cognitive neuroscientists have a more fine-grained idea of modularity: they take modules to be specified units with a narrow function that are connected in larger, distributed networks. Particular modules can be co-opted for several tasks. For example, cognitive neuroscientists have demonstrated that theory of mind (inferring mental states) is not subserved by a single module, but by several neural structures involved with narrow domains like eye-direction detection and detection of biological motion (Castelli, Happé, Frith, & Frith, 2000). The module that detects biological motion is not only used for inferring mental states, it also functions in a network involved in semantic knowledge about animals (Chao, Haxby, & Martin, 1999)—arguably, an important part of our semantic knowledge about animals is how they move.

There are no theoretical reasons why modules should correspond to domains humans find intuitively appealing, such as language, theory of mind or number. Rather, the grain of modularity is something to be empirically discovered. For example, traditionally, theory of mind was seen as a single module that could be selectively impaired, and that was engaged in inferring the mental states of others (Baron-Cohen, 1995). But recent studies with nonhuman primates have challenged this monolithic view: in a recent review paper, Call and Tomasello (2008) argue that chimpanzees know what others can and cannot see, that they understand the goals and intentions of others, but that they cannot understand false beliefs. Hence the seemingly straightforward question 'does the chimpanzee have a theory of mind?' cannot be answered by a simple yes or no. Nine-month-old human infants (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999) and even seven-month-olds (Kovács et al., 2010) are already able to understand other agents' goals and intentions. Yet, a fully-developed theory of mind that involves the ability to understand second- and even third-order intentionality (e.g., she knows that I know that he knows) is demonstrated to only mature by the age of four or five (e.g., Callaghan et al., 2005). It may therefore be useful to abandon investigating theory of mind as a whole, but rather to concentrate on more basic, finer-grained capacities (like detecting goal-directed behavior) that together constitute the ability to understand the minds of others.

As we have just seen, current neuroanatomical and neuroimaging studies point toward a fine-grained modularity, where elementary modules are recruited in diverse larger, distributed networks. A useful metaphor to capture how this might work is a large set of hundreds of lego blocks, which can be recombined to make larger, meaningful objects. In isolation, each of these blocks may not be evolutionary significant, but the role each of them fulfills in the larger wholes (the distributed networks) allows that natural selection can fine-tune them to better fulfill their role. For example, the module involved in edge detection alone cannot do much, but the role it fulfills in the visual system as a whole makes that natural selection can improve the detection of edges. Similarly, phoneme detection by itself does not do much, but its role in communication and other auditory tasks can fine-tune its ability. The view outlined here has some affinities with Carruthers' (2006) concept of massive modularity that proposes that most of our cognitive processes are subserved by dedicated modules, the input of which can be flexibly combined by the language module to produce creative thought. An important difference is that I do not conceptualize language as a module in itself, but rather as an interplay of several fine-grained modules that can be combined with others in a variety of linguistic and nonlinguistic tasks.

As an aside, we may ask whether natural selection can also detect the networks, i.e., enhance or facilitate the connections between modules. Perhaps this could be meaningfully answered in a 100,000 years or so, if by that time *Homo sapiens* has developed a distributed network specialized in reading and writing. Currently, learning how to read and write is a tedious and difficult task, because we have to co-opt a variety of modules that normally fulfill other functions. Young children struggle to connect sounds with arbitrary signs, whereas they have no problems to learn how to speak, i.e., connecting arbitrary sounds to concepts, such as objects and mental states.

Returning to Broca's area, the fact that it is a relatively large neural structure that seems to serve several not always compatible functions probably means that it contains several fine-grained modules (building blocks), involved in amongst others nonvocal imitation, analyzing auditory structures (musical and grammatical) and social communication (larger distributed networks). Each of these modules can be subject to selective pressures resulting from the role they play in these diverse distributed networks. For example, it is conceivable that the structure-analyzing neurons located within Broca's area can be fine-tuned to meet the demands of comprehending complex grammatical language. Similarly, the ability to link concepts with arbitrary signs, although not uniquely human, could have been selectively enhanced because doing so facilitates cognition and communication. As mentioned earlier, several studies (e.g., M. C. Frank et al., 2008) indicate that language is a cognitive technology, enabling us to denote cardinal numbers or keep track of the beliefs of others. According to Jackendoff (1996), the reason for this is that language allows us to hold thoughts longer in attention, enabling us to pay attention to relational and abstract aspects of thought. The human brain, when compared to other primate brains, shows indications that Wernicke's area has been under strong selective pressure during human evolution (Rilling & Insel, 1999). Interestingly, neurons within this area facilitate the forging of such arbitrary links.

This chapter has provided several lines of research from comparative psychology, developmental psychology and cognitive neuroscience that give reasons to doubt that the language faculty is subserved by a domain-specific cognitive module. This perspective has an important advantage for evolutionary accounts of language: if language is composed of numerous modules, many of which also figure in other distributed networks, no single evolutionary reason for why or how language evolved is needed. Rather, research can focus on more contained, more modest hypotheses about the evolution of the specific neural structures that underlie the language faculty and other cognitive capacities (like creating and enjoying music). For instance, comparing Broca's area and its homologs in different primate species may indicate which evolutionary pressures shaped this brain structure. Whereas the inferior frontal cortex (area F5, a homolog of Broca's area) in rhesus monkeys is a seat of mirror neurons, concerned with understanding actions (e.g., Umiltà et al., 2001), it is involved in social communication in chimpanzees (Taglialatela et al., 2008), and in language comprehension, nonvocal imitation and grammar in humans. Asking why this homolog evolved differently in rhesus monkeys, chimpanzees and humans presents a more constrained and perhaps more interesting question than the question of why language evolved in humans, but not in other species.

CHAPTER 4

CHALLENGING THE MENTAL CONTINUITY ASSUMPTION: WHY THE HUMAN BRAIN IS NOT AN ENLARGED CHIMPANZEE BRAIN

This chapter is a revised and expanded version of De Smedt, J., De Cruz, H., & Braeckman, J.(2009). Why the human brain is not an enlarged chimpanzee brain. In: H. Høgh-Olesen, J. Tønnesvang, & P. Bertelsen (Eds.), *Human characteristics. Evolutionary perspectives on human mind and kind* (pp. 168–181). Newcastle: Cambridge Scholars.

4.1 Introduction

As argued in section 1.2.1, much of current comparative psychology and neuroscience is conducted with the implicit assumption that the human mind is a kind of ape mind, differing only in degree from that of the extant apes—this is the mental continuity assumption. However, the continuity principle in evolutionary theory does not posit continuity between extant closely related species, but between extant species and their extinct ancestors. It is not unlikely that some human cognitive capacities have no parallel in extant apes, but that they emerged in extinct hominid ancestors, after the human-chimpanzee divergence. Taking social cognition as a test-case for the mental continuity assumption, this chapter will argue that human and chimpanzee social cognition not only differ in degree, but also in kind: they represent two peaks in an adaptive landscape. To explain how these cognitive specializations emerged, we examine archeological data to reconstruct the ecological and social contexts of early hominid and chimpanzee evolution.

This chapter challenges the mental continuity assumption by tracing diverging ecological and social contexts in hominid and chimpanzee evolution after their split 5.4 million years ago (Stauffer et al., 2001). First, we consider evidence from comparative neuroanatomy that suggests that human brains are not simply enlarged chimpanzee brains. We then formulate predictions on how differing ecological conditions could affect social cognition, and pit these predictions against the comparative psychological literature. This chapter concludes by examining some implications for comparative psychology: rather than asking to what extent nonhuman apes possess human cognitive capacities, it might be more sensible to examine what cognitive capacities nonhuman apes could have, bearing in mind their ecological and social evolutionary contexts.

4.2 Cognitive specializations in humans and other apes

Primate brains exhibit a considerable variation in internal organization and structure (Rilling & Insel, 1999). Which selective forces are responsible for this diversity? Some authors argue that diet and ecology are the primary forces that drive adaptive cognitive evolution. Comparative neuro-anatomical studies (e.g., Barton, Purvis, & Harvey, 1995) indicate that primate brain structure is influenced by species-typical ecological properties. Because color and smell are important cues to assess fruit, frugivorous primates have a relatively larger primary visual cortex and olfactory bulb compared to foliovores. But because olfaction is more important at night, when colors are more difficult to distinguish, nocturnal fruit-eating primates possess a relatively larger olfactory bulb than diurnal frugivores. Interestingly, De Winter and Oxnard (2001) found that ecology is more predictive of brain organization than cladistic relatedness: woolly monkeys (*Lagothrix poeppigii*), a species of New World monkeys, have an energy-rich diet consisting mainly of fruits and insects, and a locomotion comparable to that of chimpanzees. The internal organization of their brain looks similar to that of chimpanzees and bonobos, and differs considerably from that of other New World monkeys, implying convergent evolution.

A second view, the social brain hypothesis (e.g., R. I. M. Dunbar, 1998), proposes that brain evolution is primarily driven by the complexities of social life. It predicts that species with a more complex social life will have larger brains. This hypothesis has been confirmed in birds: species that live in complex social groups have a relatively larger telencephalon (involved in social cognition) compared to less social species (Burish, Kueh, & Wang, 2000)—although type and quality of the social bonding also seems to be an important factor, as the largest brain size is found among monogamous species (Emery, Seed, von Bayern, & Clayton, 2007). Given that both diet and social life are important selective pressures, these two hypotheses need not be mutually exclusive. Indeed, S. Shultz and Dunbar (2006) found that both ecological and social factors are good predictors of brain size in ungulates. Since primate species differ significantly in diet and social organization, we can expect that both ecological and social pressures are important in primate brain evolution.

Rilling and Insel (1999) compared brains of 44 primate species, using magnetic resonance imaging. They show that the human brain is not simply an enlarged chimpanzee brain: some areas have grown allometrically in humans, while others are reduced. The most intense selective pressures were exerted on the prefrontal cortex and on the posterior section of the temporal cortex, which are not only allometrically larger, but also more gyrified than the rest of the human brain. Gyrification is the degree to which the outermost layer of cell bodies of the brain (the neocortex) is folded: the more folded, the more neural tissue fits within the skull. Both brain areas have been consistently implicated in theory of mind tasks (U. Frith & Frith, 2001); the posterior temporal cortex (which includes Wernicke's area) is also involved in linking words to concepts. The increased gyrification of these parts can therefore be taken to indicate increased selective pressures on uniquely human skills like theory of mind and word learning. As can be seen on Fig. 4.1, the cerebellum is relatively larger in gibbons and orangutans than in humans and Old World monkeys. It plays an important role in coordinating locomotion. The kinematics of tree-swinging in gibbons and orangutans may thus have exerted increased selective pressure on the evolution of their cerebellum. The corpus callosum, which connects areas of similar function between the hemispheres, is reduced in humans compared to other apes (Rilling & Insel, 1999). This is an interesting finding because once the connection between corresponding brain areas has been weakened, their functions can evolve independently from each other, thus allowing for more cognitive modules in the human brain. Taken together, these studies do not support the mental continuity assumption: the human brain is not an enlarged ape brain, but, like the brains of other primate species, it has undergone evolution under ecological and social selective pressures. This hypothesis is strengthened by the fact that genetic expression in the human brain has been upregulated since the human-chimpanzee divergence (see section 1.2.2).

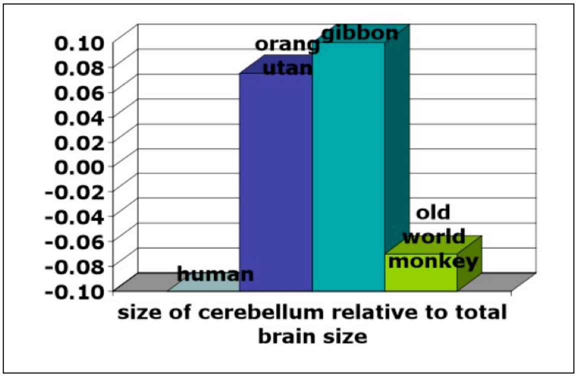

Figure 4.1: Size of cerebellum relative to total brain size in primates. Image based on Rilling and Insel (1998), Fig. 2b, p. 311.

4.3 Differential selective pressures after the split between humans and chimpanzees

The continuity principle in evolutionary biology does not apply to extant related species, but to species and their extinct ancestors. It is a matter of coincidence that we are the only surviving member of the genus *Homo*. Barely 40,000 years ago, *Homo sapiens* shared the planet with *Homo neanderthalensis* in Europe (Finlayson et al., 2008), *Homo floresiensis* (Morwood et al., 2005) and late *Homo erectus* in Indonesia (Swisher III et al., 1996), and with an as yet unnamed hominid in Siberia and probably East Asia (Krause et al., 2010). If these species were still around, we would probably not bother studying chimpanzee cognition. Since some human cognitive capacities have no parallels in extant apes, they must have emerged in extinct hominid species, after the human-chimpanzee divergence. Conversely, it is equally plausible that chimpanzees have cognitive adaptations that are absent in humans. Here, we focus on the period of the late Miocene to the early Pleistocene (between 6 and 1.8 million years BP) to examine some selective pressures that have been important in our evolutionary history, using paleoclimatological and fossil evidence.

4.3.1 Great ape dietary specializations

As a result of intense selective pressures, the extant great apes exhibit diverging dietary adaptations (Milton, 1999). During the early Miocene, the apes reached their greatest level of diversity, filling a wide range of sympatric niches. Fossil hominoid dentition indicates that their diet consisted exclusively of vegetable foods (Teaford & Ungar, 2000). By the late Miocene, however, they came under pressure from climate change and growing competition from the Old World monkeys. The few ape species that survived this competitive sweep did so by adopting unusual ecological niches, as we can see in their descendants today. Gorillas and orang-utans developed larger body sizes and turned to lower quality plant foods, such as mature leaves and bark, thus avoiding intense competition with monkeys. Chimpanzees became dietary specialists of ripe fruits, nuts, young leaves, insects and small vertebrates, which all contain high levels of calories. To obtain proteins, they rely extensively on socially transmitted tool-use. For example, if chimpanzees in Gombe (Tanzania) did not know how to probe long stalks in termite mounds or ant hills, they would only consume 1/8 of the invertebrates in their diet. In the Taï forest (Côte d'Ivoire), chimpanzees spend about 15% of their total feeding time on cracking nuts, which constitute the bulk of their caloric and protein intake (Yamakoshi, 2001). Bonobos live in the more food-rich central African rain forests. They rely on fruits, leaves and terrestrial herbaceous vegetation (leaves, flowers and pith), which is a stable and widely available source of protein. They also consume invertebrates, and even occasionally small vertebrates, but to a far lesser extent than chimpanzees (Hohmann & Fruth, 2003). However, in contrast to chimpanzees, in the wild bonobos do not use tools for dietary purposes (Hohmann & Fruth, 2003), despite their ability to use tools in laboratory contexts (Schick et al., 1999). Humans are unique in their obligatory reliance on tools to extract food. An analysis of diets in contemporary hunter-gatherers (Kaplan et al., 2000) reveals that humans are dietary specialists in food that is difficult to obtain, but that is high in energy and nutritive value. Less than 10% of all food types exploited by humans are relatively calorie-low vegetable foods that are easy to gather (fruits, leafy vegetables). In contrast, 95% of chimpanzee diets consist of easy to pick food, as is shown in Fig. 4.2.

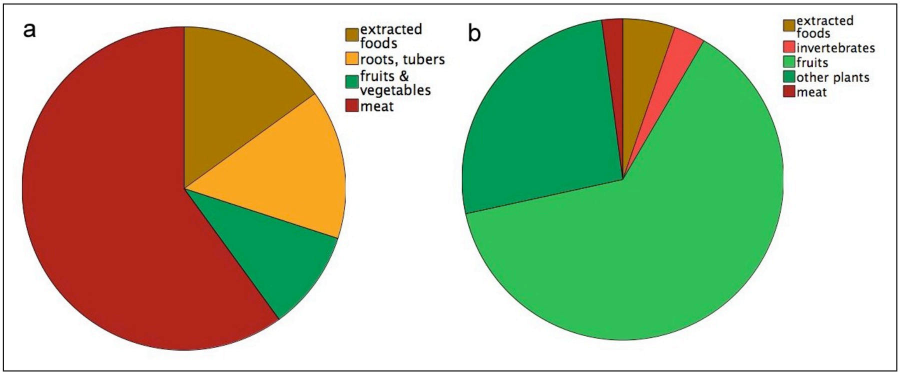

Figure 4.2: (a) percentage of caloric intake from diverse dietary sources in traditional hunter-gatherer societies (averaged); (b) in free-ranging chimpanzees (averaged), graph compiled from data in Kaplan et al. (2000).

This wide diversity of ecological niches has a profound influence on extant hominoid social structures. Due to their intake of low calorie foods, gorillas and orang-utans are unable to sustain the complex social life characterized by extensive grooming of other apes (Milton, 1999). Because high-quality food is scarce, competition for food among chimpanzees is intense. As a result, female chimpanzees with dependent offspring are forced to live and forage solitarily, because their slowness puts them at a competitive disadvantage (Hrdy, 2005). Exceptions to this general rule are communities from the Taï forest and Bossou which exploit locally abundant species of nuts with hammers and anvils. Yet, even these females compete for food and form linear dominance hierarchies (Wittig & Boesch, 2003). Male chimpanzees cooperate to defend communal ranges. They groom, and engage in coalition formation against dominant individuals. However, competition between them is also fierce; even among maternal brothers, food-sharing is rare (Langergraber, Mitani, & Vigilant, 2007). Tolerated theft is a more adequate term for their occasional sharing, which does not resemble human intentional acts of altruism—by allowing a harassing conspecific a share of the food, the donor escapes the costs of the continued harassment of the beggar (Stevens & Stephens, 2002). The stable presence of high-protein terrestrial herbaceous vegetation seems to have favored increased sociality in female bonobos, which form cooperative alliances. However, cooperation among bonobo males is restricted to periods of relative fruit abundance (F. J. White, 1998). Humans exhibit the highest degree of sociality among the primates, with both sexes engaging in enduring social bonds. Hunter-gatherers extensively share food, in particular meat, with kin as well as nonkin (Gurven, 2004). From this brief survey, it is clear that the great apes occupy a wide diversity of ecological niches. As we shall see, these divergent niches exerted a profound influence on hominid and chimpanzee cognitive evolution.

4.3.2 Hominid and chimpanzee diet and sociality in the Pliocene

Although cognition itself does not fossilize, we can infer changes in cognition through changes in behavior which leave their marks in the fossil and archeological records. Marine sediment sequences off the North African shore provide compelling evidence for stepwise increases in East-African aridity during the last 8 million years. This was caused both by a global cooling trend and by the formation of the Rift valley, which blocked East-Africa from the moist winds and precipitation from the Atlantic Ocean (DeMenocal, 2004). The increasing aridity forced early hominids to extend their daily foraging range, favoring bipedal locomotion, which is more energy-efficient than all known forms of primate terrestrial locomotion (Leonard & Robertson, 1997). Fossil evidence suggests that bipedalism evolved in *Ardipithecus* about 5.2 million years ago, almost immediately after the divergence between the chimpanzee and hominid lineages (Haile-Selassie, 2001), although by 4.4 million years ago this bipedalism was still facultative rather than obligatory (Lovejoy, Suwa, Spurlock, Asfaw, & White, 2009). The patchy distribution of food resulted in an increasing specialization in high-quality foods: analyses of australopithecine bone collagen and patterns of tooth-wear show that the australopithecines specialized in a high quality diet of fruits and young leaves, not unlike that of chimpanzees today (Sponheimer & Lee-Thorp, 1999). Bipedalism had unexpected consequences for the early hominids' social interaction, because it made female cooperation almost inevitable. A bipedal ape cannot look at her own offspring while giving birth, and thus cannot assist her young, such as removing mucus from its face or loosening a suffocating umbilical cord. Nonhuman apes habitually help their own offspring in this way (Fig. 4.3), but bipedalism requires assistance in birthing (Rosenberg & Trevathan, 2002). In all human cultures, women in labor receive help. Whereas female chimpanzees do not form alliances, female hominids as early as 5.2 million years ago required help during birth.

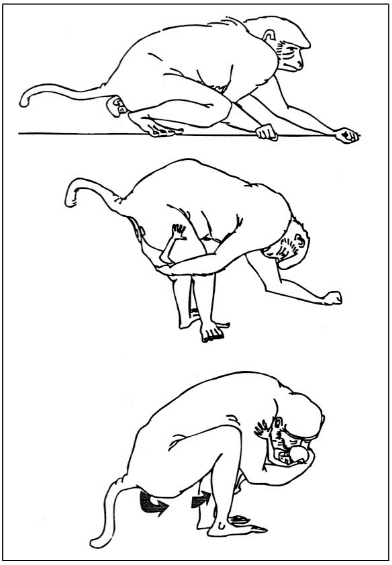

Figure 4.3: Various stages in the delivery process of an Old World monkey. The neonate is facing in the same direction as its mother; she is able to reach down and assist it as it emerges from her birth canal, from Rosenberg and Trevathan (2002), Fig. 3, p. 1202.

Female alliances were further promoted by the demands of alloparenting. Recent studies (e.g., DeSilva, 2011) suggest that the human tendency to give birth to relatively large infants (partly a consequence of their enlarged brain, which requires a considerable reserve of fat to sustain itself) in proportion to body size of the mother occurred relatively early in hominid evolution. Whereas *Ardipithecus* infants were small at birth, as chimpanzee infants are, *Australopithecus afarensis* (and *A. africanus*) infants had already an increased body size. As a consequence, *Australopithecus* mothers as early as 3 million years ago were compromised in their ability to climb trees. Once hominids developed a brain size that was markedly larger than that of chimpanzees, which occurred about 2 million years ago, they were forced to wean their infants earlier to meet the nutritional demands of the rapidly growing brain. Humans in traditional societies have the shortest lactation period of all apes, weaning infants at about 30 months, whereas chimpanzees are breastfed for about 62.8 months on average, and orangutan infants are lactated about seven to nine years (Kennedy, 2005). Shorter lactation times result in shorter interbirth-intervals: traditional human foragers have interbirth-intervals of about three to four years, compared to five to nine years in other apes. However, human children need intensive care until they are six or seven. This places heavy demands on human mothers, who must take care of several dependent children at the same time. In most pre-industrial societies, women solve this problem by developing extensive networks of alloparents. In some cases, such as the Aka pygmies, childcare networks comprise over 10 individuals including several nonkin members (Ivey, 2000). Therefore, it seems plausible that early hominids from about 2 million years BP on showed greater cooperation between females than chimpanzees, perhaps on a par with what we observe in bonobos today.

A second step toward increasing aridity in East Africa took place around 2.8 to 2.5 million years ago. Interactions between cyclic changes in orbital obliquity (the eccentricity of the Earth's axis) and oceanic currents caused profound climatic shifts, most notably the alternation of ice ages and interglacials (DeMenocal, 2004). These global climate shifts were locally intensified in East Africa because of the further formation of the Rift Valley. Paleo-ecological analysis (Bonnefille, 2000) shows that these climatic changes set in motion a cascade of speciation, migration and extinction events in plants and animals. The equatorial rainforest disappeared; forests became restricted to banks of rivers and lakes. Because fruit and young leaves became scarce and seasonally unavailable, hominids were forced to exploit alternative ecological niches which led to an adaptive radiation in the hominid lineage. One clade, *Paranthropus*, specialized in hard vegetable food such as seeds, especially during the annual periods when normal plant foods were not available (Ungar, Grine, & Teaford, 2008). Early *Homo* relied more extensively on meat to compensate for the seasonal unavailability of rich plant food sources. Examinations of fossil cut marked bones and of wear patterns on stone tools (e.g., Capaldo, 1997) indicate that early *Homo* obtained most or all of the meat in its diet through scavenging: they cut meat from partly defleshed carcasses with sharp flakes, and crushed bones with blunt hammer stones to obtain the marrow. At least three saber-tooth genera inhabited Pliocene eastern Africa. These were relatively small felids with powerful front paws and long dagger-like teeth, which enabled them to kill prey far too large to satisfy their own needs (Lewis, 1997). These partly-eaten large to medium-sized carcasses provided the hominids with a stable and reliable food source. Analyses of tooth indentations and cut marks on bones show that early *Homo* got to the carcasses before the hyenas (Domínguez-Rodrigo & Barba, 2006). Because hyenas, their only terrestrial competitors in the scavenger niche, were dangerous gregarious animals, it seems plausible that hominid males cooperated to defend the carcasses (Bunn & Ezzo, 1993). This suggests that male hominid coalitions were at least on a par with those of male chimpanzees today.

The evolution of the *Pan* lineages is less well-documented than that of the hominids. They probably evolved in wooded West- and Central-Africa, where fossil preservation, due to the acidity and humidity of the environment, is worse than in dry East-Africa. To date only teeth, dated to about 500,000 BP, belonging to one fossil species of the genus *Pan* have been recovered (McBrearty & Jablonski, 2005). However, it is interesting to note that according to Y-chromosome sequencing the split between *Pan troglodytes* and *Pan paniscus* (bonobo) occurred about 1.8 million years ago (Stone, Griffiths, Zegura, & Hammer, 2002), which coincides with an extreme cooling and drying event that also gave rise to the emergence of *Homo ergaster* in East Africa. Given that West and Central Africa experienced far less climatological instability than East-Africa, we can assume that chimpanzees and bonobos occupy their current niches for about 1.8 million years.

4.4 Differing social cognition as the outcome of unique selective pressures: Are humans simply more social?

Over the past few years, comparative psychologists (e.g., Tomasello & Rakoczy, 2003; Povinelli & Vonk, 2003) have asserted that chimpanzees possess less sophisticated social skills than humans. They have argued that in clear contrast to humans, chimpanzees do not understand intentions or beliefs, i.e., they lack a theory of mind (e.g., Call & Tomasello, 1999), and they may not even fully understand visual perspective taking (Povinelli, Bering, & Giambrone, 2000). The *scala naturae* of general intelligence is being replaced by a scale of social cognition, in which humans exceed all other apes in social intelligence. Human social cognition is chimpanzee social cognition plus some additional human faculties, alternatively described as 'unique' or 'enhanced', depending on the research group. Although we do not doubt the experimental results that lie on the basis of these conclusions, we nevertheless question their interpretation as evidence that chimpanzee cognition can simply be equated with the ancestral state of human cognition.

Given the radically differing ecological and social contexts of human and chimpanzee cognitive evolution, one can expect both species to possess specialized social skills. Hominids could afford to be more social because they enjoyed a stable and abundant source of protein in the form of scavenged meat (Blumenschine, 1987) which lowered competition for resources within the group. Moreover, ecological and social pressures that were unique to the hominid lineage such as alloparenting and confrontational scavenging (cooperative defense of large carcasses) promoted increased sociality in hominids. Considering the ecological conditions under which chimpanzees evolved, namely their exploitation of high-quality patchy resources, one could expect that chimpanzee social cognition will be tuned to competition. In what follows, we will examine comparative psychological studies to test these predictions.

4.4.1 Perspective taking

Humans seem to engage in specialized forms of social cognition: we understand others as intentional agents, and we attribute unobservable mental states such as beliefs, desires and intentions to ourselves and to others. This capacity develops before language since even 15-month-olds can predict an agent's actions on the basis of its prior beliefs (Onishi & Baillargeon, 2005). It remains an open question whether chimpanzees also possess a theory of mind: do they represent underlying intentions and beliefs, or are they behaviorists in the sense that they only represent what others do, rather than what they think? Povinelli et al. (2000) found support for the latter hypothesis by simple visual perspective tasks. Chimpanzees were trained to find a hidden food-item by following pointing gestures or gaze direction. The apes were curiously insensitive to the attentional state of the experimenter: they were as likely to follow the cue of an experimenter with a bag over her head as of one who could look inside the containers with food rewards. Later experiments (e.g., Bräuer et al., 2006) found that chimpanzees even have difficulties to learn to follow a simple pointing gesture to retrieve hidden food, a task in which dogs and even horses succeed (McKinley & Sambrook, 2000).

Chimpanzees do better in social tasks when they are placed in a competitive situation: they can effortlessly find a reward if the experimenter pretends to reach for it in vain—this gesture looks quite similar to pointing, but here the experimenter can be seen as a competitor rather than a helper. When placed in competition over food with a human, chimpanzees take food when the human cannot see it, and quickly discover routes that allow them to remain undetected by the human while they approach the food (Hare, Call, & Tomasello, 2006). This is quite a sophisticated feat in visual perspective taking that is more cognitively demanding than the Povinelli et al. (2000) tasks—that the animals succeed in this task hints at its ecological salience (see also section 1.2.1 on the importance of ecological salience in designing comparative psychological experiments). While chimpanzees seem inept at solving cooperative perspective tasks, they can easily solve them when placed in a competitive situation. As mentioned before, Hare et al. (2001) gave subdominant chimpanzees the choice between two food-items, one that a dominant conspecific could see, and one that he could not see because his vision was blocked by an obstacle. Subdominant animals consistently chose the item that the dominant one could not see, again indicating an understanding of visual perspective taking. Ironically, most experimental setups use food rewards, and it is precisely food that elicits competitive behavior in chimpanzees. This interpretation of the experimental results finds support in recent studies with bonobos. Bonobos, which evolved in environments that contain stable and abundant sources of protein in the form of terrestrial herbaceous vegetation, are less competitive over food. As follows our prediction that ancestral stability in food sources gives rise to augmented sociality, they outperform chimpanzees in cooperative tasks, such as pulling together at a rope to draw in a board that contains a food reward (Hare, Melis, Woods, Hastings, & Wrangham, 2007).

4.4.2 Uniquely human social learning

Human social learning is characterized by a set of distinctive features, such as imitation, teaching and joint attention. Imitation, the ability to reconstruct a sequence of actions through direct observation of a model, has received the most attention. Early behavioral biologists often mistakenly assumed that animal traditions were transmitted through imitation, such as Japanese macaques that washed sweet potatoes, or blue tits that pried open the lids of milk bottles to obtain the floating cream (see Galef, 1992, for review). However, more controlled observations pointed to ways of social learning that do not involve imitation, such as local or stimulus enhancement. In these cases, an animal's attention is drawn to a specific situation by the presence or action of a conspecific, or by the end-result of such an action, and this enables the learner to re-invent the behavior for itself (Laland & Hoppitt, 2003). Many cultural variations in chimpanzees can be adequately explained by such non-imitative forms of social learning which require a significant degree of individual trial-and-error discovery. For example, the length of twigs with which members of chimpanzee communities fish for ants correlates with the aggressiveness of the ant species that are present in the home ranges of these communities: it makes sense to use longer twigs when ants are more aggressive (Humle & Matsuzawa, 2002). Cultural behaviors that exhibit cumulative complexity over time, and thus cannot be rediscovered by a single individual, are notably absent in nonhuman apes. This can be seen from experimental approaches (e.g., Marshall-Pescini & Whiten, 2008) as well as from the archeological context (Mercader et al., 2007). This means that, despite our improved knowledge of chimpanzee cultures (e.g., Whiten et al., 1999), there seems to be no instance of chimpanzee social learning that cannot be adequately explained by non-imitative social learning mechanisms.

To understand why only human cultural evolution is cumulative, it is interesting to compare the development of social skills in humans and chimpanzees. In the first few months of life, the development is similar: both human and chimpanzee infants prefer their mother's face and engage in dyadic interactions with her, such as smiling and mutual gazing. At around four to six months, members of both species become proficient at following the gaze of their mothers and other individuals. However, at about nine months, only human infants develop the ability to share their attention for a specific object with another person (Tomasello & Rakoczy, 2003). This results in a referential triangle of infant, adult and the object upon which they share attention. Crucial for this shared attention is that the infant knows that it shares its attention for the object with someone else—it is thus aware of the mental state of the other (Fig. 4.4). Some experiments (Striano & Stahl, 2005) indicate that a sensitivity to triadic interactions emerges even earlier, at about three months, but that only at nine months human infants begin to overtly engage in triadic interactions. This 'nine-month revolution' does not occur in chimpanzees. In stark contrast to humans who from then on are engaged in triadic interactions —mother, infant and object—chimpanzees learn from dyadic interactions only: they observe their mothers' behavior carefully, and this helps them to reconstruct object-oriented actions for themselves. Tomonaga et al. (2004) not only observed many hours of exclusively dyadic interactions between chimpanzee infants and mothers, but also repeatedly attempted to engage in triadic interactions with infant chimpanzees; still, they failed to replicate the results obtained with human infants.

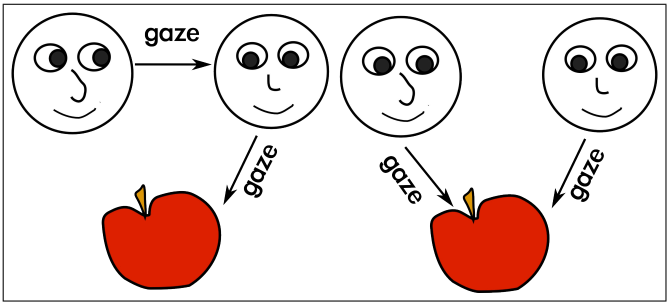

Figure 4.4: Schematic rendition of a triadic interaction: two agents share attention over an object, and are aware that they do so.

Presumably, shared attention is the most important mechanism that facilitates cumulative cultural evolution. Because humans can engage in triadic interactions that involve objects, they can quickly copy the behavior of others. This reduces the cost and time spent at individual learning, and it enables learners to build upon and improve inventions of previous generations. Indeed, Tomasello and Rakoczy (2003) speculate that cumulative cultural evolution may be absent in other species as only humans share attention.

If shared attention is indeed a uniquely human capacity, it must have emerged after the split between the human and chimpanzee lineages, and we should be able to infer its emergence from the archeological record. The Oldowan stone technology (about 2.6 to 1.5 million years BP), which is ubiquitous in Pliocene and early Pleistocene hominid sites, required extensive cultural learning on a level beyond that observed in chimpanzee cultural traditions. To obtain sharp flakes, one strikes a stone (the core) with another stone (the hammer stone) on a striking platform (a flat surface of the core). Only an oblique angled strike results in a razor-sharp flake with a typical conchoidal fracture pattern. Refitting[10] of 2.4 million-year-old Oldowan artifacts from Lokalalei, Kenya (Roche et al., 1999; Delagnes & Roche, 2005) shows that the hominids turned the core around while flaking, indicated by the multiple striking platforms, and that they chose the most efficient angles to strike the core, exploiting its natural morphology, as can be seen in Fig. 4.5. In contrast, both a chimpanzee (Kitahara-Frisch, 1993) and a bonobo (Schick et al., 1999) have been extensively tutored in how to make Oldowan-type stone tools, but neither succeeded in striking the cores at correct angles. The flakes they were able to produce (e.g., by hurling the stones against the floor) did not exhibit the typical conchoidal fracture pattern of Oldowan; if found in an archeological context, such tools would probably not be recognized as intentional flakings.

Hominids were very selective in their choice of raw material. Good flakes are only obtained from cores which have a dense, fine and isotropic (even) structure. They do not crumble; fracture dynamics are easy to control, producing razor-sharp conchoidal fractures upon impact. The earliest stone tools from Gona, Ethiopia, dated at 2.6 million years BP, were made from the locally scarce vitreous volcanic clasts, not from the locally abundant basalt, which is of lower quality, and is less easy to work (Stout, Quade, Semaw, Rogers, & Levin, 2005). When the quality of local cobbles was poor, the hominids transported raw material from other sources to the butchery sites that were often several kilometres away (Plummer, Bishop, Ditchfield, & Hicks, 1999). This anticipatory behavior in raw material selection has not been observed in extant nonhuman primates. Chimpanzees, for example, use a wide range of materials that they find in their immediate surroundings. Their hammer stones are unprocessed and weigh between 1 and 24 kg, indicating the opportunistic nature of their raw material choice (Mercader et al., 2007)—indeed, sometimes the chosen stone is so heavy that it just crushes the nut. By contrast, hominid hammers typically weigh less than 400 g, and are all lighter than 1 kg (Mercader et al., 2007, 3046). Taken together, the striking differences between Oldowan technology and chimpanzee technological skills indicate that the Oldowan is beyond the social learning skills of chimpanzees. It is

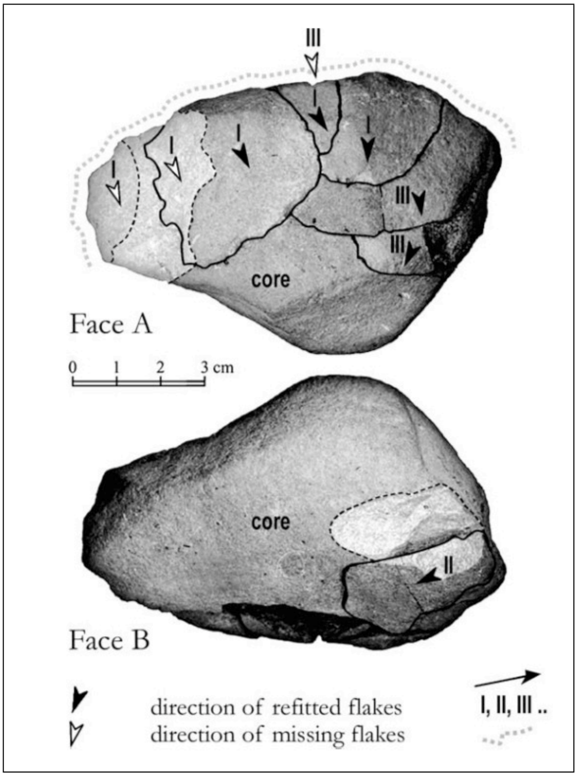

Figure 4.5: This is a refitted, i.e., pieced together cobble from which ten flakes were struck using the Oldowan technique, from Lokalalei 2C, ca. 2.34 million years old. The core is a phonolite cobble with a length of 9.4 cm, which is a typical size of source material at that site. It is quite impressive that late Pliocene knappers were able to get so many useful sharp-edged flakes from relatively small cobbles. Face B was less smooth than face A and therefore has fewer flakings. Roman numerals denote the sequence of flaking before turning the stone. From Delagnes and Roche (2005), Fig. 6, p. 443.

the first archeological evidence of cumulative cultural learning, indicating that hominids at 2.6 million year ago were able to share attention and to engage in triadic interactions.

To facilitate sharing attention and cooperation, humans have developed unique anatomical and neuropsychological adaptations. For example, the human eye shows a huge white sclera on both sides of the iris (Fig. 4.6). This makes it easy for conspecifics to follow our gaze direction. In contrast, all other primates have pigmented sclera, which makes it difficult to follow their gaze (Kobayashi & Kohshima, 2001). All primates are good at following gaze direction. Yet, in their highly competitive world it is not always good to have others know what one is up to, especially not during competition for food. In those cases, it is more advantageous to have a dark sclera which camouflages gaze direction. Human white sclera might actually have evolved in response to selective pressures that encouraged not only reading eye direction, but also having one's eye direction followed. Given that the transmission of tool use in primates is vertical (i.e., from mother to offspring), this may have increased inclusive fitness. Through triadic interactions, we still make objects part of our social world. Humans across cultures reason about artifacts in terms of the (inferred) intentions the maker had when creating that artifact (see also sections 2.3.1, 7.2.1 and 9.2.1). As we have seen, this design stance is universal in humans, and it emerges in children as early as two years (German & Barrett, 2005; Casler & Kelemen, 2007). It seems reasonable to suppose that the design stance is a direct consequence of our ability to incorporate objects in triadic interactions. The design stance seems hardly conceivable if humans, like chimpanzees, were only able to engage in dyadic interactions. In the light of this, the absence of a design stance in nonhuman primates is not surprising.

4.5 Uniquely chimpanzee social learning

Chimpanzees exhibit complex cultural behaviors, which is all the more remarkable given that many of these are transmitted from mother to dependent infant—this, as we have seen, is a consequence of the fact that female chimpanzees are forced to forage away from the group because of the intense competition for food. Laboratory and field studies have revealed a unique kind of social learning in chimpanzees. The primatologist Tetsuro Matsuzawa (2007) terms this kind of social learning 'education by master-apprenticeship', alluding to the learning practice in medieval guilds. For a period of about five years, the infant spends most of its time alone with its mother. It is highly motivated to acquire her behavior. She, however, does not teach, nor does she provide any feedback. How then,

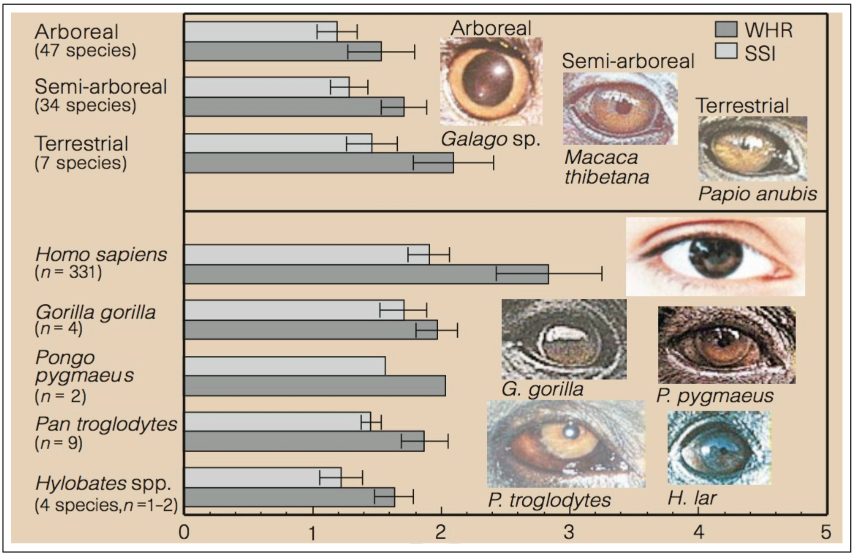

Figure 4.6: Width-height ratio (WHR) and exposed sclera size (SSI) in diverse primate taxa. As can be seen, humans have the widest eyes and the largest relative area of exposed sclera; also they are the only primates with a white sclera. From Kobayashi and Kohshima (1997), Fig. 1, p. 768.

do chimpanzee infants acquire difficult skills? Looking-time experiments (e.g., Gergely et al., 1995) indicate that human 12-month-olds can predict the actions of agents based on an inferred goal before they have acquired a fully-developed theory of mind. The comparative psychologist Claudia Uller (2004) replicated these experiments with infant chimpanzees, and found that their performance matches those of human infants. Thus, a baby chimpanzee from the Taï forest who observers its mother using a hammer (and sometimes anvil) to crack nuts, infers that the goal of her action is to eat nuts. Although chimpanzee mothers do not teach or provide feedback, they allow their young to learn by observation, even permitting them to steal the yield.

As chimpanzees rely more on individual learning than humans, they have developed behavioral adaptations to facilitate this. Young chimpanzees seem to be more intrinsically motivated to explore novel objects, which increases the chance that they discover salutary properties of these objects. A study in which both chimpanzee and human infants were familiarized with novel toys (Murai et al., 2005) shows that chimpanzee infants do not exhibit any significant habituation despite repeated presentation of the items. In contrast, human infants quickly habituate and lose interest. Moreover, chimpanzee infants possess a strong intrinsic motivation to copy their mothers' behavior which persists in the absence of food rewards. A longitudinal study (Sousa, Okamoto, & Matsuzawa, 2003), which investigated the behavioral and cognitive development of a male infant chimpanzee born in captivity revealed extensive explorative behavior. Since one week after birth, Ayumu was present when his mother retrieved rewards from a vending machine. He intently observed her actions, and unsuccessfully experimented with the apparatus for several months on a weekly basis. Although he was never rewarded or encouraged to explore the machine, he mastered its use after 17 months of intensive exploration and manipulation, proving his prowess by successfully repeating the full sequence of the task 20 times consecutively. These strong intrinsic motivations to explore novel objects and to copy their mothers' behavior allow young chimpanzees to successfully acquire their cultural traditions without shared attention or imitation.

4.6 Chimpanzee and human social cognition as two peaks in an adaptive landscape

Since tool-use plays a crucial role in chimpanzee food acquisition, it seems surprising that they did not develop shared attention. We believe that the absence of shared attention can be best explained by differing costs and benefits of individual learning and copying. All social learning can be decomposed into two elements: individual learning on a trial-and-error basis, and copying, a broad notion of learning which encompasses local and stimulus enhancement and imitation. In his simple but robust mathematical model, the anthropologist Alan Rogers (1988) already showed that pure copying does not constitute an evolutionary stable strategy. Imagine a population that consists only of individuals who acquire new skills exclusively through individual trial-and-error learning (individual learners, I.L. on Fig. 4.7). In this population, a mutant who acquires new skills by copying individual learners (social learner, S.L. on Fig. 4.7) will enjoy a higher fitness, because it avoids the costs associated with trial-and-error learning. However, as more and more individuals with a copying strategy enter the population, their mean fitness will eventually drop, either due to an accumulation of error-rates or to changes in the environment which make the strategy no longer adaptive (indicated by the dotted line on Fig. 4.7). In either case, individual learners will gain the upper hand, and cumulative cultural evolution is impossible. Rogers' quandary can be circumvented if copiers in a relatively stable environment have a reliable model to copy from, or alternatively, if they have many models from whom they can learn and select the best when they live in a changing environment. Next to this, social learners also have to be capable of individual learning to improve existing designs (Boyd & Richerson, 1995, 1996). This model fits in nicely with the archeological record that shows that Late Pliocene East Africa was subject to climatic fluctuations. One can thus infer that horizontal transmission (i.e., learning from several members of the group other than one's parents) would have been an efficient strategy for the earliest stone tool wielding hominids, putting extra selective pressure on cognitive and anatomical adaptations, such as shared attention and an increasingly white and visible sclera. Given that social and individual learning are both important in cultural transmis-

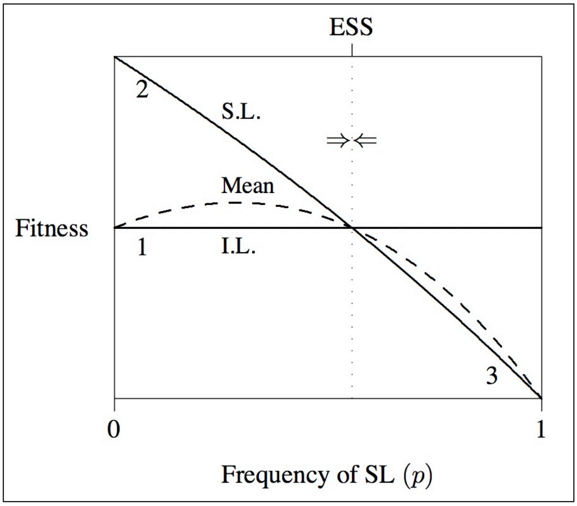

Figure 4.7: Mean fitness of individual and social learners as a function of the relative frequency of social learners in a mixed population. Based on A. R. Rogers (1988), Fig. 1, p. 822.

sion, the ratio between these strategies can vary across species, and this seems to correlate with the ecological and social contexts in which they evolve.

Applying this general framework of social learning to humans and chimpanzees, we see that both species present two different peaks in an adaptive landscape. Whereas humans place a premium on copying from many models, natural selection has favored enhanced individual learning in chimpanzees. Systematic comparisons between humans and chimpanzees (e.g., Herrmann, Call, Hernandez-Lloreda, Hare, & Tomasello, 2007) show that human 2.5-year-olds outperform chimpanzees in imitating an experimenter who solves a problem that has a rather simple but non-obvious solution, e.g., retrieving a reward from a transparent tube by violently hitting it against the floor. On the other hand, when human children and chimpanzees are confronted with a cumbersome solution to a problem (e.g., raking an object with an ill-suited tool), young chimpanzees are able to come up with their own, better solution, while children imitate the suboptimal solution of the human model (Horner & Whiten, 2005).

Social learning, especially in an unstable environment, improves when a learner can rely on several models to choose the best solution from. Consequently, Oldowan technology could only emerge in a context where young hominids were able to observe several tool makers and users. As our survey of hominid Pliocene ecology shows, early *Homo* relied primarily on scavenged medium-sized to large carcasses, which could be shared by several individuals. This facilitated and promoted social learning of tool-use: hominid infants learned to manufacture and use stone tools from several models which made their social learning more reliable and efficient. In such ecological and social contexts, natural selection can favor increased social learning skills, and cumulative cultural evolution can take off. On the other hand, chimpanzees evolved in relatively stable environments with patchier and less concentrated resources. To avoid competition over food, chimpanzee mothers with a dependent infant forage away from the group, which means that their young learn most of their cultural traditions from one model only, their mother. As the experimental literature shows, socially enhanced individual learning can provide a more robust performance than imitation if technology is relatively simple. In this case, natural selection seems to have favored cognitive adaptations that promote individual discovery, such as a high intrinsic motivation to explore objects.

4.7 Concluding remarks

Although the mental continuity assumption has generated an interesting body of empirical literature, which casts light on the evolutionary origins of our cognitive capacities, the assumption itself is fundamentally flawed. The case of social cognition illustrates that the minds of humans and other apes differ not only in degree, but also in kind. The availability and distribution of food sources play an important role in the evolution of sociality. Stone-wielding hominids exploiting large to medium-sized carcasses have evolved a dietary niche which enabled and required them to be highly cooperative. Chimpanzees, on the other hand, specialized in patchy high-quality food items, and use social cues mainly in competitive contexts. As a result, the cognitive mechanisms underlying cultural transmission are widely different between these species, with an emphasis on imitation in hominids, and a focus on individual discovery in chimpanzees.

Comparative psychologists, primatologists and neuroscientists should not solely take human cognition as the starting point of their investigations of nonhuman primate cognition, but rather the ecological and social contexts in which these species have evolved. This more ecological approach is already gaining currency in comparative psychological studies outside of primatology. For example, early studies on deductive reasoning (such as transitive inference) focused on chimpanzees, due to their proximity to humans (McGonigle & Chalmers, 1977). These studies relied on operant conditioning, where subjects were taught arbitrary transitive relationships between stimuli such as colored chips. Later experimental procedures found that the ability to infer transitive relationships is not a matter of brain size or relatedness to humans, but can be better predicted by the ecological pressures to which species are subject. For example, despite their small brain size, territorial fish (*Astatotilapia burtoni*) can predict the outcome of future encounters with unfamiliar fish based on their observation of pairwise contests between them (Grosenick, Clement, & Fernald, 2007). Species that are closely related can show striking cognitive differences based on these divergent ecological pressures. For example, pinyon jays (*Gymnorhinus cyanocephalus*) live in large, stable groups with linear dominance hierarchies, whereas the closely related Western scrub jays (*Aphelocoma californica*) live in couples. Bond, Kamil, and Balda (2003) found that pinyon jays could learn transitive relationships between arbitrary stimuli within less than 70 trials, whereas scrub jays needed more than 200 trials merely to get above chance level. The case of social cognition in humans and chimpanzees shows that this ecological approach could also turn out to be fruitful for comparative studies of primate cognition as well. Tackling such questions may help us gain insight not only in how the human mind works, but also promises a better understanding of other primate minds.

Part II

Artistic ability

One morning, when writer Elizabeth Gibson was on her way for coffee as usual, she spotted a conspicuous and colorful canvas in a pile of rubbish. Although she knew nothing about modern art, she felt compelled to take the painting to her crammed Manhattan apartment because, as she put it, "even though I didn't understand it, I knew it had power." The canvas hung for several years in her flat until she discovered that it was actually the famed work *Tres Personajes* (Fig. 4.8) by the Mexican painter Rufino Tamayo, stolen some twenty years before. After realizing its value, Gibson returned the picture to its rightful owners[11]. This anecdote illustrates that we have an intuitive concept of art—even without any formal training in aesthetics or art history, we recognize art when we see it.

Figure 4.8: *Tres Personajes*, by Rufino Tamayo, 1970, retrieved from `http://www.daylife.com/photo/0gyH5gph2K3o4`

What is it in this particular canvas that made Elisabeth Gibson decide that the object she saw was a work of art? Or, to put it differently, what is it that we see and intuit in works that we denote as 'art'? Most indigenous cultures lack a term equivalent to the western notion of art for art's sake (Dutton, 1993), which only emerged in late 18th-century Europe. This conventional western notion came into being with amongst others Kant's *Critique of Judgment* (1790 [1987]). In chapter 16, Kant famously distinguished between free beauty and beauty that is merely dependent. Free beauty is independent of concerns of functionality and even of conceptualization or categorization. Objects of free beauty per definition do not serve any function. Because of this, they appeal to our cognitive predispositions of imagination and aesthetic judgment in a disinterested fashion. By excluding functionality from his aesthetics, a large part of what is currently exhibited in museums and galleries (e.g., medieval art, nonwestern art[12]) are put outside the purview of aesthetic analysis. Actually, in the course of the 18th century, the concept of art had already been narrowed by the abbé Batteux' dichotomy between fine art (e.g., painting, sculpture, architecture, poetry and music) and the applied arts (e.g., garden architecture, design, crafts, and fashion) in his *Les beaux-arts réduits à un même principe* (Kristeller, 1997, 90–91).

The demarcation of art is one of the most outstanding problems in contemporary philosophy of art; attempting a solution to this problem falls outside the scope of this dissertation. Objects and performances that we routinely classify as art share features like skill, strikingness and beauty, but it is easy to come up with counterexamples for each of these features; for example, ready-mades (objects originally not used as art, such as common household items) do not clearly exhibit artistic skill, whereas a chess game requires lots of skill. The diversity in recent art production allows one to easily defeat attempts to capture features that are necessary (let alone sufficient) for art objects. For example, although the craftsmanship and expertise of artists are cross-culturally valued (Anderson, 1989; Gell, 1998), ready-mades seem to preclude any definition of art in terms of expertise. The late Dennis Dutton (2006) therefore convincingly argued that it is a mistake to let our theories of art be guided by borderline cases or problematic examples, such as Marcel Duchamp's fountain or John Cage's *4'33"*. Such examples are very hard to accommodate in any theory of art. Drawing on an analogy with law practice, Dutton (2006, 368) argued that "hard cases make bad law": in an attempt to understand the nature of murder, it is unwise to start out *de novo* from borderline cases like abortion or assisted suicide; rather, we must start from paradigmatic examples, from which we later move on into unchartered territory. To take a similar case from another philosophical discipline, epistemology: the definition of knowledge as justified true belief seemed, on the face of it, very intuitive. However, special and unusual cases of belief-formation challenged this assumption (Gettier, 1963). This gave rise to a cottage industry of ever more baroque examples of beliefs that seemed justified and true, but that do not qualify as knowledge[13]. The view that theories of art should conform to the extremes is perhaps a case of what Gutting (2009, 89) has dubbed “the philosopher’s fallacy.” Philosophical theories can capture important and interesting features of art, but this does not mean that philosophical knowledge is infallible. Indeed, if it were, philosophy would be an exceptional discipline, as knowledge in all other domains of human knowledge is fallible. Extreme cases are likely to challenge any definition or characterization of art that is sufficiently detailed to be interesting, or to provide novel philosophical insights. Therefore, when in chapter 7 I have my own attempt at providing a concept of art, I will not let myself be guided by borderline cases, problematic exceptions and the like. As we shall see, my cognitive approach to art is informed by empirical findings from developmental psychology and cognitive archeology, combined with philosophy of mind.

Most approaches in philosophy of art have in common that they focus on *art objects*, rather than on what caused these objects to come into being, namely human behavior. Instead of taking the art objects as a starting point, it makes sense to examine the human cognitive faculties and behaviors that are responsible for the creation and enjoyment of these objects. This shift in focus allows one to include objects and performances from distant places and cultures, and ancient artifacts, such as cave paintings and prehistoric sculptures. The following chapters will examine art as a form of human behavior. Chapter 5 provides a review of the cognitive neuroscientific and evolutionary psychological literature on art. Chapter 6 looks at art as a product of cultural group selection. Chapter 7 proposes a cognitive approach to art, where three distinct cognitive abilities are considered that lie at the basis of artistic creation and appreciation. Chapter 8 looks at the interaction between minds and material culture in the use of rock art and notched artifacts as calendrical notation systems.

CHAPTER 5

TOWARD AN INTEGRATIVE APPROACH OF COGNITIVE NEUROSCIENTIFIC AND EVOLUTIONARY PSYCHOLOGICAL STUDIES OF ART

This chapter is a revised and expanded version of the following paper: De Smedt, J., & De Cruz, H. (2010). Toward an integrative approach of cognitive neuroscientific and evolutionary psychological studies of art. *Evolutionary Psychology*, *8*, 695–719.

5.1 Introduction

In recent years, cognitive neuroscientists and evolutionary psychologists have provided reductionist accounts of human behavior in terms of the lower-level theories and concepts of biology. Reductionism in scientific practice is primarily an explanatory strategy: reductionist scientific explanations are not necessarily committed to the view that higher levels of explanation can always be reduced to more fundamental ones; rather, they attempt to gain a better understanding of a given phenomenon by focusing on a basic level of explanation. Unification, the ability to explain a wide range of phenomena using a relatively restricted set of premises, is arguably the most important of the explanatory goals of reductionist research programs (Steel, 2004). Evaluations of these programs should therefore assess to what extent they are successful in unifying a diversity of observations through a restricted set of principles. This chapter examines to what extent two flourishing reductionist approaches to human behavior—cognitive neuroscience and evolutionary psychology—provide unifying explanatory frameworks to understand art and its aesthetic appreciation, and whether they obviate the need for higher-level accounts. Additionally, it explores to what extent theoretical evolutionary considerations can outline new directions for empirical research on art production and appreciation.

Art presents an ideal case study to evaluate reductionist programs, because it is a paradigmatic domain of investigation of the special sciences (the humanities and the social sciences), such as aesthetics, art history and art sociology which typically take a more holistic approach to the phenomena under investigation. Within and across these disciplines, there is little agreement on how art should be studied or defined. Although visual art (in the form of body decoration, artifact decoration, and often sculpture and painting), dance and music appear in all known human cultures past and present (D. E. Brown, 1991, 140), most indigenous languages lack a term equivalent to the western notion of art for art's sake, which only emerged in the late 18th century. A radical solution to this definitional problem is to qualify only fine art, as it developed in post-Enlightenment Europe. But this merely shifts the problem of continuity: the functions, styles and social contexts of 19th-century art clearly differ from that of, say, the 1950s, which again radically differ from that of art today. On the other hand, Hellenistic sculptors, Gothic architects, and Melanesian wood carvers did not possess the modern western concept of art, yet we readily appreciate and appropriate their work. And just as sculptures from sub-Saharan Africa and Oceania adorn western homes, artists from these cultures have eagerly adopted western styles and media, as for example in historical ledger art, narrative drawings in pencil in used ledger books by Native Americans of the Great Plains (Fig. 5.1) or contemporary Australian aboriginal painting, which mixes indigenous themes with western media such as oil or acryl painting (see also Fig. 7.2). Thus, even though people from those cultures do not have terms that are equivalent to our notion of art, they seem to recognize similarities between their and our artistic expressions. Moreover, many cultures have indigenous terms that capture aspects of the western concept of art, such as skill or beauty (Van Damme, 1997). Experimental studies (e.g., Seifert, 1992) show that western subjects without any formal training in art or aesthetics display and freely express aesthetic judgments on works of visual art, even if they are unfamiliar with them, like African sculpture. What is it that we intuit when we judge something to be a work of art?

Figure 5.1: Kiowa drawing, possibly by Koba or Etahdleuh, of a group of men, presumably representing a warrior society meeting, 1875–1877, National Anthropological Archives, Smithsonian Museum Support Center, Suitland, Maryland, NAA INV 08547626.

We seem to have an intuitive, pretheoretical notion of what art may be (see also Osborne, 1981). Humans may possess a *folk concept of art* akin to folk biology and folk psychology, a tacit, inarticulate concept of what a work of art is like, which guides their identification of some objects and performances across cultures as art. This folk concept includes objects and performances that are typically manmade, that elicit aesthetic experiences[14], and that are embedded in social contexts. It is this broad folk concept of art that scholars across disciplines attempt to capture. Some (e.g., Davies, 2006) emphasize the aesthetic properties of artworks, attempting to discriminate from other phenomenological experiences an aesthetic sensation, i.e., a subjective sensation of pleasure derived from sensory (usually visual or auditory) perception. Others, following the art anthropologist Alfred Gell (1998), deliberately exclude aesthetics from their analysis and focus on the social role of art. Next to these, some philosophers of art (e.g., Levinson, 1993) prefer to examine artworks in terms of the intentions of their makers. None of these attempts have provided an adequate concept of art that captures all forms of human production that we intuit as art. For this reason, some philosophers of art (e.g., Mag Uidhir & Magnus, in press) propose to abandon the search for a unifying concept of art. In the light of this methodological and conceptual fragmentation, reductionist approaches with their promise of a unified explanation seem highly desirable.

Whereas traditional philosophy of art takes artworks as a starting point, recent naturalistic approaches (e.g., Carroll, 2004) concentrate on the human cognitive faculties and behaviors that are responsible for the creation and enjoyment of these objects. After all, there is no experience of art except through our cognitive and perceptual systems. Thus, to understand why people create and enjoy art, it is important to understand its neurological underpinnings. Its universality across cultures also seems to warrant an explanation in biological terms. It is therefore not surprising that the first attempts to provide a unified explanation for art in biological terms date back to the 19th century. Experimental aesthetics (see Aiken, 1998, for an overview) was in fact among the earliest domains of experimental psychological investigation, with founders of the field like Wilhelm Wundt and Gustav Fechner probing their subjects' aesthetic responses to the golden ratio[15]. Later, behaviorism was reflected in the experimental study of aesthetics. For example, Berlyne (1974) investigated the psychological basis of aesthetics as arising from the fundamental needs for arousal and excitement that are closely related to a drive for exploration and curiosity. Colin Martindale's experimental analysis of patterns of stylistic change in European music (e.g., Martindale & Uemura, 1983) suggested that rapid stylistic changes do not stem from a universal drive to innovate, but rather from the human desire to avoid repetition and boredom. Martindale held the well-understood mechanism of habituation responsible for the craving for novelty in art in modern European and American culture.

Theoretical and conceptual developments in psychology, in particular the decline of behaviorism and the growing influence of evolutionary theory in studies of human behavior are reflected in current scientific investigations of art. Evolutionary theory offers the possibility of a unified approach to human artistic behavior. Tinbergen's four questions (1963) form a useful starting point. Niko Tinbergen (1963) proposed that any evolved trait or behavior can be explained through four complementary explanatory strategies: its proximate causal mechanisms (what physical structures, such as hormones or brain structures, are causally responsible for the trait), its ultimate function (how does the trait contribute to an organism's fitness, why did it evolve), its development (how does the trait arise in individual ontogeny) and its phylogeny (its evolutionary history). This chapter will focus on two of these questions: proximate and ultimate causes. As we shall see, cognitive neuroscience primarily investigates proximate causal mechanisms (brain structures) responsible for artistic behavior, whereas evolutionary psychology mainly concentrates on ultimate causes (e.g., what are the consequences of artistic behavior for an individual's fitness). This chapter will argue that the byproduct account of art, which conceptualizes artistic behavior as a byproduct of normal cognitive processes, rather than as an adaptation, is most successful in integrating these approaches. Given the current methodological and conceptual fragmentation in the field of art studies, such an integrative approach would be welcome.

5.2 Cognitive neuroscience and art

Current cognitive neuroscience draws on two types of methods to examine modularity in cognition: studies of functional brain imaging and brain lesions (see also section 2.2.1). Cognitive neuroscience is a successful research program that provides causal accounts for cognitive states by reference to brain states. Subdisciplines like neuro-economics, neuro-ethics, or neuro-aesthetics attempt to provide neurally grounded explanations for phenomena typically investigated by the special sciences, such as economic decision-making, moral judgments or aesthetic appreciation. By looking at patterns of brain activation (neuroimaging studies) and cognitive impairments following brain damage (lesion studies), it examines how the functional architecture of the brain produces cognitive processes.

Since the brain is the only organ responsible for cognition, every cognitive task must yield a specific pattern of brain activation. Why then is it interesting to localize cognitive functions if all are localizable? If we put people who contemplate the Mona Lisa under a scanner, this will activate neural circuits dealing with face-recognition, emotion and perhaps theory of mind (our intuitive psychology that allows us to infer mental states, such as the reason why she might smile). It does not follow that the brain contains a "Mona Lisa module", even if these patterns of activation are stable across subjects. To constrain their research, neuroscientists look for psychological primitives, capacities that are not further reducible to other, more basic abilities. Due to these methodological constraints, they typically propose cognitive specializations at a relatively fine grain (Bechtel & Mundale, 1999). However, psychological primitives do not necessarily equate with single brain regions—rather, what is important is that the same areas are robustly activated across a wide variety of tasks. Theory of mind, for instance, activates a distributed network of neural circuits, including the medial prefrontal cortex, superior temporal sulcus, and temporal poles. What makes it a psychological primitive is that the same network is activated across a wide diversity of tasks that involve the attribution of mental states to others, such as beliefs and desires, including interpreting cartoons and stories, or even watching simple geometric shapes 'chasing' each other (Gallagher & Frith, 2003).

Does art constitute a psychological primitive? Neuroimaging studies of subjects looking at visual art indicate that propensities and biases of the visual system can account for many recurring features of art. Indeed, several authors (e.g., Latto, 1995) have argued that works of art capture our attention precisely because the artists that created them have unconsciously homed in on propensities of the human nervous system. For example, the search of artists like Piet Mondriaan and Kazimir Malevich for pure forms accords with the presence of orientation-selective cells in the primary visual cortex (V1) that respond selectively to dots and straight lines, especially to horizontal and vertical ones (Zeki, 1998). This is part of the earliest stages of processing by our visual system. Mondriaan's *Composition with Red and Blue* (ca. 1936) is a typical example of visual art that stirs the orientation-selective neurons in V1 (Fig. 5.2, top left). Since the Late Pleistocene, combinations of straight lines are commonly found, for instance in the engraved ochre plaquettes from Blombos cave, South Africa (about 77,000 years old), as are dots on Franco-Cantabrian cave walls (e.g., the spotted horses from Pech Merle, France, 16,000 years old, see Fig. 5.2, top right). Such designs are also observed on artifacts from diverse periods (e.g., decorative lines and dots on earthenware from the Linear Pottery culture from the European Neolithic, 5500–4500 BC) and in the artistic production of many nonwestern cultures (e.g., geometric patterns on basketry or cloth, see Fig. 5.2, bottom left). The pervasiveness of geometric designs across widely divergent cultures and periods may be explained by the fact that they are appealing to the early human visual system (Hodgson, 2006). Although the popularity of geometric designs could also be due to the fact that they are simple to render, and that they can be used as building blocks of more complex designs, as in Yuan and Ming dynasty Chinese painting, where bamboo is rendered with a few simple brush strokes (see Fig. 5.2, bottom right), the fact that they are consistently used alongside more complex designs (e.g., dot and stripe patterns alongside animals depicted in Paleolithic imagery) provides evidence for their intrinsic appeal.

Some forms of art key in on trichromatic color processing, a visual system humans have in common with most diurnal primates. Color-sensitive cells in the visual areas V1 and V2 are mainly concerned with registering the intensity and presence of color fields (Zeki, 1999, 189). Artists like Mark Rothko or Yves Klein produced paintings with large iridescent color fields that key in on this stage of color processing. By contrast, fauvist and expressionist canvases evoke responses in V4 and in the inferior temporal and frontal cortices (Zeki & Marini, 1998), which are involved in matching colors to objects. People process images with correct colors in a different way from images that have colors that are not commonly associated with the objects they depict, such as blue strawberries. The latter elicit a strong activation of the dorsolateral frontal cortex (Zeki & Marini, 1998). The unusual neural pathways associated with our perception of mismatching colors may provide an explanation for why such images are attention grabbing. Fauvist and expressionist painters unknowingly hit upon this when they began to paint objects in mismatching colors, like Henri Matisse's portraits of his wife, with green and blue patches across her face, or the blue horses by Franz Marc, as can be seen in Fig. 5.3.

Yet other forms of art are experimentally associated with an increased activation in the motion-sensitive visual areas, such as the medial temporal and medial superior temporal cortices (Zeki, 1998). This is not only the case for dance, but also for contemporary art forms like mobiles by Jean Tinguely and Alexander Calder. A PET study (S. Brown, Martinez, & Parsons, 2006) of subjects who tango revealed that dance involves a network of neural circuits normally engaged in ordinary bipedal locomotion and in the organization of complex sequences of movements. Somewhat surprisingly, the activation of the medial temporal and superior temporal cortex is also observed in subjects who look at classical and renaissance sculptures in *contrapposto* stance[16] (Di Dio, Macaluso, & Rizzolatti, 2007). Apparently, brain areas that visually analyze motion

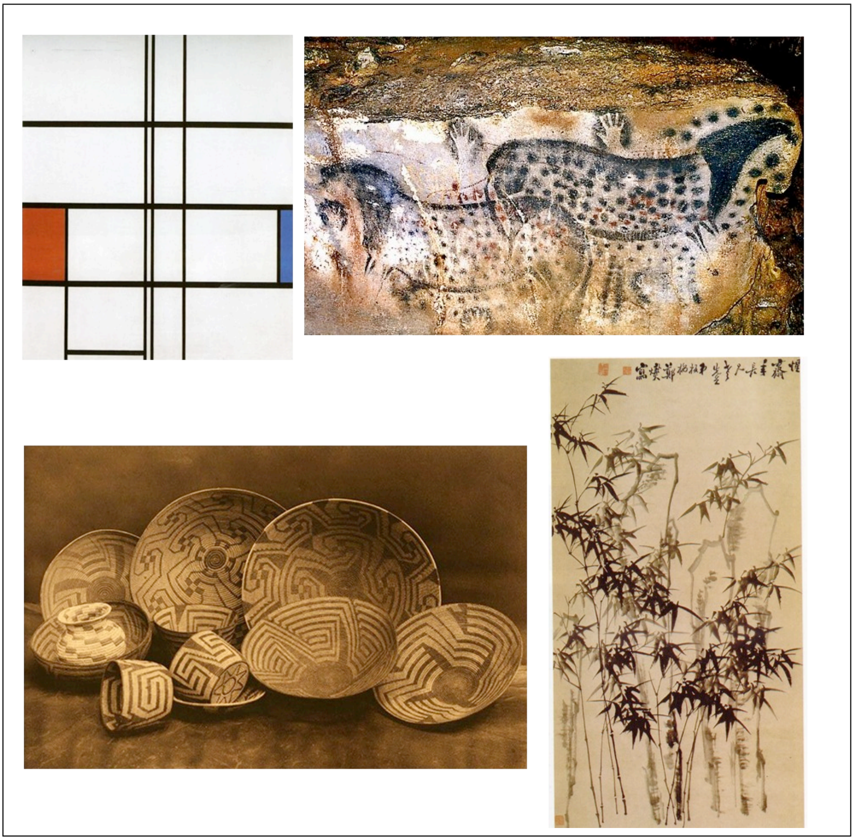

Figure 5.2: The appeal of straight lines and dots. Clockwise: Piet Mondriaan, *Composition with Red and Blue* (ca. 1936), retrieved from `http://www.abcgallery.com/M/mondrian/mondrian57.html`; spotted horses, Pech Merle, 16,000 BP, retrieved from `http://france.cherylfortier.com/wp-content/uploads/2009/09/PechMerleHorses.jpg`; basketry from the Akimel O'odham Native Americans (living across the border of Arizona and Mexico), retrieved from `http://thetextileblog.blogspot.com/2010/01/pima-basketry.html`; painting of bamboo by Ming dynasty painter Zheng Banqiao (1693–1765), retrieved from `http://china4200.com/`.

are not just active when seeing actual motion, but also when it is implied (see also sections 2.2.2 and 5.5).

Figure 5.3: Henri Matisse, *Madame Matisse (a.k.a. The green line)* (1905), retrieved from `http://sharonlaffertyart.blogspot.com/2010_03_01_archive.html`; Franz Marc, *The large blue horses* (1912), retrieved from `http://www.artinthepicture.com/paintings/Franz_Marc/The-Large-Blue-Horses/`.

Music, too, recruits brain mechanisms that are associated with a variety of normal, everyday cognitive activities. Listening to music recruits Broca's area and the orbitalis region of the left inferior frontal cortex, neural regions specialized in the processing of grammatical structure (Levitin & Menon, 2003). Music that violates expectations in rhythms or harmonic structures activates brain areas that were previously implicated in violations of syntax in language (Maess et al., 2001), see also section 3.1. At the same time, experimental evidence (e.g. Huron, 2004) indicates that people who listen to music have a clear preference for expected over unexpected sounds, and find the former more pleasant. Many musical devices, such as the *appoggiatura* (an embellishment along the main note) or harmonic cadences (the use of at least two chords to conclude a section or phrase of music) promote prediction by the listener (Huron, 2004). Classical period compositions, for instance by Joseph Haydn or Wolfgang Amadeus Mozart, often balance on a cognitive optimum between predictability and violation of expectation: they are predictable enough to evoke pleasurable responses, but occasionally violate these predictions so that the audience remains interested and focused, for example by inserting changes in modulation and rhythm, introducing elements from folk music, or by incorporating unusual instruments (e.g., Leopold

Mozart's *Cassation in G for toys, two oboes, two horns, strings and continuo*, that introduces toy instruments into an otherwise normal orchestral piece). Because neuroimaging studies rely on stimuli of limited duration, at present no such studies have probed what neural mechanisms underlie the perception and appreciation of literature. It seems, however, that short stories and jokes invoke neural circuits involved with theory of mind (Gallagher & Frith, 2003; Mano, Harada, Sugiura, Saito, & Sadato, 2009) —presumably, the same would be true for someone reading Leo Tolstoy's *Anna Karenina* (1878).

An interesting pattern emerges from these studies on different types of art: in all cases, the aesthetic responses are elicited by tapping into the normal functions of perceptual systems in unconventional ways. Why should the perception of blue horses which yields an enhanced response in the inferior temporal cortex, or of atypical musical structures, leading to an increased activity in Broca's area, elicit aesthetic responses? Given the limited attentional resources of the brain, perceptual inputs compete for neural space. It thus seems likely that because of their importance to the survival and reproduction of an organism, some cues are given priority by the early perceptual systems—for example, as we shall see further on (section 5.4), the human auditory system is especially well attuned to the acoustic properties of the human voice, and the human visual system is apt at recognizing face-like stimuli. The brain could be regarded as a set of world-interpreting mechanisms that lead us to ignore some aspects of the world, while others are accorded disproportionate attention (see also section 12.2). Aesthetic responses may find their origin in the brain's reward system, which guides attention to relevant perceptual input (Barry, 2006). Ramachandran and Hirstein (1999) propose that successful art exploits these tendencies, thereby eliciting strong emotional responses. Some cognitive neuroscientific studies provide support for these views. Looking at paintings one deems beautiful activates reward-based emotional circuits compared to duller paintings (Vartanian & Goel, 2004). Similarly, participants looking at canonical classical and renaissance sculptures show higher activation in the anterior right insula compared to a control condition in which the proportions of these sculptures have been digitally altered so as to look less harmonious (Di Dio et al., 2007). The anterior right insula is a part of the limbic system that is consistently involved in mediating cravings for food and so-called recreational drugs and in providing an emotionally relevant context for perceptual experience (Garavan, 2010). Likewise, people listening to their favorite music show stronger activation in reward and motivation-related brain areas compared to control compositions (Blood & Zatorre, 2001).

This intimate connection between the function of art and the function of the brain led Zeki (1999, 10) to quip that artists are in a sense neuroscientists, since art, in order to be successful, must appeal to human perceptual, conceptual and motivational systems. In other words, art appeals to us because it exaggerates or appropriates features that human perception is tuned to (e.g., faces, color contrasts) while ignoring or underplaying other features that are less important to human perception. Indeed, many works of visual art contain revealing systematic mistakes in rendering perspective, shadows, and reflections accurately. Take shadows as an illustration. Painters typically do not depict shadows realistically. Outside of western art, most traditions omit shadows altogether (Gombrich, 1995). When artists do attempt to paint shadows, they often fail to do so consistently: an examination of a corpus of western historical paintings (Casati, 2007) revealed that painters tended to produce a replica of the visible profile of the caster when depicting shadows, which yields impossible shadows, as is illustrated by Witz' depiction of the shadows cast by Mary and Jesus (Fig. 5.4, left). Most observers are also not bothered by inconsistencies in lighting—indeed, without being told about them, they do not even notice them (Cavanagh, 2005). For example, Fra Carnevale's *Birth of the virgin* (Fig. 5.4, right) is full of inconsistent shadows, but to a casual observer these inconsistencies do not stand out. In accordance with this, developmental psychological studies indicate that an understanding of the behavior of shadows only emerges in late childhood. Infants, for example, show no surprise when a shadow behaves anomalously with respect to the object by which it is cast (Van de Walle, Rubenstein, & Spelke, 1998). Even adults have difficulties predicting what shadows will look like given the distance and angle of a light source and the shape of an object (Ostrovsky, Cavanagh, & Sinhaô, 2005). Shadows have been put to dramatic use in film noir and expressionist movies such as Murnau's *Nosferatu, eine Symphonie des Grauens* (1922), yet even there the actual shape of the shadows has been distorted beyond what would normally be cast by the actors, something that does not seem to bother the audience.

The intimate fit between artistic production and human cognition can explain why artists are unconsciously drawn to some art forms over others,

Figure 5.4: Impossible shadows. *Adoration of the Magi* by Konrad Witz, 1446, from `http://allart.biz/photos/image-2522.html`; detail of *The birth of the virgin* by Fra Carnevale, 1467, from Cavanagh (2005, fig. 1, p. 301).

or when, if a new artistic style is developed, it tends to evolve in specific ways. Take the example of abstract art: since the 18th century, artists have attempted to break free of aesthetic conventions in order to capture the essence of their subject matter, culminating in abstract art. Yet, as we have seen, abstract art often appeals strongly to early perceptual systems, by using vivid colors, straight lines or sharp contrasts, exploiting amongst others areas V1, V2 and V4. The perceptual tendencies of the human brain can be seen as cognitive attractors that have channeled abstract art in preordained directions, in particular, a tendency toward more clear-cut, simplified and geometric shapes, brighter colors and higher color contrasts, arguably because these features elicit stronger responses in the artists' and viewers' early perceptual systems. In the work of well-known artists like Paul Klee, Piet Mondriaan and Henri Matisse, one can indeed observe an evolution toward the progressive influence of these cognitive attractors, in the increasing use of strong lines, vivid colors and bold contrasts. As can be seen in the series of images on Fig. 5.5, Mondriaan, who started out painting naturalistic fruit trees, progressively abstracted them into horizontal and vertical lines in the course of a few decades. Ironically, by striving to escape from artistic conventions, abstract artists were lured into the conventions of the human perceptual systems. Or, to put it more positively, as 'to abstract' means 'going back to the essentials,' abstract art has indeed succeeded in stripping away cultural conventions by reverting to elementary responses of the human perceptual systems.

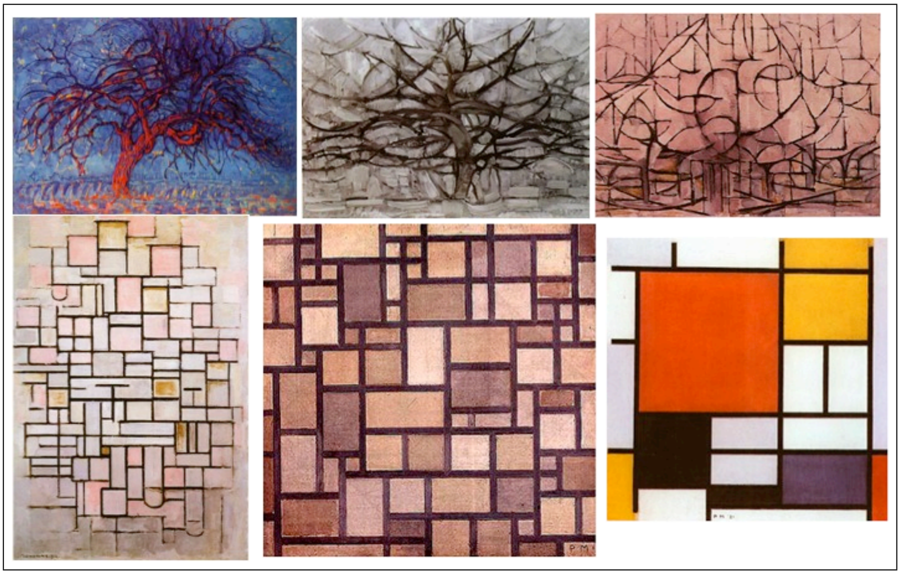

Figure 5.5: Mondriaan: from orchards to straight lines. From left to right, and top to bottom, Piet Mondriaan, *Red tree* (1909); *Grey tree* (1912); *Blooming trees* (1912); *Composition No. 6* (1914); *Composition: Light color planes with grey contours* (1919); *Composition with red, yellow, blue and black* (1921), retrieved from `http://www.abcgallery.com/M/mondrian/mondrian.html`.

Taken together, neuroimaging studies suggest that art is not a psychological primitive. Rather, it hijacks the preferences of normal perceptual and motivational neural circuits. Lesion studies provide an equally compelling case: art production seems to continue irrespective of the location or extent of the lesions in the brain of the artist. Not even at the very rough level of hemispheric specialization do we see any modularity in artistic behavior—the loss of function in either hemisphere does not automatically lead to an inability to create art (Zaidel, 2005). In a case study of an Asian-American artist, Mell, Howard, and Miller (2003) document the gradual shift over 12 years from conventional Chinese themes to a bolder, expressionist style throughout her cognitive decline due to fronto-temporal dementia (FTD), as shown on Fig. 5.6. Remarkably, some patterns of brain damage, resulting from FTD, are correlated with an emergence of artistic skills in previously non-artistic individuals (e.g., B. L. Miller et al., 1998), Fig. 5.7. The five patients (all in their 50s or 60s) described by B. L. Miller et al. (1998) all spontaneously began to take up art classes, painted, sculpted or photographed obsessively without any previous interest in art, and were later diagnosed with FTD. Their interest in art is thus not a result of therapy. FTD patients typically have impairments in language, executive control and social skills, but remain relatively unaffected in the domains of visual perception and motor skills. According to B. L. Miller et al. (1998), the decline in inhibitory control that is typical for FTD might facilitate the already present capacities for visual art production in these subjects. Alternatively, the patients may have chosen to focus on visual art because of the difficulties they experienced in other domains, such as social interaction, and the relative preservation of their motor and visual skills. Either way, this research suggests that the capacity to make art is not restricted to the select few, but is present in the population at large. This may also be true for music. A study that investigated musical memory (Racette & Peretz, 2007) suggests that professional musicians are not significantly better than laypeople in recalling the melody, rhythm and lyrics of unfamiliar folk songs, despite their extensive training in and familiarity with music.

If art is not a psychological primitive but an epiphenomenon, cognitive neuroscience cannot study art as such—indeed, what the neuroscience studies seem to tell us is that when subjects view a work of art, they do not see, say, a canvas or a statue, rather, they react to what it represents (e.g., a seascape, a nude woman). However, cognitive neuroscientists who examine artistic behavior (e.g., Zeki, 1998; Vartanian & Goel, 2004) do not claim that art does not correspond to anything in the real world. Quite on the contrary, many of them (e.g., Cavanagh, 2005) argue that the history of art can inform theories of the human mind, because successful art provides a window onto invariant properties of the human perceptual systems.

Figure 5.6: Changes in style in an accomplished American-Asian artist with FTD. From left to right: *Quan Yin*, prior to the artist's illness; *Male nudes*, 9 years into her illness (at this time she was affected by aphasia); *Four Masks*, 13 years into the artist's illness and her last painting. Images from Mell et al. (2003), Figs. 1, 2 and 3, pp. 1708–1709.

Figure 5.7: Paintings by two amateur painters who made their first artworks in their 50s: by an FTD patient in his late 50s, depicting a church he remembered from early childhood (left); by a 64-year-old FTD patient, depicting a rural scene from her childhood (right). Images from B. L. Miller et al. (1998), Figs. 1 and 3, p. 979.

5.3 Art as adaptation

Evolutionary psychology aims to explain features of human behavior as a product of an interaction between evolved psychological mechanisms and the environment, making use of methods from evolutionary biology, such as kin selection or parental investment theory. It does not regard culture as completely autonomous but as at least in part reducible to the human evolved cognitive architecture. Evolutionary psychologists disagree about the extent to which this reduction of culture to evolved cognitive tendencies is possible. Some (e.g., Tooby & Cosmides, 1992) argue that most of culture consists of 'evoked' cognitive predispositions, while others (e.g., R. I. M. Dunbar & Barrett, 2007) allow for a larger influence of culturally transmitted norms and rules in governing human behavior. Nonetheless, much of the evolutionary psychological literature is clearly unificationist, as it attempts to "integrate the social sciences into a seamless system of interconnected knowledge that runs from astronomy to biology" (Tooby & Cosmides, 1992, 19).

Although evolutionary psychologists are interested in both proximate and ultimate explanations in a variety of domains of human behavior, their examinations of art have so far concentrated on ultimate explanations of why people spend considerable time and energy in their production and enjoyment of art. Two types of approaches to explaining artistic behavior have been proposed: either that it is an adaptation, which has evolved in direct response to one or more selective pressures in our ancestral past, or that it is a byproduct of other adaptations that does not serve an adaptive function in itself. Its complexity makes it implausible that art would have evolved through random genetic drift.

Those who favor the view that art is an adaptation invoke its universality across cultures, its costliness in terms of time and energy, and its early and spontaneous development in children. We will briefly discuss a selection of recent adaptationist models for art. Geoffrey Miller (2000) argues that art and other forms of human creative behavior evolved as a result of sexual selection: their costliness in terms of time and energy provided ancestral hominids with an honest signal of the fitness of the art-producing person (in Miller's view, primarily the art-producing male). Just like a lush but burdensome tail in peacocks or birds of paradise is a good signal of its owner's qualities to live with such a handicap (Zahavi, 1975), the artworks honestly signal the artist's qualities as a mate. In support of his hypothesis, Miller (1999) shows that the artistic production of western male writers, jazz musicians, and painters peaks during prime reproductive age, with a higher productivity in quantitative terms compared to their female peers. The latter have a more even distribution of artistic output across their lifespan, and do not experience the sharp decline in artistic production during middle age that is typical of their male fellows.

A potential problem with this evidence is that it is solely based on an analysis of western artists. The quantitatively higher male output may be due to socio-cultural factors, such as gender-based prejudices in perception of male versus female artistic qualities. A way to control for this possible western bias would be to replicate Miller's study in non-western cultures, especially in those where women are responsible for a substantial part of the art production. For example, in Tonga (a Polynesian kingdom), woven ceremonial mats that are exclusively the work of women have high aesthetic and cultural value—a collection of such mats constitutes the Tongan crown jewels (St. Cartmail, 1997). These ceremonial mats are not primarily functional objects (although they resemble functional, non-decorated mats in some respects) and are thus a good analogy to the (primarily non-functional) art production in western culture. Tongan men, on the other hand, carve functional wooden objects like decorated bowls and neck supports. A cross-cultural test of Miller's hypothesis evaluating art production in cultures where both men and women are active artists (such as Tonga, or Navajo native Americans) could examine whether men still have a higher quantitative production in these cultures, and whether there is a correlation in men (but not in women) between a peak in artistic production and the prime reproductive years. Even if this were the case, there is yet another possible confound to Miller's hypothesis, namely more general sexual differences in motivation and drive: men might be more prone to have a high quantitative output of art for the same reason that they seek higher income jobs. Indeed, Kanazawa (2000) found that male but not female scientists tend to write the lion's share of their papers in their prime reproductive age. Thus, sexual differences in art production could be the result of sexual selection, but this does not entail that sexual selection specifically targeted art and other cultural displays.

Tooby and Cosmides (2001) point out that pretend play emerges universally in toddlers. This ability provides us with the imagined worlds of (oral and written) literature and visual art, risk-free environments where learning can take place through vicarious experience: fairy tales like Snow White tell of the competition that may arise between fading mothers and nubile daughters, whereas novels like Jane Austen's *Sense and Sensibility* (1811) provide an insight into human mate selection dogged by financial worries. Although this hypothesis sounds intuitively plausible, it has not been empirically investigated. A possible test for Tooby and Cosmides' (2001) claim might be to investigate correlations between early exposure to fiction and performance in theory of mind tasks. Some studies (e.g., M. Taylor & Carlson, 1997) indicate that children who engage more in imaginative play, i.e., creating fictional environments or inventing imaginary friends, are advanced in theory of mind comprehension compared to their less imaginative peers. Future work may indicate to what extent being engaged in fiction (such as children's books, read aloud by parents) has an effect on the developing theory of mind.

Ellen Dissanayake (2000) proposes that art is the intentional act of making everyday behavior special through exaggeration, formalization, or manipulation of expectations: dance exaggerates and formalizes normal bodily movements; songs distort normal speech and prosody. Performing such actions together relieves tension and anxiety, thus improving social bonds within the community: such rituals "build and reinforce feelings of unity among adults, all of which ultimately serve to hold the group together" (Dissanayake, 2000, 64). She traces the evolutionary precursor of these behaviors to mother-infant dyadic interactions, where mothers and infants spontaneously engage in intentionally modifying their vocalizations, gestures and facial expressions. One potential source of tension in this account is that it has conflicting notions on the level at which selection operates. On the one hand, Dissanayake seems to favor a group selectionist account of art, as she identifies fitness benefits of art at the group level, such as an increased cohesion between group members (e.g., Dissanayake, 2000, 64, 168). On the other hand, she has emphasized that art is a result of individual selection, since "art is a behavior potentially available to everyone because all humans have the disposition to do it" (Dissanayake, 1995, 34–35). To Dissanayake, this indicates that art is the result of selection at the individual level: "art-inclined individuals, those who possessed this behavior of art, survived better than those who did not. That is to say, a behavior of art had 'selective' or 'survival' value" (Dissanayake, 1995, 35). Unfortunately, the claim that art improves survival chances has not been experimentally tested. Furthermore, insisting that a selectionist account needs to operate at the individual level requires more backing up: cross-cultural research (Anderson, 1989) indicates that the production of art by adults is usually the work of specialists. As Davies (2005, 295) pointed out, Dissanayake could have opted for a weaker position, where only a few talented persons make art, but where art is still a pan-cultural phenomenon. As long as a sufficient number of individuals make art, the adaptive benefits of art could be available at the group level. Indeed, mathematical models of cultural group selection can be applied to the evolution of particular artistic traditions, such as the development of portable art (so-called Venus figurines) in Ice Age Europe, as we shall see in chapter 6.

For art to be an adaptation, it does not suffice to come up with the observation that art serves adaptive functions in some context. Adaptationist explanations for art need to specify what it is an adaptation for. Clearly, it is not difficult to come up with adaptive functions for art, but that is exactly the problem of such adaptationist accounts. It remains as yet unclear what selective pressures may have promoted the emergence of art in the Late Pleistocene, therefore theorizing about it remains fairly unconstrained. The current selective benefits of art (for example, in terms of sexual selection) are not necessarily the same as those in the past. It is interesting to note that most adaptationist approaches to art are concerned mainly with literature (see e.g., the papers collected in Gottschall & Wilson, 2005), where the function of vicarious learning is quite plausibly explained. However, it remains unclear to what extent such an approach can be generalized to other arts, especially abstract art, music and dance. Those approaches that sketch a theory that encompasses most arts have the problem that the category of objects that is being explained is wider than what we normally regard as art. Miller (2000) explains not only art, but also humor and even conspicuous consumption, the wasteful advertising of one's resources by spending them on luxury items or giving them away, as described Veblen (1899). Tooby and Cosmides (2001) themselves point out that their adaptive account is about fiction, the broad human ability to imagine counterfactual worlds and situations. Dissanayake (1995, 2000) provides not only an explanation for art but also for ritual and ritualized behavior, which is not even restricted to humans, but can be observed in many animals living in captivity and perhaps also in the wild (see Bekoff, 2009, for a tantalizing report about grieving magpies). To date, no adaptationist explanation makes a plausible case that targets artistic behavior in its entirety.

5.4 Art as byproduct

Some evolutionary psychologists explain art as a byproduct of the evolved human mind, without the further claim that it is an adaptation. For instance, to Pinker (1997, 524–525), art's primary function is not to increase our biological fitness, but to "press our pleasure buttons." To Pinker, art exploits aesthetic preferences that were (or are) adaptive in other contexts, just like cheesecake gratifies our craving for sugar and fat. Dutton (2009, 95–96) has criticized this cheesecake analogy, aptly pointing out that there is an important sense in which our craving for sugar- and fat-rich food is *not* a byproduct, but decidedly an adaptation—it is just that it is maladaptive under current conditions to consume large amounts of such foodstuffs when they are plentiful available. Dutton (2009) makes the case that art, like cheesecake, directly appeals to our evolved dispositions.

A potentially fruitful domain of investigation for byproduct explanations of art is the study of cross-culturally stable properties of artistic production. The cross-cultural prevalence of some forms of art can be explained by their efficiency to exploit our evolved cognitive predispositions. Although human creativity can in principle create a wide diversity of artistic expressions, some of these will enjoy more success and have a higher chance to be incorporated in artistic traditions because of their fit with our cognitive biases. In the domain of music, scales provide an interesting example. Scales are collections of tones that divide octaves into specific intervals. Since humans can discriminate between about 240 pitches over an octave in the mid-range of hearing (Fastl & Zwicker, 2007), in principle a very large number of scales are possible. Yet, in practice, musical traditions only explore a modest subset of these possibilities: most scales across time and cultures are only between five and seven tones, often with well-defined intervals between them. Gill and Purves (2009) argue that this conformity can be explained by the fact that pentatonic and heptatonic scales—natural scales, not well-tempered scales as in modern western music—are close to harmonic series, which find their origin in the way humans perceive speech. Human vocal fold vibrations characteristic of voiced speech are mathematically best described by harmonic series. These function as cognitive attractors: the cross-cultural preference of a very limited number of scales may be explained by their fit with the evolved human auditory system, which is tuned to harmonic series.

Gill and Purves (2009) demonstrated that scales that are widely used cross-culturally, like the minor pentatonic scale (as in *Mary had a little lamb*) and the Phrygian heptatonic mode (e.g., Ralph Vaughan Williams' *Fantasia on a Theme of Thomas Tallis*), indeed correspond closely to harmonic series, whereas scales that are only rarely used across cultures, such as the Locrian mode (for instance, Metallica's *Sad but true*), bear the least resemblance to them. An external confirmation of this hypothesis is the sound produced by a replica of a 36,000-year-old flute made of swan bone from Geißenklösterle, southwestern Germany, by the experimental archeologist Friedrich Seeberger. The flute produces four tones and three overtones that fall neatly into a minor pentatonic scale. Seeberger (2003) can be heard playing the flute on a CD. The minor pentatonic scale is the most widely used musical scale cross-culturally, and it is also the scale that is closest to harmonic series.

Next to this, most music, even purely instrumental music, is composed within the human vocal range, indicating that music may be based to some extent on auditory adaptations involved in human speech perception. A recent study with cotton-top tamarins (Snowdon & Teie, 2010) provides indirect support for this hypothesis. The monkeys did not exhibit any noticeable behavioral reactions to human music, compared to a baseline control condition in which no music was played, which the experimenters interpreted as indifference. By contrast, the animals responded strongly to cello compositions that were modeled on tamarin vocalizations, showing arousal when they heard music based on aggressive vocalizations, and decreased activity and calm behavior when they listened to melodies based on affiliative calls. Human subjects found neither of the tamarin-vocalization based compositions pleasant. Although music is more than a rendition of vocalizations, these studies indicate its species-specificity.

Conversely, some authors (e.g., Hauser & McDermott, 2003) argue that music depends on ancient auditory properties that predate the evolution of language. The salience of some tonal intervals in musical scales may be based on auditory sensitivities that humans share with other primates. There is some experimental support for this. Rhesus monkeys, manifestly a species that does not produce music, can correctly identify two versions of the same short tonal melody as the same, for example, when one version is played an octave higher. Interestingly, like with humans, their performance drops sharply when they have to identify atonal melodies (Wright, Rivera, Hulse, Shyan, & Neiworth, 2000). However, in other respects, human musical ability is more akin to that of distantly related clades, such as songbirds and cetaceans, than to that of our closest living relatives, the nonhuman apes. Whereas songbirds and cetaceans learn songs through social transmission (e.g., Foote et al., 2006), apes, with the exception of gibbons, do not produce anything akin to song (Geissmann, 2000)—and gibbon song does not depend on transmission through learning but is stereotypical and species-specific: a hybrid of two species of gibbon will combine songs of both parents, even if it was only exposed to the song type of one of its parents (Geissmann, 2000, 108–110). Despite many efforts, no nonhuman ape has mastered the ability to learn complex, novel vocalizations through social transmission (Fitch, 2005). Taken together, the limited evidence for musical ability and recognition in primates indicates that music may be specific to humans within the primates, and that it draws to an important extent on adaptations that are involved in the production of voiced speech, including vocal fold vibrations and grammar, which evolved after hominids split from other ape lineages.

In the domain of visual art, we can also expect that visual stimuli that are significant from an evolutionary perspective will feature prominently in art production. The canvases by Vitaly Komar and Alex Melamid indicate that the taste of naive art observers may be guided by more than cultural influences. These paintings, based on polls that probed aesthetic preferences in different countries, are remarkably stable across cultures: they invariably feature tranquil landscapes around a lake with relaxing humans in the foreground and some large animals in the distance. (Readers can visit `http://www.diacenter.org/km/` for a flavor of this work.) This is in line with studies (e.g., Orians & Heerwagen, 1992) that reveal a universal preference for semi-open savannah-like landscapes with trees and water, reminiscent of the environment in which a large part of hominid evolution took place.

Another example is face perception. Newborns can already discriminate faces from other objects by detecting the shadowy patches created by eyes and mouth (Farroni et al., 2005). Face-recognition is a highly specialized capacity in humans and other primates. Its neural basis is the fusiform face area, a part of the cerebral cortex that is specialized in the processing of face-like stimuli, and that has characteristic features, such as a diminished ability to recognize inverted faces (Pascalis & Bachevalier, 1998). Face recognition probably evolved as a means to visually recognize conspecifics, as diurnal primates have less developed olfactory capacities compared to other mammals, and therefore cannot easily recognize each other by smell. A considerable part of the world's art production (e.g., portraits, busts, and masks) keys in on this evolved face-recognition system. Interestingly, some studies tentatively suggest that cultural face-like stimuli emphasize those parts of the face that humans find especially salient. Infants pay most attention to the eyes and mouth, and less to features like eyelashes or cheeks (Farroni et al., 2005). Still, face-like stimuli that are very schematic (such as smileys) elicit less neural response in the fusiform face area than realistic faces (Tong, Nakayama, Moscovitch, Weinrib, & Kanwisher, 2000). One could predict on the basis of this that successful cultural face-like stimuli will have some degree of realism, but that they nevertheless emphasize the eyes and mouth, and pay considerable less attention to eyebrows, eyelashes, cheeks or nose (think, for example, of Aztec mosaic masks, or Dan masks from Côte d'Ivoire). In support of this, Costa and Corazza (2006) found that realistic self-portraits and likenesses drawn from memory by art students show significant increases in the size of the eyes and the lips. The effect is also discernible in historical portrait art, such as in the striking Fayum mortuary portraits (Fig. 5.8).

Future research can elucidate how cognition and culture interact, for example, in the cultural evolution of face-like stimuli such as portraits or masks within particular traditions. An fMRI study of one novice and one expert portrait artist, who were asked to draw a series of faces (Solso, 2000), revealed an increased activity in the fusiform face area in both participants (albeit somewhat less in the expert) compared to a control condition (drawing geometric figures), indicating the importance of this area for the production and perception of face-like stimuli. The lower activation in the expert's brain might be a consequence of more efficient processing of faces, a result of extensive training and practice. However, since both subjects were allowed to look at the faces and their own drawings during the production task, it is unclear whether this activation is merely due to visual perception, production or both. Miall, Gowen, and Tchalenko (2009) asked untrained participants to draw cartoon faces from memory, preventing them from looking at their own hand or drawings during the task, thereby controlling for visual perception versus production of face-like stimuli. Their fMRI study indicated that drawing cartoon faces

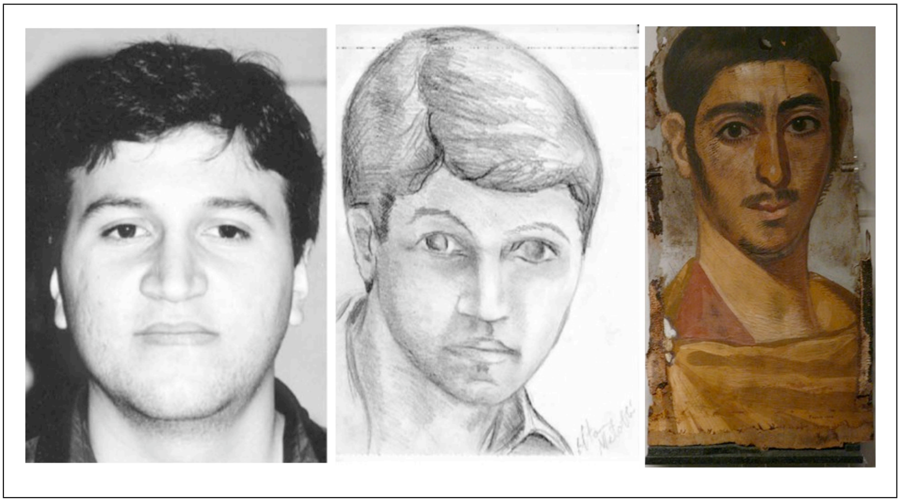

Figure 5.8: Self-portrait (middle) by an art student (left), made by use of a mirror. Notice the larger eyes and fuller lips in the drawing compared to the photograph, from Costa and Corazza (2006), Fig. 3, p. 237. Fayum mortuary portrait (right), 2nd century AD, from the Oxford Ashmolean Museum (author's photograph).

without direct visual perceptual input indeed also activates the fusiform face area.

Equally striking is the prevalence of animal imagery in visual art across the world, from the early Upper Paleolithic on. Indeed, the earliest representational art depicts almost exclusively animals. Large dangerous carnivores, large and medium game, and birds figure prominently among the mammoth ivory figurines (see Fig. 7.3.1) of between 40,000–32,000 years old, excavated in southwestern Germany (Conard, 2003) and among the slightly younger cave paintings of the Grotte Chauvet in southern France (Feruglio, 2006). Even in industrialized countries, where contact with animals is relatively sparse, depictions of animals have not diminished in popularity—unsystematic observations by parents and teachers indicate that the drawings by young western children teem with quadrupeds, birds and fish. The salience of such imagery may be explained by the priority our perceptual systems give to animal shapes. New et al. (2007) demonstrated that subjects are substantially faster and more accurate at detecting changes in complex scenery when animals (even small ones, like pigeons) were introduced or omitted compared to inanimate objects, even vehicles, which they have been trained for years to monitor for sudden life-or-death situations in traffic. As this efficiency could not be accounted for by differences in lower-level visual characteristics or expertise, the authors assumed that people might have an advantage in animal categorization by virtue of the ancestral importance of this ability, regardless of its current utility. After all, hominids have been active hunters for at least one million years (Rabinovich, Gaudzinski-Windheuser, & Goren-Inbar, 2008) and had to be aware of predators and venomous animals for a much longer period. Interestingly, the visual detection of predators can persist long after the danger of predators has disappeared: tammar wallabies (*Macropus eugenii*), an Australian marsupial found on offshore islands on the southern and western Australian coasts, have lived in isolation from mammalian predators since the last Ice Age. Yet, the animals exhibit fear and increased vigilance when confronted with stuffed foxes and cats and models of thylacines (extinct marsupial carnivores) (Blumstein, Daniel, Griffin, & Evans, 2000). Section 2.3.2 already mentioned neuroimaging studies that suggest that some parts of the temporal and occipital cortex are exclusively dedicated to perceiving and thinking about animals (e.g., Mahon et al., 2009), indicating that this neural organization is not the result of perceptual features of animals, but rather of selective pressures that have formed specialized areas within the human brain that deal with semantic knowledge about animals. More systematic empirical research could examine to what extent art that has animal imagery or themes is influenced by evolved cognitive predispositions. For example, given their evolutionary salience, one can expect that art will tend to represent those kinds of animals that humans interacted with (prey animals, predators), regardless of their current effect on human fitness—it will rather show large carnivores than malaria-carrying mosquitoes, even though the latter have currently more impact on human fitness. Some artistic traditions, like Upper Paleolithic animal imagery in sculptures and cave paintings, indeed seem to conform to this, showing high frequencies of predator and prey animals in prototypical postures. More systematic work is needed to examine to what extent this is also the case for more recent animal imagery in figurative art in western and nonwestern cultures.

If we take consilience of inductions, the convergence of two or more independent scientific disciplines (see also section 1.3), as a useful scientific heuristic, the byproduct account of art is preferable to the adaptationist view, because the former is more in line with cognitive neuroscience. The cognitive neuroscientific evidence reviewed here provides strong empirical support for the claim that various forms of art, including visual art and music, are attention-grabbing because of their correspondence with evolved propensities of the human neural system. The most likely proximate explanation for why masks, for example, elicit attention is that they activate the fusiform face area. The functional specialization of face-detection is such that perceiving faces is ineluctable: we cannot look at a depiction of a face and choose to regard it as a meaningless configuration of colors. A visual stimulus that has the main features of a face, such as a portrait or mask, thus compels the brain to pay close attention to it. The ultimate reason for the cultural success of masks and portraits around the world can be found in the evolutionary salience of face detection for humans—highly social animals that put a premium on individual recognition.

It is important to note that artists need not be consciously aware of this effect. Artists generally do not know the effects their work has on the neural activity of their audience. Random variations in artistic style can be cumulatively retained to the effect that specific artistic traditions come to correspond more closely to evolved cognitive predispositions as a form of cultural selection. We already looked into the tendency of early 20th-century abstract art to emphasize bright color contrasts and lines, and the cross-cultural prevalence of musical scales that correspond to harmonic series.

A short historical example can further clarify how this unconscious selection of artistic variations may be one of the driving forces in the cultural evolution of artistic traditions, next to culture-specific norms and preferences. The developmental psychologist Willem Koops (1996) examined the physical appearance of children depicted in Dutch and Flemish paintings from the 15th to the 20th century. He drew on Lorenz' (1943) theory of the 'child schema' (*Kindchenschema*), which proposes that specific anatomical proportions of the face and body (in particular, a relatively large head, high forehead, large eyes, and short, thick limbs) elicit nurturing behavior and affective responses. In the Middle Ages, babies and children were depicted as miniature versions of adults. From the 17th century onward, infants, children and even adolescents look progressively more neotenous (Koops, 1996). In other words, more recent paintings turn out to correlate more closely with the child schema, perhaps because Dutch and Flemish painters and their patrons found neotenous children more attractive. It is not that visual preferences changed; the preference for neoteny is probably a stable feature of adult cognition. Rather, this feature may have played a role as a cultural selective pressure to retain small variations in the depiction of infants and children. Paintings with infants and children that had slightly larger eyes and slightly higher foreheads were more successful than those with smaller eyes and lower foreheads, pushing the design of these portraits in the direction of babylike faces. (By comparison, Shaun Nichols' (2002) study of disgust and table manners indicates that a stable human aversion for bodily fluids drove the cultural evolution of more and more refined table manners. It is not that people's innate disgust mechanisms changed within the past few centuries.) The increasing chubbiness cannot be solely explained as a result of a better diet, since this long period (15th to 20th century) was punctuated by famines. It is also unlikely that the increased neoteny in depicted infants and children was solely driven by concerns for realistic depiction, as late medieval painters like Rogier Van Der Weyden or Hugo Van Der Goes could paint very realistic-looking adults, animals and plants, while the infants they painted looked like tiny adults. Moreover, exaggerated neoteny is observed in other cultural stimuli, such as the increasing childlike appearance of teddy bears in the course of the 20th century which display increasingly higher foreheads and shorter snouts (Hinde & Barden, 1985). More recent examples of neoteny include toys like *Littlest Pet Shop* and *My Little Pony,* where there is a similar increasing size of eyes and head, accompanied with a progressive shortening of snouts and limbs, as is illustrated in Fig. 5.9. Interestingly, Morris, Reddy, and Bunting (1995) found that this cultural evolution in toys was not driven by the consumers (the children) but by their parents, who buy the toys, and are thus the selecting agents. The ultimate explanation for why humans prefer cuteness in cultural stimuli is the fitness benefit it conferred to ancestral parents who were compelled to nurturing and caring for individuals whose features corresponded to the child schema. It remains a topic of future research, however, to identify the primary selective agent in the evolution of art: the preferences of the artists, or of the patrons and purchasers, or of both?

The evolutionary psychological byproduct account of art provides a

Figure 5.9: The evolution of *My Little Pony* from a somewhat neotenous horse (1982, left), with increasing neoteny throughout the 1990s and early 2000s (second, third) to an almost unrecognizable baby-shaped zoomorphic toy (2010, right), author's collection. Without cultural context, one would hardly be able to guess that the toy on the right is a pony.

satisfying explanation for the cross-cultural human drive to create and enjoy art, and for the recurrence of some forms of art (e.g., musical scales, faces, animals) across time and cultures. The evolutionary byproduct explanation and cognitive neuroscientific account strengthen each other. However, a few questions remain unanswered. The byproduct account does not explain why we do not invariably prefer art that maximally conforms to evolved cognitive mechanisms. Academic art[17] by painters like William-Adolphe Bouguereau or Jean-Honoré Fragonard generally responds to our evolved tastes in depicting attractive men and women in lush landscapes. Yet some influential art critics (e.g., Greenberg, 2003, 32) derisively refer to this type of art as overpolished and clichéd. Many highly acclaimed works of visual art are hardly eye candy, such as Francisco Goya's gloomy political canvases or Francis Bacon's haunting papal portraits (Fig 5.10). Unsurprisingly, and in accordance with the folk concept of art, untrained art observers do prefer academic painters like Lawrence Alma Tadema or Bouguereau (Martindale, 1998), probably because their works are more in agreement with our evolved cognitive tendencies. Nevertheless, the fact that this preference for such artistic forms is not universal remains unexplained.

Another future challenge for the empirical study of art consists of individual differences in art perception and production. What makes some

Figure 5.10: Bouguereau or Bacon? Why is Bouguereau's *The earring*, 1891 (left) less well regarded than Bacon's *Study after Velazquez's Portrait of Pope Innocent X*, 1953 (right)? Retrieved from `http://kevinalfredstrom.com/art/v/paintings/William+Bouguereau+-+The+Earrings+_1891_.jpg.html` and `http://www.artquotes.net/masters/bacon/paint_study.htm`.

people more prone to create art? What distinguishes art critics from the general public? Cross-culturally some people are more drawn to art production than others. Even relatively egalitarian societies have artists, i.e., individuals that are regarded as especially competent in sculpting, storytelling, or dancing by members of their community (Anderson, 1989). An adaptationist perspective, such as the one advocated by Miller (2000), can explain such individual differences as a result of frequency-dependent selection. Indeed, empirical tests that examine the relationship between artistic creativity, schizotypy and reproductive success indicate that an increased reproductive success associated with artistic capacity may be offset by the prevalence of traits indicative of schizotypy (which reduces fitness) in British poets and visual artists (Nettle & Clegg, 2006). This does not exclude an explanation of individual differences in artistic capacities under a byproduct account. If art is a byproduct of evolved cognitive capacities, we may expect that a combination of individual differences in these capacities, and personal interest and circumstance may explain why some become artists, whereas others do not. Indeed, such models have been developed for other capacities that are seen as byproducts of evolved abilities, such as mathematical reasoning skills (e.g., Geary, 1995). Like art, these skills are the result of a co-optation of abilities that have an unrelated evolutionary function, and they are sensitive to cultural context.

5.5 *Do reductionist approaches obviate the need for higher-level accounts of art?*

Cognitive neuroscientific and evolutionary psychological approaches can help us understand the cognitive processes that underlie art. From this examination of both approaches, a coherent picture emerges of art as a byproduct of normal perceptual, motivational and emotional brain circuits that have evolved in response to problems originally unrelated to art. However, from neither discipline does it become clear that art should be a meaningful subject of investigation within their explanatory frameworks. As discussed earlier, several cognitive neuroscientists (e.g., Ramachandran & Hirstein, 1999; Barry, 2006) argue that art draws on perceptual and motivational neural structures involved in everyday experience. As we have seen, evolutionary psychologists who propose adaptationist accounts for art (e.g., G. Miller, 2000; Dissanayake, 1995) typically target a category of behaviors that is broader than art (e.g., cultural display). Byproduct explanations too, do not consider art as a natural category: they make no distinction between an artwork and perfume, cheesecake or pornography, since all these exploit our evolved perceptual biases.

The special sciences, such as aesthetics and art theory, can investigate aspects of art that are not reducible to universal features of human psychology, but that are variable across time and cultures. Arguably, the striking dissimilarities in the way human figures are rendered in Utamaro's or Hokusai's woodcuts (Japan, Edo period) and Rembrandt's etchings are better explained through art historical accounts than through differences in internal brain organization. The possible ways in which a human figure can be drawn are constrained by the human visual system. Our perceptual preference for clear-cut shapes (Cavanagh, 2005) may account for the strong delineated shapes and the absence of shadow in many artistic traditions, for instance in the Japanese Edo period woodcuts that portray human figures. These strong lines also allow for the depiction of implied motion and imbalance in the human figures (e.g., sword-fighting or standing on one leg) in Katsushika Hokusai's *Manga* (1814), see Fig. 5.11, right. Indeed, a recent fMRI study (Osaka et al., 2010) indicates that motion-sensitive areas of the extrastriate visual cortex are recruited when participants look at these images. By contrast, Rembrandt van Rijn's use of shadows and diffuse shapes provides more static, almost rigid figures, but allows for a more dynamic expression of emotions on their faces (see Fig. 5.11, left)—by making facial expressions diffuse, there is room for the observer's interpretation, heightening emotional response (Vuilleumier, Armony, Driver, & Dolan, 2003). Thus, there seems to be a trade-off between clarity of shape and expression of emotions—both are in tune with human perceptual predispositions, but cannot be realized simultaneously. In order to explain the choices that have led to these divergent artistic styles, one needs to consider the cultural and historical contexts in which they evolved. In the case of the Edo period woodcuts, limitations inherent to the medium of woodcuts and a preference for clear shapes and striking compositions in Japanese visual art may be contributing factors. In the case of Rembrandt's etchings, an increased emphasis on expressing emotions in Baroque art may provide an explanation. In this way, empirical findings from cognitive neuroscience provide building blocks for testable hypotheses on the cultural evolution of stylistic traditions, a topic that is currently underexplored in evolutionary studies of art.

The evolved preference for savannah-like landscapes might explain some recurring features of garden and park design, such as a relatively sparse implantation of trees and the frequent use of water-sources like ponds or fountains, but it does no exhaust the types of landscape we find attractive. Japanese rock gardens, which consist of large stones surrounded by white raked sand or gravel, are a case in point. In contrast to many other types of gardens, Japanese rock gardens do not contain water; rather, the sand or gravel symbolizes seas, rivers or lakes. The aesthetic appreciation of landscapes seems to be subject to considerable

Figure 5.11: Rembrandt, *Self-portrait as beggar*, etching, 1630 (left), retrieved from `http://www.mystudios.com/rembrandt/rembrandt-etchings-beggar.html`; Hokusai, page with dancing human figure from *Manga*, 1814 (right), retrieved from `http://commons.wikimedia.org/wiki/File:Hokusai_Manga_03.jpg`.

cultural influence. For instance, the enjoyment of the sea and mountains is a relatively recent phenomenon in western culture—these places were thought of as threatening and hostile until well into the 19th century. As Corbin (1988) notes, it was only in the course of the late 18th century that people started to visit the beach for recreational purposes.

This ineluctability of the special sciences may be true for many domains of human culture. Consider jet-lag: suppose scientists were able to explain all its effects through neural and genetic processes, i.e., they uncovered the relevant neural structures responsible for generating 24-hour wake and sleep rhythms, and identified the genes that encode circadian rhythms in humans and other animals (indeed, most of these have been identified, see e.g., Antle & Silver, 2005, for an overview). Still, this would not explain jets or the recent phenomenon of people habitually making air voyages that span half the globe—for this, we need to resort to historical accounts of jet propulsion and sociological explanations of the rise of mass tourism and inexpensive charter flights to exotic destinations (which in turn is linked to the colonial history of these places). Similarly, a host of factors influence the appreciation and production of art, including the social status, education and economic background of the observer or artist, and the context in which one is exposed to the artwork. Consider listening to a piece of music in a concert hall to hearing it while waiting on the phone: the exact same piece of music can elicit feelings of emotion and exultation in the concert hall, while provoking boredom and irritation at the phone.

Accepting the validity of higher-level accounts of art does not automatically lead to a rejection of reductionism. Weaker forms of pluralism (the position that the study of human behavior, including art, requires multiple autonomous perspectives) pragmatically imply that a given phenomenon can be studied by a variety of perspectives (see also section 1.3) —there is no objective reason why lower-level or higher-level accounts should be the only ones worth pursuing. Since scholars are also interested in various properties of art that are not part of human biology, they can legitimately study these through the humanities. For instance, prevailing Buddhist and Taoist influences among Chinese scholars adequately explain the emergence of landscape painting in the Southern Song period and its persistence throughout the Ming dynasty (Cheng, 1991). We can therefore maintain that evolved neural circuits in the human brain can account for the production and appreciation of art. But there must be more to the study of art than simply stating that it can be reduced to the physical structure of the brain. A promising line of research is to investigate how evolved aesthetic preferences causally relate to existing styles, formats and themes in artistic production across cultures. Such an account could help us gain insight into why some art forms are more salient than others. For example, it seems puzzling that figurative visual art is more prevalent and more appealing to naive observers than abstract art, although the latter taps more directly into very early stages of evolved perceptual preferences. Indeed, to some authors (e.g., Hodgson, 2006), abstract art is most successful in tapping into primary visual areas, because of the prevalence of bold lines and colors. Maybe art observers not only use aesthetic value to gauge artworks, but also other evaluative criteria, such as the perceived difficulty in making the artworks. For abstract art, the expertise of the maker is often less easy to judge than it is for naturalistic representations. The search for causal mechanisms in the human brain may well be the most powerful strategy to account for cross-cultural universal patterns in artistic production and appreciation, with the potential of unifying sciences dedicated to the study of art.

CHAPTER 6

CULTURAL GROUP SELECTION AND MAGDALENIAN MOBILIARY ART

This chapter is a revised and expanded version of De Smedt J., & De Cruz, H. (in press b). Human artistic behavior: Adaptation, byproduct, or cultural group selection? In K.S. Plaisance & T.A. Reydon (Eds), *Philosophy of behavioral biology. Boston Studies in the Philosophy of Science*, Dordrecht: Springer.

6.1 What is cultural group selection?

As we saw in the previous chapter, while the byproduct account of art is more in accordance with the data, neither the adaptationist nor the byproduct account can adequately explain the time and energy people invest in art. While this by itself is not a reason to reject such explanations out of hand, it does provide room for an alternative explanation that will be explored here. As will be argued, this explanation accords well with empirical observations of the function of art in contemporary small-scale societies and with the archeological record of Paleolithic art. We will explore how some forms of art could be maintained through cultural group selection, in particular as a means to emphasize within-group identity. This chapter will examine the proliferation of some forms of art in the Late Pleistocene, in particular, the mobiliary art from the Magdalenian (a *Homo sapiens* Ice Age culture), by an appeal to cultural group selection. Group selection was originally proposed as a mechanism to explain altruism (e.g., Wynne-Edwards, 1962). In this view, groups composed of altruists do better as a whole than groups composed of selfish individuals, favoring the retention of altruistic behavior. In the second half of the 20th century, prominent evolutionary theorists like John Maynard Smith (1964) and George Williams (1966) argued that the assumptions on which group selection relies are very implausible. For one thing, altruistic groups are vulnerable to subversion from within—given that a single cheater within a group of altruists has higher fitness, this individual's genetic success will far outstrip the success of the altruists, as the latter have costs as well as benefits. Moreover, the replicators in biological evolution are genes, and it turns out that most instances of altruism can be explained in terms of the propagation of these genes (kin selection). As a result, group selectionist ideas fell on hard times in mainstream evolutionary theory. While no one claimed that group selection was inherently impossible, it was argued that special conditions need to be fulfilled before it could work. Group selectionist ideas are making a comeback, both in theories of altruism in the natural world (e.g., Wilson & Hölldobler, 2005) and in models of the cultural evolution of human altruistic behavior (e.g., Henrich, 2004a). Cumulative culture, which gives humans the capacity to transmit complex behavioral traits at a fast rate, indeed creates a set of special circumstances that might allow for group selection to occur.

A sensible way to interpret group selection is to see it as claiming that groups can fulfill the same role as organisms do. In evolutionary theory, a distinction is made between *replicators* (genes) and *vehicles* (i.e., entities that interact with the environment). Genes can interact as cohesive wholes with their environment through their vehicles, typically organisms. Thus the behavior of a given vehicle has direct consequences for its replicators: the vehicles' differential reproductive success ultimately causes the reproductive success of their replicators, thereby making the vehicles important units of selection (Sterelny, 1996). From this, it already becomes intuitively clear that groups must be distinct from each other and form cohesive wholes for group selection to occur.

Group selection requires that the fitness benefits of altruistic groups over selfish groups must outweigh the fitness benefits of selfish individuals over altruistic individuals within mixed groups. This condition can be mathematically described using the Price equation (Price, 1972), which provides a formal way to study changes in the frequency of heritable traits at two levels[18]. In this case, we are interested to find out whether the benefits of art for the group (i.e., all members of the group together, including nonproducers) is greater than the fitness costs of the production of art by individual members of the group. The Price equation is a statistical statement that relates the expected change in the frequency of a gene or cultural trait $\Delta\overline{x}$ per generation, the absolute fitness w_j, and the current frequency of the trait x_j. We start with a population of N

individuals subdivided into groups indexed by j, each with n_j members. There are no restrictions on how the groups are composed, except that all groups must contain at least one individual.

$$\overline{w}\Delta\overline{x} = \overbrace{Cov(w_j, x_j)}^{between\ groups} + \overbrace{E(W_j \Delta x_j}^{within\ groups}) \tag{6.1}$$

The first term on the right side of equation 6.1 represents the relationship between the fitness of the groups and the initial frequency of the culturally transmitted trait within them, i.e., what is the effect of having this trait in the group as a whole as compared to other groups. The second part represents the expected changes in this trait, based on its impact on the fitness of individual members of the group. Given that covariance expresses the product of a variance and a regression coefficient (β), we can rewrite the Price equation as follows (simplifying by ignoring factors like mutation and recombination):

$$\overline{w}\Delta\overline{x} = \beta_{w_j,x_j} Var(x_j) + E(\beta_{w_{ij},x_{ij}} Var(x_{ij})) \tag{6.2}$$

The two terms on the right side of the equations 6.1 and 6.2 oppose each other, since altruism increases group fitness but decreases individual fitness to a certain extent. If most of the variance in the population is within the group, but all groups have nearly the same frequency of the culturally transmitted traits, then the variation between groups $Var(x_j)$ will be very small, whereas the expectation of the variation within groups $Var(x_{ij})$ will be nearly the entire variance of the population. In this case, cultural traits that favor altruism will not be maintained. If groups can be isolated from each other, the variance between groups can become larger than the variance within groups due to cultural drift, which provides an ideal basis for the development of altruistic behavior. Cultural drift is the emergence and spread of cultural elements that arise by chance within a given group and that are copied randomly by members of that group. This is a mechanism that results in between-group differences when groups are sufficiently isolated. However, frequent contact between groups and migration can quickly undermine this: behavioral traits from one group can percolate into another, which increases variation within groups $Var(x_{ij})$ at the expense of variation between groups $Var(x_j)$. Cultural mechanisms that enable humans to mark group identity and to maintain between-group differences can counter these effects, giving rise to within-group altruistic behavior. Subversion from within is routinely countered by social rules such as altruistic punishment (Fehr & Gächter, 2002) that discourages selfish behavior and nonconformism. Furthermore, the presence of conformists dramatically increases the group size for which cooperation can be sustained (Guzmán, Rodríguez-Sickert, & Rowthorne, 2007).

Henrich's (2004a) derivation of the Price equation (see equation 6.3) also shows that group selection only works if the benefits of being in an altruistic group outweigh the costs of bestowing benefits to other members of the group.

$$\beta_{w_i x_i} + \beta_{w_i x_j} \beta_{x_j x_i} > 0 \tag{6.3}$$

The first term of equation 6.3 is always positive, as it models the benefits of being in an altruistic group. The second term is always negative, because it represents the costs of bestowing benefits to others. Obviously, the sum of both terms needs to be larger than 0 for cultural group selection to occur. Cultural group selection is one type of group selection in which the group is defined through cultural markers, such as a distinct language or dialect, religious beliefs, dress code, food taboos, or other cultural norms. Languages and dialects, for instance, serve as a hard to fake signal of group membership, successfully constraining between-group migration (Nettle & Dunbar, 1997). Cultural groups are also fairly stable because people have a conformist bias: they tend to follow the norms of the culture in which they were raised (Henrich & Boyd, 1998). This conformist tendency is well attested ethnographically (Richerson & Boyd, 2005; Tehrani & Collard, 2002) and archeologically (Collard, Shennan, & Tehrani, 2006), in the way material culture tends to evolve together with a particular ethnic group. As groups are culturally, rather than genetically, defined, and given that such culturally defined groups are fairly stable, cultural group selection can be invoked to explain human prosociality, i.e., the exceptional degree of cooperation and altruism found within most human societies. Rather than explaining this through genetic changes, one could argue that human culture, with its ability to differentiate groups from each other, allowed for the formation of distinct groups that each have their own norms and cultural practices (see also Henrich, 2004a). As we have seen above, once stable groups have been formed, altruistic behavior can be favored within such groups, and the individuals within such groups will have higher reproductive success compared to members of other (less altruistic) groups.

During the Late Pleistocene (126,000–10,000 years ago), members of *Homo sapiens* began to create various forms of material culture that, because of their aesthetic properties and putative symbolic value, are often referred to as visual art. Unfortunately, the archeological record does not provide reliable evidence for other forms of art such as music until much later, namely the recovery of flutes made of bird bone and mammoth ivory of Aurgnacian sites in southwest Germany, dated at about 36,000 BP (Conard, Malina, & Münzel, 2009). The evidence for dance can only be indirectly inferred, from Magdalenian representations of dancers, such as the dancing therianthropes in the Grotte des Trois-Frères, dating to about 13,000 BP (Clottes, Menu, & Walter, 1990). Because of the poor archeological preservation of music and dance, we will here concentrate on visual material culture. The earliest convincing examples of body decoration are in the form of beads made of seashells from Israel and Algeria, dated to 135,000–100,000 BP (Vanhaeren et al., 2006), shell beads from South Africa, Blombos cave, dated to 75,000 BP (Henshilwood, d'Errico, Vanhaeren, van Niekerk, & Jacobs, 2004) and ostrich eggshell beads from Kenya, dated to 50,000 BP (Ambrose, 1998). For reasons of space and clarity, we leave aside the engraved ochre artifacts from Blombos and other South African sites, as their status as art objects is still contested within the archeological community. (In chapter 7 we will return to these artifacts for a more thorough discussion on the earliest art.) Figurative art, such as figurines, painting and engravings, appears somewhat later still. Although it remains unclear whether cognitive or cultural changes lie at the basis of this transition, theoretical models (e.g., Powell, Shennan, & Thomas, 2009) indicate that cultural changes brought about by different patterns of interaction and population density can explain the emergence of art without the need to invoke new cognitive capacities due to genetic mutations, moving away from so-called silver bullet explanations. A cultural account of art is also supported by the fact that different art forms (e.g., musical instruments, beads, rock paintings, engravings) emerged independently at different time periods across the world, a pattern that cannot be explained by gaps in the archeological record alone (see section 7.1).

We here propose that some forms of Paleolithic art, in particular mobiliary art and body decoration, could have been invented and maintained as a way to signal group identity which allows for a differentiation between groups, an essential condition for cultural group selection to occur. We will now consider two theoretical models to explain in detail this signaling function of art: green beards and ethnic markers. We will pit these models against the archeological record to determine how useful they are for explaining the emergence of some forms of art.

6.2 Green beards

Art may have been used as a conspicuous tag to signal altruism directly. In theoretical models such tags are often referred to as green beards: if green-bearded creatures bestow their altruism exclusively on fellow green-beards, natural selection will promote the presence of the tag as well as the altruism. This theoretical framework can be easily extended to cultural evolution. Simulations (e.g., Riolo, Cohen, & Axelrod, 2001) indicate that cooperation can evolve easily in a population of agents who follow the simple rule 'cooperate with others who bear the same tag as you.' But as Dawkins (1989b) already recognized, green beard altruism can be undermined by cheaters, who show the tag but are not altruistic. The inherent instability of green beards has been demonstrated extensively in models of biological forms of green beard, where the linkage between the allele that signals the altruism (A) and the allele that codes for the display of the altruistic trait (G, for green beard) gets disrupted (McElreath & Boyd, 2007). The possible combinations of such genes in a haploid organism are summarized in table 6.1.

Table 6.1: Different fitness outcomes of signalers and nonsignalers, adapted from McElreath & Boyd 2007, p. 202.

Genotype	Phenotype	Fitness
NN	nonaltruist, no green beard	w_0
NG	nonaltruist, green beard	$pb + w_0$
AN	altruist, no green beard	$q(-c) + w_0$
AG	altruist, green beard	$pb - qc + w_0$

Here, fitness outcomes are calculated as follows: genotype NN represents baseline fitness w_0, p is the frequency of altruists in the population, b is the benefit one receives from an altruistic donor. Given that signaling nonaltruists NG can always expect to get b, but that they do not incur costs c, their benefit is $pb + w_0$. Altruists without signal AN are worst of, because they never get b but suffer costs c whenever they encounter a potential recipient who signals, the frequency of which is given by q. Finally, altruistic signalers AG get benefit pb but also have to pay cost qc. It is easy to see that genotype NG always has higher fitness than any other type as long as $c > 0$ and $b > 0$. Therefore, any process that breaks up the association between the tag G and the altruism A can result in an invasion of NGs, thus eroding the value of the signal. Selective forces work against the linkage between A and G. This association can be expressed as D (linkage disequilibrium). If A is associated with G, D is positive; if A and G are assorted at random, $D = 0$; and if A is paired with N, D will be negative. Because NG has the higher fitness, D will decline, until selection no longer favors the A allele. (Note that the selective force that breaks the linkage between the alleles coding for green beards and altruism does not play when green beards are rare alleles that are good proxies of relatedness. Due to the dynamics of kin selection, if two organisms who are reasonably closely related have the same rare marker, they can use this as a reliable indicator of relatedness.)

In cultural evolution, to counter this effect, one can change the tag regularly. Once a tag becomes too common, the chance increases that one encounters an organism with the tag but not the altruistic intentions. This can be mathematically expressed in equation 6.4.

$$\beta(p_j, q_j) = \frac{\frac{pq+D}{q} - p}{1-q} = \frac{D}{q(1-q)} \tag{6.4}$$

Here p_j is the frequency of the altruism trait in the donor given the frequency of the green beard characteristic in the recipient q_j, p is the frequency of altruists in the population, and q is the frequency of green beards. As mentioned earlier, D expresses the association between green beard and altruism. One can see that the strength of cultural group selection through tags is proportional to the amount of D, but inversely proportional to the variance of the green beard trait—in other words, rare markers work best. Additionally, green beards can repel cheaters if the tag is costlier to produce for cheaters than for cooperators. As simulations (e.g., van Baalen & Jansen, 2003) show, a population of agents that signal their altruism through green beards can withstand cheaters when the temptation to cheat is very low, i.e., when the costs of adopting the tag are very high.

When we pit these criteria against the archeological record, it seems unlikely that green beards can be a good model for the evolution of Paleolithic art. As art is not a genetic characteristic, D will not be high —there is no intrinsic reason why those who make and/or display art would be more altruistic than those who do not. Therefore, populations using art as a signal for altruism can be easily invaded by cheaters. Furthermore, as rare markers work best, green beard models predict that the signal for mutual altruism should be rare and subject to frequent stylistic turnovers. However, taking taphonomic and other destructive processes into consideration, Paleolithic art is found in abundance. Next to this, art styles in the Upper Paleolithic are remarkable stable in space and time: they are typically in use for several thousands of years with few stylistic changes over large areas (see section 6.4 for an example). Although mobiliary art requires much effort to produce, it can be displayed by anyone. Several Upper Paleolithic child burials have been found, where the individuals were covered with hundreds, or sometimes thousands of beads, each of which took considerable skill, time and energy to make—it seems unlikely that the children would have produced these beads themselves. The positioning of the beads suggests that they were attached to clothing, such as shoes, trousers or parkas, indicating that the children did not receive them as exceptional grave gifts, but that they were part of their attire (Vanhaeren & d'Errico, 2005). Clearly, the person who made the beads, and bore the costs of its production was not always the one who displayed the tag, and this association is a necessary condition for green beards to work. It is also not clear how mobiliary art could be less costly to produce for people who behave altruistically than for those who do not. In sum, green beard dynamics are an unlikely explanation for the emergence of Paleolithic art.

6.3 Ethnic markers

Like green beards, ethnic markers are easily recognizable tags that mutual altruists can use to exhibit or infer altruistic intentions. The crucial difference is that ethnic markers do not signal altruism per se, but provide information on an agents' behavior during social interactions; they are a proxy for social norms and conventions, such as marriage rules, religion, or moral practices. As social norms and conventions are not readily observable, arbitrary characteristics, like hair style, dress code or dialects, can provide good indications for them. Meeting an individual with similar ethnic markers facilitates social interactions which can be conducive to cooperation. An influential illustration of how ethnic markers can work is Nettle and Dunbar's (1997) model of languages and dialects. Their simulation indicates that individuals with similar languages or dialects can cooperate better and as a result of this achieve higher fitness. Given a limited memory-span, artificial agents can withstand invasion from cheaters who speak the same language, especially given that cheaters need to relearn another language each time they are found out and have to move to another group where they are not known as cheaters.

We will now examine how art could have been used as an ethnic marker. Cross-culturally, artistic ethnic markers are widely observed. Examples include decorated functional artifacts, where the style gives information about the ethnic group the owner belongs to, such as decorated household artifacts in mixed Phoenician Mediterranean settlements from the 8th century BCE (Delgado & Ferrer, 2007), and arrow point style as social information in Kalahari San (Wiessner, 1983). Artistic style enables individuals to distinguish people who belong to the ingroup from those who do not. Like dialects, artistic styles are difficult to imitate—it typically takes years for an artist to master a particular style.

Anthropological studies show that hunter-gatherers typically live in small bands of about 25 individuals (minimum bands); they are highly mobile within a large territory, moving on when resources are depleted. During parts of the year when resources are concentrated and abundant, these small groups aggregate with other bands that share their language, customs and beliefs. Group size is then between 200 and 800 individuals (maximum bands), depending on the carrying capacity of the environment. During such seasonal aggregations, information, gifts and sexual partners are exchanged (Mandryk, 1993). In the Upper Paleolithic, we see the alternation between these group sizes in two types of sites: smaller residential sites with relatively little material culture, and larger sites with high concentrations of material culture. Theoretical models of hunter-gatherer interactions (e.g., Wobst, 1974) stipulate that minimum bands are hexagonally arranged across the landscape, thus minimum bands typically interact with six neighbors. A hexagonal structure is optimal, because it ensures a maximum level of interconnectedness between different minimum bands. (In contrast, in a linear structure, any band would only have about two neighbors to communicate with. Linear structures, although often used in mathematical modeling of group dynamics, are not an ethnographic reality.) These theoretical concepts can be attested: ethnographically, bands have on average between 5.4 and 5.9 neighbors (Gamble, 1982, 100). The spatial distribution of minimum bands within a maximum band is illustrated in Fig. 6.1.

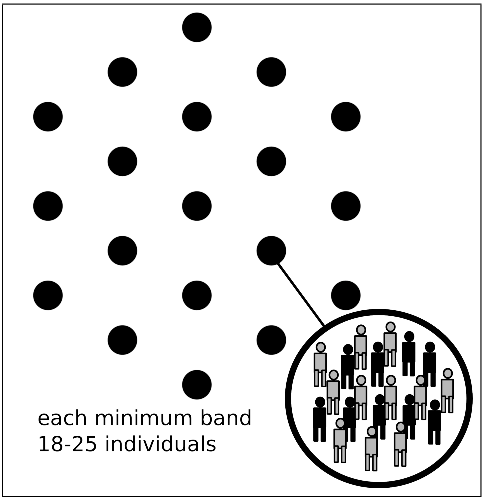

Figure 6.1: A mathematical schematization of the structure of hunter-gatherer minimum bands within a maximum band.

Altruism within minimum bands is widely attested in the ethnographic record in the form of food-sharing (e.g., Hill, 2002) or alloparenting (e.g., Ivey, 2000). It can be easily explained by two well-established evolutionary mechanisms: kin selection (since most members of these small bands are related) and reciprocal altruism (since all members have social contact on a daily basis). There is also anthropological evidence that members of maximum bands help each other in times of hardship (Whallon, 2006). This type of altruism is much more difficult to explain through biological evolutionary mechanisms, since most people within the maximum band are not that closely related, and social contact between them typically takes place sporadically. Thus, kin selection and reciprocal altruism alone cannot explain why people from different minimum bands would help members from other minimum bands within the maximum band.

From a behavioral ecological point of view, it is easy to understand why hunter-gatherers who live under marginal or unpredictable climatological circumstances, such as the historical Inuit or Kalahari !Kung, help each other to lessen the risk of local scarcity. When resources are unevenly spread in the landscape, small bands will sometimes starve before they find food. Under very difficult circumstances that are both cold and dry (the environment typical for Late Pleistocene Europe) it is not uncommon that 10% of the population dies of starvation each year (Mandryk, 1993). This is a situation that is characteristic for Late Pleistocene Europe (126,000–10,000 BP), where people mainly subsisted on herds of large migrating animals, like reindeer, horse, mammoth and bison. Under these circumstances, where the main sources of food are unpredictable and patchy in distribution, inter-group contact and movement will become increasingly advantageous and necessary. Fruitless (wrong) moves across the landscape can be lethal, leading to starvation and population decline. Not only do groups need information on where to find resources, they must also get access to them. These conditions set the stage for alliance networks between minimum bands, who can through visits, gift-giving and other regular contacts exchange valuable information on resources, and help each other in times of need. This help can take the form of passive tolerance, for instance, allowing another group to trespass on their territory, or can consist of active food sharing (Whallon, 1989). Social security networks come with a set of defined rights and obligations that people can exercise when they are in need or that they must fulfill when others are in distress (Gamble, 1982; Whallon, 1989). Such mutualistic ties are widely attested in ethnographically documented hunter-gatherers from tundra and arctic environments, such as the Tareumiut and the Nunamiut Inuit in northwest Alaska (Minc, 1986), and desert and arid environments, such as the well-known *hxaro* network of the Kalahari hunter-gatherers (Wiessner, 2009).

How could such networks be maintained? Although face-to-face contacts can play an important role, they are limited to adjacent local groups, and cannot be used to establish relationships between individuals from groups that have little or no previous face-to-face contacts. The use of a tag turns out to be a stable strategy to signal social security network membership. The *hxaro* network of the Kalahari !Kung uses ostrich eggshell beads as gifts to keep their social security network up to date. Ostrich eggshell is difficult to obtain, because the eggs are jealously guarded by both parents who ferociously defend their brood. The shell is also notably difficult to work: it has to be fresh but nevertheless fractures easily. Interestingly, ostrich eggshell beads from the Kenyan Middle Stone Age site of Enkapune Ya Muto are among the oldest examples of uncontested body decoration, dated to about 50,000 BP. Many of the beads broke prematurely and were discarded as waste, which shows how difficult it is to produce them (Ambrose, 1998). Upper Paleolithic Europe saw a prolific production of beads from mammoth ivory, tooth and shell. Interestingly, although some beads were found in burial contexts, most of them were found in living sites (R. White, 1982). These findings suggest that beads were part of the everyday attire of European Ice Age hunter-gatherers. The production of the beads and the acquisition of the raw materials required effort and time. Experimental archeological studies (e.g., R. White, 1997) indicate that fashioning one mammoth ivory bead, as is found in Aurignacian western European sites, takes one to two hours, and we know from burial contexts that clothing could contain thousands of such beads (Formicola & Buzhilova, 2004). Next to this, some shell beads were excavated in sites that are found up to 600 kilometers from the Atlantic or Mediterranean coasts (Whallon, 2006), indeed indicating extensive exchange networks across Europe. Such high investments of time and energy can be explained when one interprets these objects as ethnic markers.

6.4 The case of the Magdalenian

We will now focus on the Magdalenian, a European cultural complex that presents a pertinent illustration of how art may have played an important role in maintaining social security networks. Although the Magdalenian spanned Europe from the Pyrenees to Poland and Ukraine, its material culture was remarkably invariant. During the Last Glacial Maximum, which lasted from about 25,000 to 18,000 BP, temperatures had plunged and ice sheets had expanded from Scandinavia and the Alps. Most of Europe was depopulated, because conditions were too harsh for human subsistence. Only southern France and northern Iberia were hospitable enough to maintain relatively high population densities[19]. From these regions, humans gradually recolonized Europe between 18,000 and 11,000 BP. The recolonization is supported by archeological data, which show the spread of the Magdalenian, a markedly uniform material culture from south of the Loire to a large part of Europe (Jochim, Herhahn, & Starr, 1999). It is also confirmed by analysis of mtDNA sequence variations in extant European populations which indicate that a population originating from southern France and northern Iberia spread to central and eastern Europe about 15,000 years ago (Torroni et al., 1998, 2001; Achilli et al., 2004). Due to the severe population bottleneck that took place during the Last Glacial Maximum, about 60 % of the European mitochondrial DNA lineages (Richards, Macaulay, Torroni, & Bandelt, 2002) and even a higher proportion of the Y chromosome lineages (Semino et al., 2000) can be traced back to the Magdalenian recolonization. Figure 6.2 shows the area of distribution of the Magdalenian, as well as the vegetation types at the end of the Last Glacial Maximum.

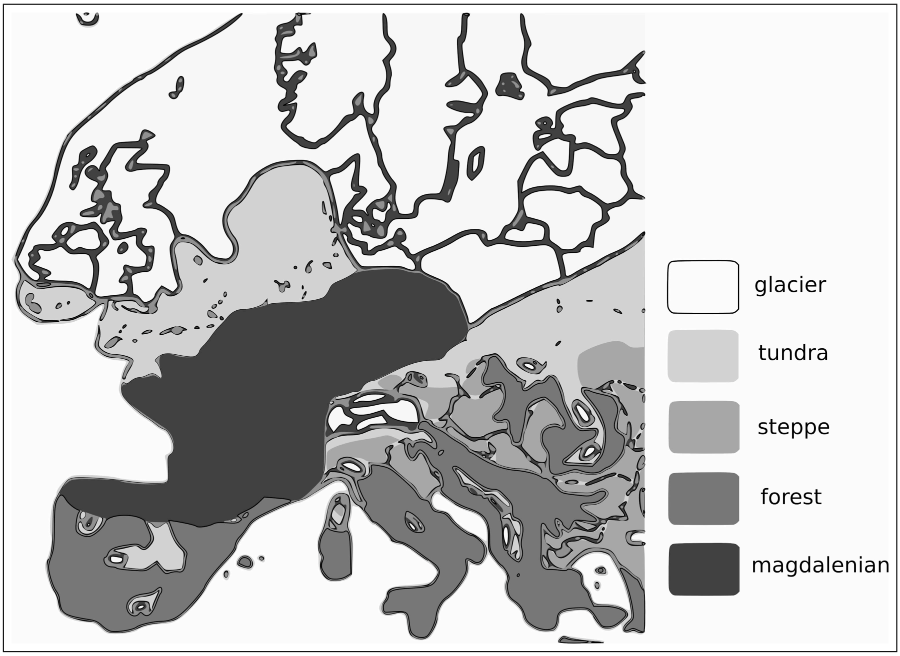

Figure 6.2: Extent of vegetation types at the end of the Last Glacial Maximum and range of distribution of the Magdalenian, adapted from Jochim et al. (1999), Fig. 1, p. 131, and from Ray and Adams (2001), Fig. 7.

Since the Magdalenian spans an enormous geographic area with a low population density, we would expect human groups to become isolated, and their art and other forms of material culture to diverge. Local climates, divergent geography of the areas and types of prey show considerable variability across Europe which again would lead to the prediction that these groups would diverge. For example, settlements closer to water relied to an important extent on aquatic food resources, whereas groups living inland subsisted mainly on reindeer and other large terrestrial mammals, reflected in a larger size of the settlements as preying upon large herds requires many hunters and can sustain higher population densities. However, the striking uniformity of the Magdalenian material culture suggests that groups maintained extensive contacts. Cultural innovations such as harpoons and spearthrowers (the latter already invented during the preceding Solutrean) were ubiquitous. Also, the frequent occurrence of exotic shells, amber and nonlocal stones found hundreds of kilometers away from their place of origin suggests the maintenance of long-distance exchange networks (Dolukhanov, 1997). The Magdalenian expansion was characterized by a significant increase in population density. During the Last Glacial Maximum, the density of sites across the southwest European landscape remained low, suggesting a population size of about 4400 to 5900 individuals. The Magdalenian recolonization led to a marked increase in site density across western and central Europe, suggesting a population of up to 28,800 individuals (Bocquet-Appel, Demars, Noiret, & Dobrowsky, 2005).

Colonizing marginal territory requires extensive social security networks, since environmental conditions are unpredictable. Similar mobiliary art and body decoration in the form of beads and pendants enabled these small bands to maintain contact and to signal membership of large aggregation bands. Over thousands of kilometres, Magdalenian art shows striking stylistic similarities, including perforated bone discs with zoomorphic figures, antler spear-throwers with zoomorphic sculpture, and hundreds of stylized female figures in profile. These figurines have been found in a wide geographical area from the Dordogne to Ukraine, as can be seen in Fig. 6.3. These objects were sculpted from a wide variety of materials, including flint, bone, ivory and steatite, which all have specific properties in terms of workability, fracturing and density. Despite this diversity in raw materials, they are stylistically markedly homogeneous, representing stylized women in profile with large buttocks, elongated headless torsos, small or absent breasts, without arms or feet. None

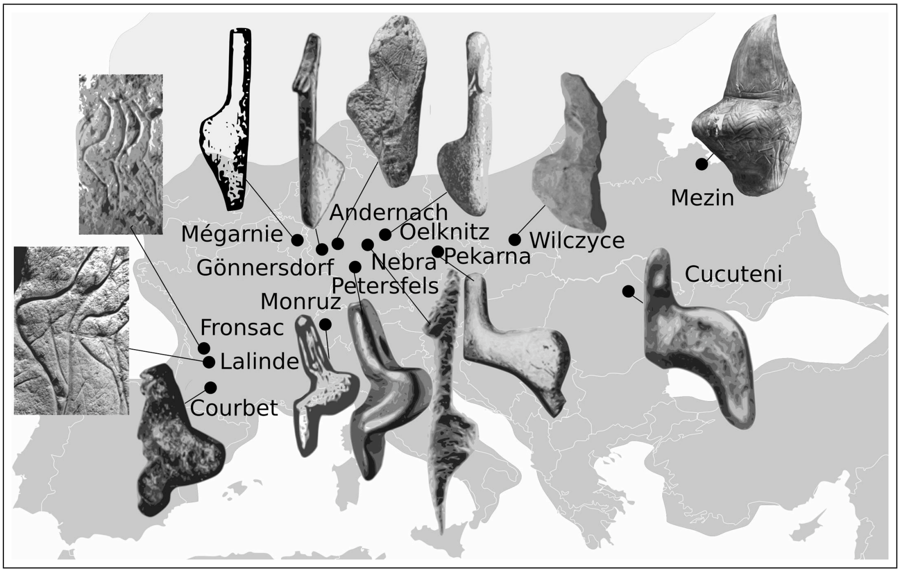

Figure 6.3: A selection of Magdalenian so-called Gönnersdorf-Lalinde type Venus figurines and their locations.

of the figurines, including those made of flint, show traces of wear, so they were not used as tools. On the contrary, they often exhibit traces of extensive polishing, which firmly establishes that the artisans and owners were concerned with their aesthetic properties. The statuettes fall within the Late Magdalenian, between 16,000 and 14,000 BP (Fiedorczuk, Bratlund, Kolstrup, & Schild, 2007), a period characterized by population expansion and settlement of humans in large open-air and rock shelter sites. Long-distance contacts are documented in the transfers of exotic materials such as Mediterranean shells and Baltic amber found more than 600 kilometres from their places of origin (Gamble, Davies, Pettitt, Hazelwood, & Richards, 2005). We propose that the abundance of these figurines within living sites (e.g., more than 20 in Wilczyce, Poland (Fiedorczuk et al., 2007) alone), the continent-wide adherence to a canon, and the care with which the objects were made and looked after suggests their use as ethnic markers. Importantly, none were found in burial sites which indicates they were not associated with particular individuals but rather with groups. The fact that some of the objects (e.g., in Monruz, Switzerland,

and Petersfels, soutern Germany) have holes for suspension (Braun, 2005) strengthens this interpretation, as they were probably worn as necklaces or other types of body decoration, signaling group identity. As the climate became milder around 10,000 BP due to the start of an interglacial period, Magdalenian visual art in all its forms disappeared. Large animals became extinct or rare, and were replaced by smaller game such as deer, birds and hares, which are more evenly spread across the landscape. The risk of starvation became smaller and social security networks were less essential for survival in this richer environment. There was a marked decrease in the spread of exotic stone and ornamental materials in Mesolithic assemblages compared to Magdalenian assemblages (Eriksen, 2002). The lack of material manifestations of social safety nets in the archeological record during this period supports our hypothesis.

Based on converging lines of evidence, this chapter sketched a cultural group selectionist model in which Paleolithic mobiliary art and body decoration were used as a signal of membership of mutual altruistic groups. Archeological and genetic evidence shows that anatomically modern humans migrated out of Africa during the Last Pleistocene. Around 50,000 years ago, they colonized Australia, including the arid inland with its inhospitable and unpredictable climate (R. G. Roberts, Jones, & Smith, 1990; Turney et al., 2001). At around 45,000 years ago they expanded into arctic Siberia (Goebel, 1999). As ethnographic parallels and our case study of the Magdalenian show, risky and marginal environments can only be colonized by hunter-gatherer groups if they form social security networks. These networks require recognizable ethnic markers in the form of portable art and body decoration. It is no coincidence that mobiliary art and pierced shell beads were first made during the last two Ice Ages, as soon as population density allowed it (first in Africa and later in Eurasia), as at least some forms of art can be explained as an adaptive cultural response to harsh and unpredictable environmental conditions. Mutual altruism was necessary for Upper Paleolithic European hunter-gatherers, since they lived in uncertain and marginal environments, where the risk of starvation was always considerable.

It is important to note that this model was not designed to provide an all encompassing explanation for artistic behavior, in the sense that more traditional adaptationist approaches have attempted (see preceding chapter). Indeed, the fact that art spontaneously arises as a byproduct of normal perceptual and motivational processes leads us to suspect that no silver bullet theory will be able to successfully explain all forms of art production. Art objects have a diversity of roles and meanings in present and past human societies, and each of these roles and meanings might require different explanatory frameworks. The purpose of this chapter was to examine how some forms of art in a particular context (such as the mobiliary art from the Magdalenian) could proliferate and be maintained through cultural group selection.

Chapter 7

A cognitive approach to the earliest art

This chapter is a revised and expanded version of De Smedt, J., & De Cruz, H. (in press d). A cognitive approach to the earliest art. *Journal of Aesthetics and Art Criticism.*

7.1 *The problem of first art*

Paleolithic paintings, sculptures and engravings are unequivocally recognized as art: many historical overviews of art (e.g., the widely used textbook Janson, 2004) start with prehistoric material, usually Franco-Cantabrian cave paintings from Chauvet, Lascaux, and Altamira. The recent archeological discovery of older symbolic artifacts may push back the time when the earliest art appeared. These artifacts include objects in bone, ochre and ostrich eggshell with geometric engravings from southern Africa, dated to 77,000–55,000 BP, and figurative mammoth ivory sculptures from Swabia, southwestern Germany (40,000–32,000 BP). The BBC[20], for example, hailed an engraved ochre piece from Blombos Cave (Fig. 7.7) as "the world's oldest example of abstract art." What warrants the intuition (not only voiced by journalists, but also by archeologists, e.g., Conard, 2003) that these objects are artworks? After all, the cultural and social contexts of these Ice Age artifacts differ from those of the modern world, and there are no written records to reconstruct their meanings and functions.

First art is a theoretical concept that denotes the earliest artworks within a particular tradition (Davies, 1997). It is doubtful whether there is a single first artwork. Arguably, multiple artworks qualify as first art: archeological evidence indicates that some forms of art emerged independently at different times across the world, a pattern that cannot be explained by gaps in the archeological record alone. To give but one example, figurative painting (Fig. 7.1) appeared significantly earlier in Europe and (possibly) in Australia than in Africa or East Asia, suggesting that figurative painting may have been invented independently in disparate cultures. The oldest figurative paintings in Europe (Chauvet Cave, France) date to 32,600 BP (Valladas, 2003). Australian rock paintings in the Kimberley region (northwestern Australia) probably predate 40,000 BP[21]. In Africa, the first figurative rock art, found in Apollo 11 Cave, Namibia dates from between 27,500 and 25,500 BP (Wendt, 1976), whereas East Asian hand stencils have been dated between 27,300 and 9,900 BP[22] (Plagnes et al., 2003).

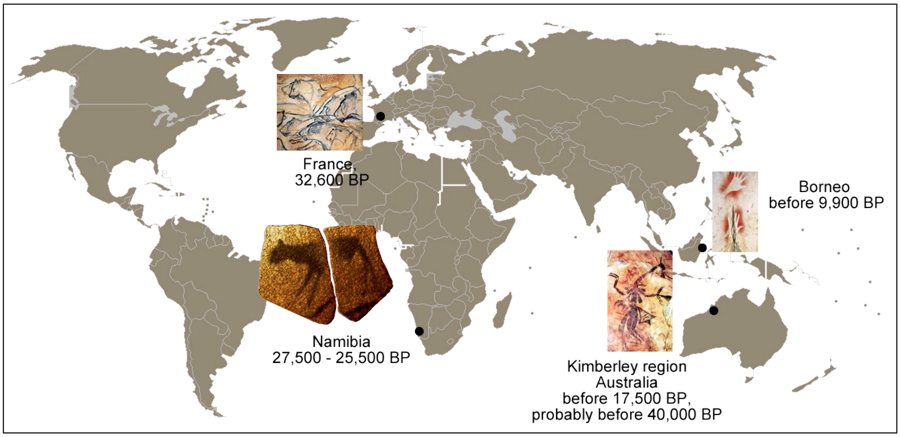

Figure 7.1: Dates of the earliest rock art in various places across the globe.

First art presents a puzzle to most recent concepts of art, because these require cultural contextual information on the function, producers, and the art critical context in which artworks are made—information unavailable for Paleolithic art. Did the cave painters of Chauvet, Cosquer and Altamira depict large terrestrial mammals and birds mainly as a source of aesthetic pleasure, a form of art for art's sake (Halverson, 1987)? Were these paintings primarily meant to be accurate depictions of animals, similar to instructive illustrations in field guides, used for educational purposes (Mithen, 1988)? Or do the cave walls bear evidence of encounters with the denizens of the spirit world during trancelike states in shamanic rituals (Lewis-Williams, 2002)? Cluster concepts, as advocated by amongst others Gaut (2005) and Dutton (2006), involve a list of features that are typical for art objects, but it is unclear which of these apply to Paleolithic art, e.g., are they expressive of emotion (Gaut), or was there anything akin to artistic criticism (Dutton)? Historical definitions (e.g., Levinson, 1993) cannot easily accommodate first art either, because they have a recursive structure: they define artworks by virtue of their relationship to earlier artworks, and again, we know nothing of these. The philosophical analysis of first art presents problems additional to that of nonwestern art. In both cases, one cannot indiscriminately apply criteria specific to western art; a focus on western art in aesthetic theories has left other artistic traditions underanalyzed (Davies, 2000). Although one can often rely on ethnographic information to get insights into the function and aesthetic significance of nonwestern art objects, this information is unavailable for first art.

Yet, as the philosopher of art Stephen Davies (1997, 27) observes, "our acknowledgement of certain items as first art seems to rest on our direct recognition of them as such, not on abstract reasoning." In a similar vein, the aesthetician Peter Lamarque (2005, 33) reflects that "what is most striking about all Paleolithic cave painting is the sense of affinity that modern viewers experience, despite the immense cultural divide," even though we have no idea about their cultural meaning. We readily identify objects from remote cultures and periods as art, and seem to possess a folk concept of art (see also section 5.1). Just like humans have had folk concepts of biological species long before the rise of modern biology, they may have a tacit and inarticulate concept of what a work of art is like (Osborne, 1981), which guides their identification of artworks independent of aesthetic theory. This does not imply that folk concepts are immune to cultural influence. On the one hand, folk concepts have universal features, like the supposition of internal mental states that is common to folk psychology across the world. On the other hand, western folk psychology is arguably influenced by Freudianism (e.g., the supposition of a subconscious state of mind), whereas that in China is influenced by Confucianism (e.g., the importance of ancestry in a person's identity). Similarly, the western folk concept of art may be colored by aesthetic theories, such as in its higher regard for painting and sculpture compared to other art forms. Yet, although indigenous terms for 'art' may be lacking, people across cultures seem to be able to recognize and appreciate what we would call artworks. Vanuatu tree-fern sculptures and Ivory Coast masks have a place in western museums and interiors, and Melanesian (Fig. 7.2) and West African artists incorporate western media and styles in their work. Were it not for stable human cognitive capacities, we would have a hard time explaining the appeal of Lascaux II, the replica of the Magdalenian cave that attracts thousands of visitors every year, or indeed the adoption of western techniques and media in artistic traditions from small-scale societies, like Native American ledger art (Fig. 5.1)—and vice versa, like the influence of those traditions on post-impressionists.

Figure 7.2: Eddie Daiding Bibimauri is a Melanesian artist who mixes western media with traditional themes. The painting, part of a series of murals called *Custom images* (1974), depicts a war canoe (note the traditional imagery like the birds) and shark totem. Plastic housepaint mural on copra shed, Point Cruz Wharf, Honiara, Solomon Islands. From D'Alleva (1998), Fig. 118, p. 152.

This spontaneous recognition of artistic behavior across time and space, back to the Paleolithic, motivates a cognitive approach to art. It is likely that Paleolithic artists had a mind like ours. For one thing, they were members of our species, *Homo sapiens*. Also, archeological evidence for behavioral modernity, in the form of standardized tools, structured living spaces, and economic exchange networks, dates back to at least 40,000 BP in Europe (Conard, 2007). In Africa, this transition was probably earlier and more gradual (McBrearty & Brooks, 2000). As Sterelny (2008) has proposed, behavioral modernity is likely not a purely psychological property, but arose as an interaction between human cognition and culture. (In the next chapter, we will see the importance of material culture in human cognitive evolution.) A recent computer simulation (Powell et al., 2009) indicates that fluctuations in Pleistocene demography seem to go hand in hand with the archeological appearance or disappearance of modern human behavior since the existence of anatomically modern humans. This indeed suggests the importance of social dynamics, including population density, coalition formation and migration, for the emergence of behavioral modernity (see also chapter 6). Stable features of human cognition may explain what is common to art behavior in disparate cultures.

This chapter proposes a cognitive approach to art. Rather than listing features that are characteristic of art objects, we will consider what cognitive processes are typically involved in the recognition of objects and performances as artworks. The shift in focus from art objects to cognitive agents is motivated by naturalistic theories that propose that art is a product of normal human perceptual and motivational processes (see sections 5.2 and 5.4 for a discussion of these theories). These theories provide a fruitful framework to approach art production and appreciation with methods from cognitive psychology. From this point of view, artworks do not form an exceptional category of objects, but rather, they are products of cognitive capacities that are present in all neurologically healthy humans. The ubiquity of art across cultures, the universal human ability to recognize and appreciate it, and the early and spontaneous emergence of artistic behavior in child development—as is evident in an early disposition to draw, sing, dance, play word games (Dissanayake, 2000)—suggest that producing and enjoying art may be a stable part of the human cognitive repertoire. This cognitive approach allows us to include artworks from distant places and cultures, even from those we know virtually nothing about, like material culture from the Paleolithic.

7.2 Cognitive requirements for art

In terms of conceptual analysis, a cognitive approach to art provides a set of higher-order criteria that need to be satisfied so that artworks can be created and recognized. In other words, it concentrates on abilities that are necessary to create and understand art, not on any features that define the objects themselves. This approach can be situated within the *abilities view of concepts*, a philosophical theory that argues that concepts are not definitions but abilities that are specific to cognitive agents (see e.g., Millikan, 2000). According to a descriptivist theory of concepts, having the concept CAT requires one to list features typical of cats, like furriness, triangular ears, and a long tail. By contrast, the abilities view argues that agents who possess the concept CAT do not have to provide a definition of what cats are, but rather, that they are able to recognize cats from non-cats with fair reliability under a broad range of conditions (Millikan, 1998). Likewise, having the concept ART entails the ability to recognize art in a wide variety of circumstances. Additionally, it enables one to make meaningful inferences about artworks one has not encountered previously, and to guide actions like art production or art criticism. Regarding the concept ART as an ability can provide a solution to the problem of borderline cases, since the ability need not be infallible. After all, a child who can identify specific cats, like a Siamese behind a window, or Misty, the neighbor's tabby, with fair reliability has the concept CAT even if she is puzzled by ocelots or wildcats. Similarly, borderline cases like found art or chimpanzee paintings can challenge the expertise of art critics, but it would be far-fetched to conclude from this that said critics do not have the concept ART. According to the abilities view, having the concept ART does not require that one is able to list any properties of art, but rather that one is able to identify particular instances (artworks) that fall under this concept's extension. The abilities view allows for concepts to be inarticulate and tacit, as seems to be the case for the folk concept of art.

To identify which cognitive processes are required for art production and appreciation, this chapter will draw on theories, experimental results and empirical evidence from developmental psychology and cognitive neuroscience. (The use of developmental studies does not mean to imply that Paleolithic artists were like children. Rather, the results of developmental psychology point to stable features of human cognition that robustly arise early in development.) Although art production and recognition require a wide range of cognitive skills (e.g., semantic memory, visual or auditory perception), we focus on those skills that we believe typify behaviors related to art. They include the design stance (the recognition of intentionality), symbol-mindedness (the realization that something represents something other than itself) and aesthetic sensitivity (the qualitative appreciation of perceptual stimuli). We then examine to what extent these processes played a role in the production of Paleolithic artifacts, in particular figurative sculptures from southwestern Germany and engraved objects from southern Africa, using methods from cognitive archeology. A cognitive approach to art can draw meaningful links between Paleolithic and contemporary western and nonwestern art, despite the widely diverging cultural and social contexts in which these objects were made.

7.2.1 The design stance

Artworks are almost invariably products of human intentional actions. This forms the basis of Jerrold Levinson's intentional-historical theory of art (1993), which conceptualizes artworks as those entities that have been successfully created with the intention that they be regarded in a certain way, namely the way in which prior artworks have been correctly regarded. The developmental psychologist Paul Bloom (1996) has extended this concept to artifacts in general. He argues that manufacturing and understanding artifacts is governed by an intuitive design stance—humans are guided by the inferred intentions of the designer when they categorize and name artifacts. One can infer that a schooner in a bottle belongs to the category of ships, even though the object is not seaworthy, because one can infer from its shape that the maker intended it to represent a ship. Also, we still see a broken chair as a chair, even though it may no longer fulfil its function (see also section 9.2.1). Levinson (2007) has objected to this extension of his intentional-historical stance to artifacts in general, because it places artworks on a par with other artifact kinds, and does not seem to reserve a special place for artworks. However, if we conceptualize art in terms of its constituent cognitive abilities, this is not a serious objection, since there is no *a priori* reason why humans would not draw on cognitive capacities that are used in other domains when reasoning about or creating artworks. Consequently, to gain a better understanding of how intentionality plays a role in art production and evaluation, it is useful to examine how humans infer design, and how creator and artifact are causally linked.

The design stance emerges early in ontogeny, and it is a characteristic feature of children's art. Although they are not skilled artists, toddlers name their drawings using the same terms as the real-world objects that capture their interest, such as 'house' or 'daddy'. These early works are similar to those of adult artists in that both skilled artists and young children take an intentional perspective toward categorizing and naming their artworks (see e.g., Fig. 7.3 for an example of this). When one asks three-year-olds to draw a picture of a lollipop and a balloon, these two drawings look virtually identical. Yet the subjects will consistently refer

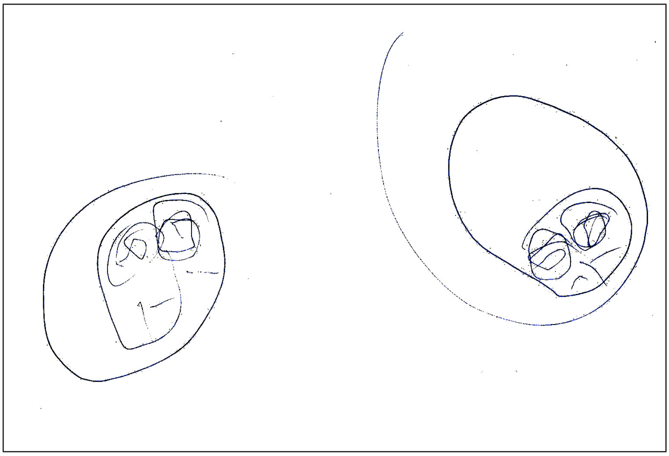

Figure 7.3: *Mommy* (left) *and daddy* (right). Although the drawings do not resemble what the child depicted, the two-and-a-half-year-old who drew this consistently referred to the drawings as what they were intended to represent. Drawing by author's daughter.

to the pictures according to what they intended to depict when they produced the drawings (Bloom & Markson, 1998). Also, like adults, children as young as two years are guided by the intention of the maker when they name pictures that hardly resemble what they depict. When they witness an adult drawing a circle that could be either of two unfamiliar disc-shaped objects, they take the gaze direction of the artist as a cue for which of the items is drawn. The toddlers reliably point at the object the adult was looking at when asked which object was depicted (Preissler & Bloom, 2008).

These and other studies suggest that foreknowledge about the intentions of the maker is a critical feature in our evaluation of artifacts. Gelman and Bloom (2000) showed children and adults a variety of objects, but subjects were divided into two groups, each of which got distinct accounts of how the objects came into being. For example, in the case of an irregular-looking stone object, the unintentional version said that someone smashed a piece of rock in a fit of rage. In the intentional account, subjects heard how an agent carefully chipped pieces off the rock. Only the children and adults who heard the latter version called the object a sculpture. This indicates that our appreciation that something is an artwork is substantially driven by our beliefs about its genesis, not only by its perceptual characteristics. This is also detectable at the neural level: when subjects believe they are listening to a piece of music that was written by a composer, activation patterns in their brain look very different from those of subjects who listen to the same piece that they believe is computer-generated. The first group of participants, but not the latter, exhibit a high activation in brain areas that are involved in the attribution of mental states and the inference of intentions of others (Steinbeis & Koelsch, 2009). The experimental evidence indicates that the design stance is an important element of art appreciation. Although one can never claim with absolute certainty whether or not the *Iliad* was intentionally created to be a work with literary qualities, we can reasonably infer this from formal properties of the work, such as its elaborate language and extended imagery (Levinson, 1993).

7.2.2 Symbol-mindedness

Humans today are immersed in a world of visual markings, such as arabic digits, letters, and pictures, in the form of advertisements, documents and traffic signs. Our fluency with these representations makes it hard to realize the complex cognitive processes involved in their interpretation. In order to make and understand artworks, one must be able to decouple the symbolic meaning of an artwork and the material it is made from. Understanding this decoupling between the meaning of an object and its medium constitutes a necessary condition for symbolic thought. For instance, in order to interpret Rousseau's *Surprise* (Fig. 7.4), one needs to realize that the painting itself is made of canvas, covered with oil paint, but that it represents a tiger in a stormy tropical landscape. Given that in this case referent and symbol are so much alike, some might not even consider the tiger to be a symbol at all. For the purpose of this chapter, we will not draw fine-grained distinctions between symbol, token, etc., but use Judy DeLoache's (2004) psychologically motivated concept of symbol, according to which a symbol is something that someone intends to represent something other than itself—nothing is inherently a symbol, but only becomes so by virtue of an intentional act. This relatively simple working definition presupposes fairly complex skills: next to an understanding of the dual nature of a symbol as both object and representation of something other than itself, it requires the recognition of intentionality and design. The decoupling of the material nature of a symbol and its referent emerges early in development. Controlled experiments have shown that infants prior to 18 months treat pictures much as if they were real objects, attempting to pick a photograph of a toy off the page, or to put on pictures of shoes (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998). By the second year of life, however, children can interpret pictures correctly, point to them and name them, and pay more attention to their meaning than to their shape (Preissler & Bloom, 2007). Two-year-olds were shown a picture of an unfamiliar looking artifact which was called a 'wug'. When asked to give the experimenter a 'wug', the children gave the experimenter an object that resembled the depicted object. However, when asked 'look at the picture, can you give me another one?' the children gave the experimenter another picture with a dissimilar looking object. Such studies indicate that by the age of two, children can flexibly switch between the material nature of a symbol and its referent.

Figure 7.4: Henri Rousseau, *Surprise!* (1891). Understanding this painting requires the ability to decouple materiality (oil on canvas) and inferred intended meaning (representing a tiger in a landscape). From `http://free1000s.blogspot.com/2008/06/rousseau-henri-surprise-1891.html`.

Although representational visual art is not produced in all cultures, several empirical studies have shown that people unfamiliar with figurative representations can recognize and even produce them spontaneously. An early study (Hochberg & Brooks, 1962) focused on a western child, brought up without exposure to any pictorial representations, such as picture books, television or figurative wallpaper. At 19 months, the boy was able to recognize and reliably name line drawings of his toys and common household objects. Deregowski, Muldrow, and Muldrow (1972) showed line drawings of complex scenes, such as a hunter stalking a goat, to members of an Ethiopian culture without pictures or drawings. Again, these subjects recognized and named the depicted objects correctly. Martlew and Connolly (1996) asked children from a Papua New Guinean culture without figurative art or access to photography to draw a man. Although the children had never produced drawings before, they drew recognizable anthropomorphic figures. These studies indicate that people are probably naturally endowed with an ability to recognize iconic representations for what they depict, and that cultural exposure is not necessary for its development. Art critically depends on this pre-existing ability, as even most nonplastic arts require the ability to make a distinction between medium (e.g., sound waves or moving limbs) and what it represents, such as the moods expressed in a piece of instrumental music, like the traditional Chinese *guqin* piece *A drunken fisherman sings in the evening*, where the plucking on pentatonically tuned strings is meant to juxtapose the tranquillity of rustic life with the rowdiness of the drunken fisherman.

We can safely infer that early representational artworks are about something, i.e., that they are meant to symbolically convey something other than themselves—it seems reasonable to suppose that a small Paleolithic sculpture that has the shape of an ibex actually represents an ibex. Thus, among archeologists and cognitive psychologists, the presence of figurative art is universally regarded as evidence for symbolically-mediated behavior (e.g., Deacon, 1997, 374–375). As we will see, there is more controversy about the symbolic meaning of nonfigurative designs. In order to be of methodological interest, a concept of symbol should not be so broad as to include all objects that have some ornamental or aesthetic value (Currie, 2004, chapter 12), yet not so narrow that all forms of non-iconic representation are *a priori* excluded. Deloache's (2004) definition of symbols is productive in this regard, since it also allows for non-iconic symbols. Shell beads, for instance, can be symbolic, provided that they encode social meaning (e.g., when they are used as ethnic markers), but not if they are merely used as body-decoration.

7.2.3 Aesthetic sensitivity

Many authors take aesthetic appreciation to involve the sensory and qualitative appreciation of artworks and other objects, yielding a distinct sense of pleasure. Like in other animals, the human nervous system is wired in such a way that some forms of sensory input appear to us as more striking and pleasing than others. Artworks capture our attention precisely because artists that created them have unconsciously homed in on propensities of the human nervous system (Zeki, 1998; Cavanagh, 2005). Given that our senses are constantly bombarded by impressions, the nervous system needs to prioritize some cues over others (Ramachandran & Hirstein, 1999). Barry (2006) argues that aesthetic preferences find their origin in the brain's reward system, which guides attention to relevant perceptual input, i.e., perceptual input that is likely to yield information that is relevant to survival and reproduction. (For a more detailed discussion of the cognitive neuroscience of art, see section 5.2.)

While this evolved function provides a plausible explanation for why humans are capable of aesthetic experience, and which aesthetic criteria are likely to be more culturally widespread than others (see section 5.4), it does not imply that all pleasurable sensations are aesthetic responses. Still, if correct, this theory could explain why at least some forms of art are particularly salient across cultures, such as the representation of the human face in masks, portraits, and busts, as argued in section 5.4.

7.3 Cognitive capacities and the earliest art

In the previous section, we outlined three types of cognitive processes that play a role in the production and appreciation of art. By focusing on human cognition, Paleolithic artworks can be understood as products of the same kinds of cognitive processes that still give rise to art today. In order to allow for an in-depth discussion, this chapter will examine two case studies: mammoth ivory sculptures from Swabia, Germany and engraved objects from southern Africa.

7.3.1 Sculptures from southwestern Germany

As we have seen, archeologists universally accept the emergence of representational art as proof of symbolically-mediated behavior. The earliest uncontested figurative representations found to date are small mammoth ivory figurines from Swabia, southwestern Germany, that represent animals, therianthropes (half-human, half-feline creatures), and humans (Fig. 7.5). They are dated to 40,000–32,000 BP, and belong to the Aurignacian cultural complex, the oldest *Homo sapiens* culture in Europe (Conard, 2003). These objects are unequivocally the result of intentional design. This can be inferred from the highly complex shapes, and the resemblance to objects in the real world, mainly mammoths, horses, and carnivores. Several of the objects are pierced, presumably to be suspended as personal ornaments. The sculptures are made of mammoth ivory, a material that is notably difficult to work due to its growth rings (Fig. 7.6). Their production required considerable expertise with ivory and its fracturing properties, and a great investment of time—using only materials that were available at the time, it took an experimental archeologist 27 hours (R. White, 2005) to copy the 5 cm-long horse figurine from Vogelherd (Fig. 7.5d). The artifacts were finished with incisions and polished with hematite, an effective metallic abrasive that is still used by contemporary ivory carvers (R. White, 2005). Although mammoth tusks are large, most figurines are tiny, no more than 5 cm across. We can infer that the objects were made with much care and attention to detail.

The easily recognizable depictions, the attention with which they are finished, and the consistent style (preference for ivory as material, small size) indicate a fully developed design stance. Given that most objects resemble entities in the world, we can be fairly certain that the makers imbued them with symbolic meaning. At the very least, the mammoth-shaped figurine (Fig. 7.5b) was intended to represent a mammoth. Next to this, it may have had other symbolic meanings as well (e.g., endurance, power), but we know none of these. The sculptures are rich in relevant details, including the hump on the mammoth's shoulder (Fig. 7.5b), the horse's arching neck (Fig. 7.5d), and the protruding breasts and buttocks of the female figurine (Fig. 7.5f), while less telling details, like hands and feet are underplayed. Interestingly, 15- to 18-month-olds gain most information from pictures that are rich in relevant details. They can transfer this knowledge to objects in the real world: detailed pictures, but

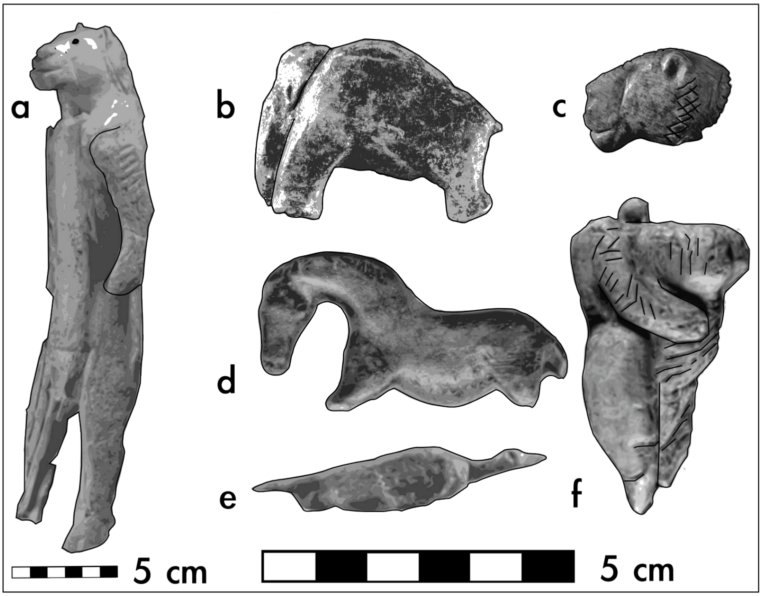

Figure 7.5: Mammoth ivory figurines from Swabia, Germany. (a) therianthropic figure from Hohlenstein-Stadel; (b) mammoth, (c) feline head and (d) horse from Vogelherd; (e) waterfowl and (f) female figurine from Hohle Fels, Figs. a–e are redrawn from `http://www.ice-age-art.de/`; Fig. f is redrawn from (Conard, 2009).

not schematic depictions, enable them to learn the names and properties of novel objects or animals they never encountered in the real (Ganea, Pickard, & DeLoache, 2008). Moreover, three-year-olds find prototypical images more useful as symbols than less prototypical ones (Allen, Bloom, & Hodgson, 2010). This may explain why Paleolithic animal imagery tends to represent animals in profile, the way they are most recognizable, not unlike the widespread use of animal profiles in natural history books. This strongly indicates that the Swabian figurines were intentionally made to symbolically represent the real-world objects they resemble. Many of the objects have geometric engravings, including crosshatchings (Fig. 7.5c), parallel lines (Fig. 7.5a) and chevrons (Fig. 7.5f). The stability of these motifs across the figurines may suggest that they had an additional symbolic meaning, the code of which is lost. The therianthropes

Figure 7.6: Mammoth ivory tusk. When sculpted injudiciously, there is a realistic chance that the ivory crumbles off at any of the growth rings (author's photograph).

form a special case, since their referents are non-existing entities. The therianthropes from Hohlenstein Stadel (Fig. 7.5a) and Hohle Fels probably represent religious agents, as many cultures know supernatural entities that are part human, part animal.

What about aesthetic value? Although the Swabian sculptures look alluring and beautiful to us today, there is no guarantee that they had the same effect on their Pleistocene makers. Even within western culture, the aesthetic appreciation of Paleolithic art has been variable. As recently as 1972, the paleoanthropologist Gustav von Köningswald (cited in Nelson, 1990) proposed in earnest that the Gravettian Venus figurines, which are now uniformly praised for their charismatic beauty, were grotesques carved with the purpose to scare intruders away. Nevertheless, there is some reason to believe that the Swabian figurines were made with the intention to be aesthetically appealing. Our main motivation for this is the choice of the material, mammoth ivory. Interestingly, the Aurignacians did not use ivory to make tools, for which they preferred stone, bone and antler, but exclusively reserved this material for beads and sculptures (R. White, 2004). Together with the technical difficulties involved in the working of ivory, this suggests that it was a choice material, maybe also because of its specific sensuous lustre. The fact that the makers or the owners polished the sculptures carefully, and used special material to do so, further supports this hypothesis.

7.3.2 Engraved artifacts from southern Africa

Let us now examine whether engraved ochre and ostrich eggshell objects from the Middle Stone Age (MSA, a *Homo sapiens* African culture) might qualify as the oldest forms of non-representational art. They date between 77,000–55,000 BP. As evidence for symbolic and artistic behavior is markedly rare prior to 40,000 BP (R. White, 2005), claims for non-representational art before this date need to be treated with caution. To see whether these engraved objects might indeed qualify as art, we will examine whether they were deliberately designed, had symbolic meaning and appealed aesthetically to their contemporaries.

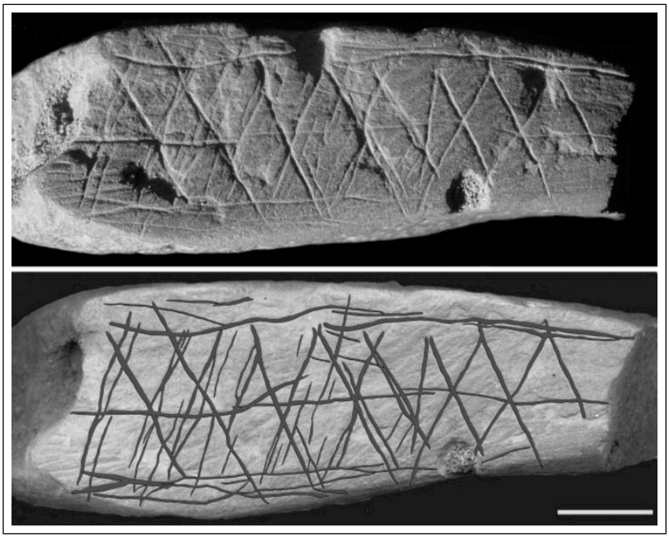

Figure 7.7: SAM-AA 8938, engraved ochre piece from Blombos cave, ca. 77,000 BP, 5.4 cm long, from Henshilwood et al. (2002), Fig. 2, p. 1279.

The term ‘engraved’ already carries an inherent implication of design, and indeed some of the markings look convincingly intentional. The best-known exemplar is SAM-AA 8938, an engraved ochre piece from Blombos Cave, dated to ca. 77,000 BP (Fig. 7.7). It appears to show a crosshatched design, consisting of two series of parallel lines that are intersecting, bounded top and bottom by long horizontal lines and divided through the middle. However, most other engraved objects from Blombos look far less spectacular, as shown in Fig. 7.8. In order to assess whether the makers had an intentional design in mind, the shape of the objects alone does not provide enough information. Blombos Cave yielded 8224 pieces of ochre; among this plenitude only 15 bear incisions. The majority of these incised ochres show signs of grinding (as can be seen for example on Fig. 7.7), and most are intentionally knapped or broken (Henshilwood, d'Errico, & Watts, 2009). Experimental studies (e.g., Wadley, 2005) demonstrate that ochre is an effective binding agent for adhesives, in particular, to haft stone or bone points onto wooden shafts. Many MSA points have ochre and plant residues on their ends, indicating that they were hafted by mastic that contained ochre, and bound with twine (Lombard, 2007). This implies that at least some of the engravings on ochre may have been byproducts of functional processes. On the other hand, despite their rarity, engraved artifacts are found in several southern African MSA sites, suggesting that they may be part of a regional tradition (Cain, 2006). These objects bear non-representational incisions, and are of durable but soft materials. Microscopic analyses (e.g., Mackay & Welz, 2008) suggest that some of the markings are deliberate, not merely byproducts of functional activities. An ochre piece from Klein Kliphuis, for example, has several crosshatched lines, almost perpendicular to each other. Each of these lines is the result of multiple incisions by the same tool—the best explanation for this is that the maker intended to draw these particular lines. The engravings on SAM-AA 8938 were made using the same procedure, as can be seen on Fig. 7.7.

The fact that the engravings were deliberate does not entail that they were symbolic. As virtually anything can be a symbol, and as in principle there are no limitations to what a symbol might refer to, it is difficult to assess this archeologically. For example, small variations in functional stone blades might have had symbolic meaning (e.g., provide information about group membership), but this would be impossible to confirm without cultural background information. The incision patterns on the these MSA artifacts may well be the result of the scoring of ochre fragments for

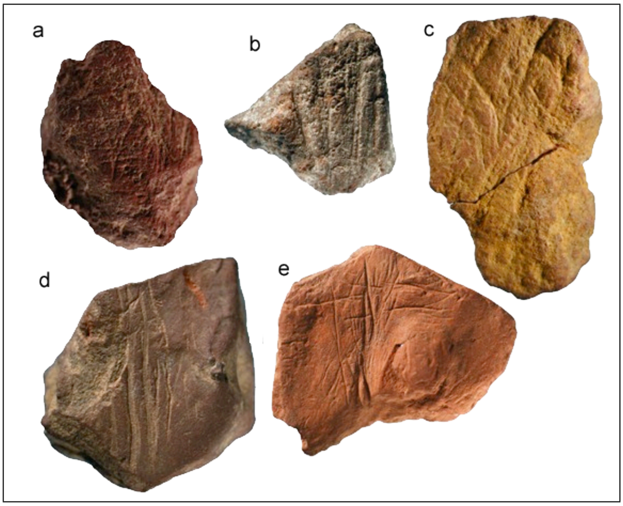

Figure 7.8: Engraved ochre pieces from Blombos cave, all dated ca. 77,000 BP, from Henshilwood et al. (2009), (a) Fig. 3 (p. 31), (b) Fig. 4 and (c) Fig. 5 (p. 32), (d) Fig. 6 (p. 33), (e) Fig. 11 (p. 36).

testing their suitability as hafting agent. Of course, these explanations (functional and symbolic) need not be mutually exclusive: a person may have started scoring ochre to test how it crumbled, but gotten caught up in this act and developed the strokes into an appealing design.

Even if the design is deliberate, this still does not mean it is symbolic, as modern telephone-pad doodling aptly illustrates (Davis, 1986). Let us assume for a moment that the engraved pieces are symbolic. The question is then, why are they so rare? After all, symbolic cultures, even those with sparse material culture teem with symbolic artifacts. The archeologist Chester Cain (2006) suggests that the marked artifacts might have served to affirm personal identity. Hunter-gatherers like the Kalahari !Kung typically live in egalitarian communities, where food and other resources are shared equally among members. In order to differentiate themselves from others, some members of these groups make personal art objects (Wiessner, 1983). These objects are typically rare, vary in quality (since the artists are not specialists), and are stylistically and materially diverse—properties that fit the engraved MSA artifacts. If Cain's hypothesis is correct, then the marked artifacts would indeed have had symbolic meaning. However, the !Kung are but one small-scale society, and it would be mistaken to take them as a model for all African Stone Age cultures. Consider the following ethnoarcheological parallel. The archeologist Robert Gunn's (2007) analysis of scratchings in Australian aboriginal rock art reveals that these highly variable motifs are mainly a result of spontaneous scribbling, with little or no symbolic meaning, mainly serving as a creative outlet for the individual, not unlike doodling. Thus, Henshilwood et al.'s (2009) characterization of the MSA ochres as symbolic seems premature.

One potential line of evidence for symbolism is the existence of enduring or repeated designs (conventions) that change or get replaced over time. Using this criterion, a more convincing case for symbolism can be made for engravings found on 270 ostrich eggshell fragments from Diepkloof Rock Shelter, dated to 65–55,000 BP (Texier et al., 2010), a selection of which is shown on Fig. 7.9. These fragments were likely parts of flasks that were used for storing and transporting water—some of the pieces exhibit evidence of a circular punctured opening on the apical side of the eggs. Ostrich eggshell containers are still used by southern African hunter-gatherers today (Wannenburgh, Johnson, & Bannister, 1999, 30). Many small-scale societies use stylistic abstract elements on functional objects like basketry, weaponry or pottery as a way to denote ownership, group membership, gender or social status (David, Sterner, & Gavua, 1988; Hegmon, 1992). These elements encode social meaning, hence are symbolic. The eggshell fragments bear a limited number of recurring motifs, including hatched bands (Figs. 7.9a and 7.9c) and parallel lines (Fig. 7.9b). These motifs suggest a degree of standardization: the hatched band motif, for example, always began by the long parallel lines, followed by engraving of the shorter, perpendicular lines. A diachronic change in the designs can be observed: the hatched band pattern is only found in the lower layers of Diepkloof, and is absent in its upper levels, where it is replaced by the parallel line motif (Texier et al., 2010). Both the limited number of designs and the cultural evolution manifest in this site stand in stark contrast with the variable Blombos material, where no recurring motifs can be discerned. Given the clear imposition of recurrent design and the difficulties associated with engraving eggshell (which is prone to fracture, Ambrose, 1998), it seems unlikely that these designs were spontaneous scribbles. The Diepkloof eggshells are therefore more plausible (although not indubitable) candidates for symbolic material culture in the MSA than the Blombos ochres.

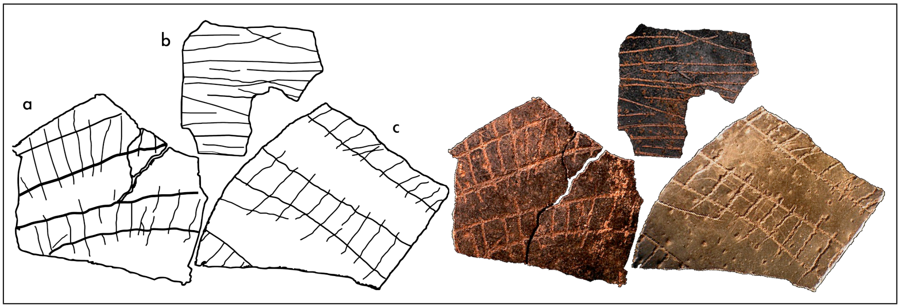

Figure 7.9: Ostrich eggshell fragments from Diepkloof Rock Shelter, dated to 65–55,000 BP, from Texier et al. (2010), Fig. 1, p. 6181 (redrawn by author).

As the extensive media coverage of the South African material shows[23], it has an obvious aesthetic appeal to us. How can we assess whether it held the same appeal to MSA people? The fact that many of the Blombos ochres are red implies to some archeologists (e.g., Henshilwood et al., 2009, 43; Conard, 2005, 310) that they were intentionally picked out for their color, which would have had not only aesthetic value but also symbolic meaning. However, the redder ochre is, the higher its iron content, and the higher the iron content, the better it makes bone or stone points stick to wooden shafts, as it critically contributes to the homogeneity of the adhesive (Wadley, 2005). Moreover, in extant small-scale societies red ochre is also used for tanning hides, as an insect repellent, or for medicinal purposes (see e.g., Wadley, Williamson, & Lombard, 2004, for an overview), although it is unclear whether Pleistocene hunter-gatherers used it as such. Therefore, the selection of red ochre could have been for functional, rather than aesthetic or symbolic purposes, though one does not exclude the other—there is no way to make it out.

The MSA engravings are geometric, mostly consisting of straight lines. Geometric designs are a pervasive element of Paleolithic art. They feature on most of the Swabian figurines, and are found alongside many animal paintings in Franco-Cantabrian cave art (Lewis-Williams, 2002). Did straight lines appeal aesthetically to Paleolithic people, as they did to more recent artists like Mondriaan or Malevich? As we have seen in section 5.2, according to the cognitive archeologist Derek Hodgson (2006), the pervasiveness of geometric motifs across human cultures from the earliest art onward can be explained by the fact that such designs evoke strong responses in our early visual system. Orientation-selective cells in the primary visual cortex (area V1) respond strongly to straight lines, especially horizontal and vertical ones. Does the fact that geometric designs appeal aesthetically to us imply that the MSA engraved objects were intended to be aesthetically pleasing? After all, some of the regular geometric designs on younger African artifacts have been interpreted as calendrical notation systems (e.g., Marshack, 1991a). But, as we will see in chapter 8, in those cases, notches are grouped into sets that have some numerical correspondence to lunar cycles or other seasonally recurring events. The older MSA material does not show this systematic grouping, making a notational interpretation unlikely. It seems therefore reasonable to infer an intended aesthetic value for the Diepkloof ostrich eggshells, especially given that their geometric designs show a high degree of standardization, being stably reproduced for long periods of time. The Blombos material is more idiosyncratic: if it appealed aesthetically to its engravers, this did not lead to a widespread adoption of designs in the community.

7.4 Concluding remarks

What guides our spontaneous recognition of some Paleolithic artifacts as artworks? Cognitive archeology, developmental psychology or ethnoarcheology by themselves may not be enough to shed light on the problem of Paleolithic art, but the consilience of inductions from these disparate domains may lead to a coherent philosophical picture of first art. This approach allows for a relatively fine-grained conceptual analysis of artworks. Because it does not require culture-specific contextual information, it can be extended to the study of first art. Underlying our ability to recognize art are three cognitive abilities: the design stance, symbol-mindedness and aesthetic sensitivity. By conceiving art as an ability that is present in all neurologically healthy humans, it is possible to trace continuities between early artworks and art today. In this context, it is meaningful to say that the Swabian ivory sculptures and perhaps also the more elaborate among the southern African engraved objects, especially the decorated eggshell flasks from Diepkloof, are artworks.

CHAPTER 8

HOW MATERIAL CULTURE EXTENDS THE MIND: THE CASE OF TIME-KEEPING

This chapter is a revised and expanded version of De Smedt, J., & De Cruz, H. (in press c). The role of material culture in human time representation: Calendrical systems as extensions of mental time travel. *Adaptive Behavior.*

8.1 Introduction

Ever since Darwin, comparative psychologists have considered the problem of the apparent mental discontinuity between humans and other animals. Why are humans, more so than other animals, capable of advanced cognition? Some authors (e.g., Hutchins, 1995; A. Clark & Chalmers, 1998) have suggested that a distinctive feature of human cognition is its interaction with the external environment. Humans rely heavily on environmental support such as books, electronically stored documents, nautical slide rulers, or simply pen and paper to delegate computational problems to the external world. How can we properly gauge the influence of artifacts in reasoning processes? Empirical investigations of the role of material culture in human cognition involve well-controlled conditions in which cognitive performance aided by external tools is pitted against purely internal mental operations. Kirsh and Maglio (1994), for example, compared the performance of subjects playing Tetris who were allowed to physically rotate blocks to fit them into the slots to players who were forced to mentally rotate them. The former performed faster and made less mistakes. However, participants in studies like these are typically western college students, who are thoroughly enculturated into a world filled with artifacts that serve epistemic purposes, including banknotes, signposts, and nutritional information on packaging. It is no exaggeration to say that we inhabit a world that is primarily made up of our own creations, and many of these play a role in our cognitive lives. This makes it difficult to experimentally assess how unaided cognition (the naked brain) compares to externally aided cognition, or to examine the effects of material culture on human cognitive evolution. Some authors have developed computational models that examine how the use of the external environment can reduce cognitive load. Chandrasekharan and Stewart (2007), for example, have constructed a simulation where agents can learn to lower their cognitive load by generating task-specific external cues, such as using their own tracks. This chapter will take a qualitative approach, concentrating on material culture used in epistemic contexts from extant small-scale societies with sparse material culture and prehistoric cultures, where people had not amassed such a vast body of epistemic artifacts (i.e., artifacts that help us think).

The aim of this chapter is to develop an account of interactions between internal human cognitive abilities and external media based on findings from developmental and cognitive psychology, anthropology and cognitive archeology. It will argue that artifacts such as calendars extend evolved cognitive abilities by allowing humans to accurately predict cyclically occurring events. The term ‘calendar’ is here used in a broad sense, as a shorthand for any artificial memory device that helps to recognize and record temporal events, such as astronomical or environmental observations. Calendrical notation systems are an illuminating case study, because they do not physically alter the environment, but render it more cognitively congenial. They do not increase the number of potential prey in a territory; however, they enhance foraging success, amongst others by predicting animal migration events, and by allowing people to make preparations and arrangements in advance, thereby saving time and resources. As will be demonstrated, evolved human cognitive capacities that deal with time are limited in their ability to recognize cyclical events in the environment in a way that a coupled cognitive system, consisting of a calendar and interpreting humans, is not.

The chapter begins with an examination of cognitive mechanisms for keeping track of time that are naturally available to humans, focusing on mental time travel. Cognitive psychological evidence indicates that mental time travel is a highly constructive process that is liable to distortion. As a result, the naked human brain cannot accurately predict cyclical occurrences such as animal migration events or the fruiting of plants. Next, anthropological examples will illustrate how humans routinely supplement their evolved mechanisms for keeping track of time with material objects (both natural events and especially designed epistemic artifacts). We then argue that the extension of mental time travel by material culture dates back to the late Middle Stone Age in Africa and the Upper Paleolithic in Europe, and illustrate this with examples of material culture interpreted by archeologists as calendars. It will be shown that the emergence of the earliest unequivocal epistemic artifacts in the archeological record coincides with marked improvements in foraging efficiency. The chapter concludes by outlining possible ways in which the claims put forward here could be tested using analytic and computational modeling, and by considering implications of the case study for philosophical concepts of extended cognition.

8.2 Cognitive processes underlying the perception of time

8.2.1 Salient systems of time processing

The natural world is filled with temporal regularities, which organisms are adapted to exploit. Timing enables animals to anticipate opportunities and risks, which greatly improves their chances of survival. Multicellular organisms are equipped with circadian rhythms, internally generated 24-hour cycles (Antle & Silver, 2005). For shorter durations ranging from a few seconds to a few hours, animals rely on interval timing, which enables them to optimize their foraging behavior in terms of time and energy costs (Bateson, 2003). Some species possess highly specialized abilities to keep track of somewhat longer spans of time. Male house mice, for instance, kill any neonate in their territory, except when they have mated 18 to 22 days before. During this period, when the possibility exists that the neonate is their offspring, they switch to nurturing behavior. This hormonal mechanism enables house mice to detect relationships between events widely distributed in space and time (fertilization and birth) that could never be perceived through associative learning alone (Kummer, 1995).

The Earth's yearly orbit around the Sun produces seasons, cyclical climatic changes that have a high impact on animal fitness. Seasonal fluctuations in temperature, food availability and predation pressures pose challenges to survival and reproduction. Consequently, many species have acquired seasonal behavioral and physiological adaptations, such as migration, seasonal mating, hibernation and changes in pelage or plumage.

In many cases, these adaptive responses are directly triggered by environmental fluctuations. Nevertheless, as many shifts in behavior would occur too late if they were a direct response to environmental factors, there is intense selective pressure on the capacity to anticipate seasonal changes —if squirrels waited to store nuts until the onset of winter, their caches would be insufficient to help them through winter. As a result, several vertebrate species use predictive cues—usually the duration of daylight per day—as a proxy for seasonal changes (Paul, Zucker, & Schwartz, 2008).

Some animal species can anticipate future events that are highly variable and hard to predict from external cues alone, using past experience as a proxy for the future. Western scrub jays (*Aphelocoma californica*) cache both perishable (e.g., larvae) and non-perishable (e.g., seeds) foodstuffs. Under experimental conditions, their recovery of previously stored items shows sensitivity not only to what type of food was cached but also where and when it was stored, enabling them to prioritize perishable items (Clayton & Dickinson, 1998). Moreover, these corvids also appear to be able to anticipate the future: they flexibly adapt their caching behavior to future needs, such as preferentially caching food in a room where they foresee they will be hungry the next day (Raby et al., 2007). This ability to take into account future events independent of current motivations is rare in the animal world, and can plausibly be explained as the result of selective pressures that are associated with food caching. A comparative study (Stevens, Rosati, Ross, & Hauser, 2005) with two types of New World monkeys indicates that feeding ecology indeed exerts considerable selective pressures on an animal's ability to take into account future events. Marmosets (*Callithrix jacchus*), which feed on tree exudates, require patience to wait for sap to exude from the trees, whereas tamarins (*Saguinus oedipus*), whose diet is composed mainly of insects, perform more quick, impulsive actions. As a consequence, marmosets are willing to wait much longer than tamarins to obtain a larger food reward. One can glean from these examples that ecological conditions and feeding behavior are important factors in shaping cognitive processing of time.

8.2.2 Episodic thinking and mental time travel

Since current and historical human populations, including hunter-gatherers, horticulturalists, fishers and farmers, rely on food that is seasonally variable, one can expect that *Homo sapiens* has cognitive adaptations that allow for the recognition of temporal regularities of the environment. Humans are equipped with circadian rhythms and interval timing. Next to this, they rely on past experience to simulate future events. This ability is termed episodic thinking or mental time travel. Episodic memory (see Tulving, 2002, for review) refers to our capacity to remember personally experienced events and to mentally travel back in time to re-experience those events; it is distinct from semantic memory, which stores factual knowledge about the world. The ability to travel mentally into our experienced past is supplemented by episodic future thinking (Atance & O'Neill, 2001), a capacity to project oneself into the future to simulate possible scenarios, enabling one to foresee possible future consequences of one's current behavior, or to make preparations in anticipation of a planned activity.

A growing body of empirical evidence indicates that episodic memory and episodic future thinking are subserved by the same neural mechanisms. Their onset during cognitive development is synchronous. Episodic memory arises gradually between three to five years of age (Perner & Ruffman, 1995). Although younger children's rapidly expanding lexicon indicates that they have an excellent semantic memory, they seem unable to store long-term autobiographical memories. For example, when taught a novel fact (e.g., a new color name) or skill, three-year-olds believe that they have always possessed this knowledge; the realization that this is not the case only emerges between four and five years of age. The ability to travel mentally into the future follows a similar developmental trajectory (Thompson, Barresi, & Moore, 1997): given the choice between a small immediate reward and a larger delayed reward, only children of four years and older forgo immediate gratification and choose the delayed one.

More direct evidence that episodic memory and episodic future thinking are subserved by the same neural circuits comes from neuropsychology. An fMRI study by Addis, Wong, and Schacter (2007) found that imagining future experiences or recollecting vivid memories activates a similar network of brain regions, including the left hippocampus and posterior visuospatial regions like the right middle occipital gyrus. Hassabis, Kumaran, Vann, and Maguire (2007) examined the ability of amnesic patients with focal hippocampal damage to imagine fictitious autobiographical experiences, such as visiting a museum or sunbathing on a tropical beach. Their subjects showed a seriously compromised ability to make vivid, detailed and sensory descriptions of imagined experiences. Presumably, episodic memory and episodic future thinking are subserved by the same neural correlates because they share similarities in terms of their underlying psychological mechanisms. Both are constructive processes, which require a system that flexibly recombines bits and pieces of information from various sources. Therefore, we shall refer to episodic memory and episodic future thinking collectively as 'mental time travel,' following Suddendorf and Corballis (1997). The likely adaptive function of mental time travel is not to recollect past events per se, but to enable one to anticipate and predict future events on the basis of past experiences. According to Suddendorf, Addis, and Corballis (2009, 1319), episodic memories provide a vocabulary from which one can construct possible scenarios, which can be compared in order to optimize future behavior. Its combinatorial flexibility allows one to predict the consequences of events that one has never experienced, leading to the prediction that pickled herring with chocolate is a challenging combination of tastes, or that a naked dance in front of one's superior will get one fired, unless one is a professional pole dancer.

8.2.3 Mental time travel as a human cognitive specialization?

Since Suddendorf and Corballis (1997) suggested that the ability to travel mentally in time is a uniquely human cognitive specialization, comparative psychologists have developed experimental paradigms to investigate this capacity in nonhuman animals. To date, the strongest candidate is the Western scrub jay: as mentioned earlier, members of this species appear to remember where and when they previously cached food-items. However, their mental time travel seems to be highly domain-specific, only concerned with the caching and retrieval of food, whereas human mental time travel is domain-general: we are able to reminiscence or anticipate upon virtually any aspect of our personal lives, be it food, social encounters, or weather circumstances. While Clayton, Bussey, Emery, and Dickinson (2003) argue that the ability of scrub jays to remember the what, where and when of caching events is similar to human mental time travel, Suddendorf et al. (2009) contend that it does not follow that these animals actually mentally reconstruct the event of caching.

Nevertheless, the accuracy of some nonhuman animals is superior to that of humans—whereas scrub jays can cache food based on future needs irrespective of current utility, humans exhibit systematic errors in predicting the consequences of their actions. The latter are driven by current feelings of hunger or satiation to predict future appetite: hungry subjects are more likely than satiated participants to choose a high calorie snack to eat at a distant point in the future, and hungry people mistakenly expect to like eating spaghetti for breakfast the next day (Gilbert, Gill, & Wilson, 2002). If there is indeed a qualitative difference between mental time travel in humans and memory in some nonhuman species, it remains unclear what this difference might be. As will be argued, an underexplored possible explanation is that humans, unlike other animals, routinely supplement their episodic thinking with material culture.

Given that episodic memory and future thinking are constructive processes, it is not surprising that they are liable to distortion. Mental time travel involves the simulation of future experiences through past events, leading to the omission of inessential features, the abbreviation of the simulated event (which is, of course, less long than the true event), and the absence of context. Indeed, episodic memory retains only information that is likely to be needed for future reference—we rarely need to remember all the exact details of our experiences. For example, people typically remember their worst train-missing experience when simulating how painful and inconvenient a next train-missing experience will be (Morewedge et al., 2005). These puzzling features of episodic recall can be explained by the hypothesis that mental time travel does not serve the adaptive function of a disinterested representation of true events, but that it allows for simulations that guide action in adaptive ways. Overestimating the discomfort of an unpleasant experience may help us avoid that situation in the future. Adaptive as this may be, it poses severe limitations on the reliability of our long-term episodic memories. Numerous experiments (e.g., Marsh & Tversky, 2004) show that even vivid and confident episodic memories are vulnerable to distortion. Retelling personal recollections typically involves exaggerations, omissions, and simplifications to entertain or help the audience better understand. Under controlled experimental conditions, biased retellings of incidents alter the memories one has of these events (Tversky & Marsh, 2000); they routinely become part of one's own episodic recall, replacing more accurate memories.

People can also be induced to remember personal experiences that have never happened. In a series of experiments, the psychologist Elizabeth Loftus and co-workers gave participants descriptions of childhood experiences provided by family members, and encouraged them to remember these (see Loftus, 2003, for an overview). One of these stories was actually a pseudo-event that had never taken place (e.g., getting lost in a shopping mall at age five and eventually being rescued by an elderly person). About 25% of participants claimed to 'remember' this traumatic childhood experience, often adding embellishing details to their accounts. As Loftus (2003, 872) puts it "the story creates a memory rather than the other way around." Precisely because narratives require subjects to generate their own details, they encourage false memories. Memory distortion can thus be seen as part of the adaptive operation of a healthy memory system.

8.3 Material culture and internal time representation

Animals regularly modify their external environment in order to reduce the number and cost of mental operations. For example, ants mark paths from food-sources to the nest with pheromone trails (Jackson, Holcombe, & Ratnieks, 2004), because it is easier to follow a pheromone trail than to store and compare landmarks, which places high demands on visual memory (Judd & Collett, 1998). Kirsh (1996) terms such actions epistemic actions, because they are not aimed at bringing about physical goal-directed changes in the environment, but rather at making it more cognitively congenial. Drawing a map, for instance, does not physically alter the environment, but makes it easier to navigate—one does not have to level the terrain or cut trees to get a comprehensive overview. Humans rely on external cognitive resources to a considerable extent—they fashion tools that are explicitly aimed at fulfilling epistemic needs. One need but think of instruments, such as compasses or thermometers, which allow for accurate measurements, external memory storage in texts or diagrams, or objects that otherwise lighten cognitive load, like tallies or calculators. Such epistemic artifacts—which are made to serve epistemic purposes—are a distinctive feature of human cognition. Nonhuman animals sometimes use objects for epistemic purposes. An example is the female gorilla observed by Breuer, Ndoundou-Hockembal, and Fishlock (2005) that probed the depth of a pool with a stick before deciding to cross it. (This is an especially intriguing example, since gorillas usually do not use tools.) More recently, Wimpenny, Weir, and Kachelnik (in press) used a controlled experimental condition to elicit epistemic tool use in New Caledonian crows, a species that often uses tools for pragmatic purposes (see also section 1.1). The authors presented the birds with unfamiliar objects, to wit rubber snakes and rubber spiders, stimuli that elicit spontaneous fear reactions in many animals. Wimpenny et al. (in press) observed eight occasions in which first contact with these novel objects was mediated by a stick, suggesting that the stick was used for the exploration of the unknown items. To our knowledge, however, no animal has ever been observed to make tools (i.e., intentionally modify objects) primarily for epistemic purposes.

The use of external media is not limited to contemporary societies, but seems to be a pervasive element of human cognition at least since the Late Pleistocene (ca. 120,000 BP). From this period onward, archeologists find shell beads, notched pieces of ochre and bone, and—somewhat later—representational art, demonstrating that humans conveyed ideas externally in symbolic media. Some authors have proposed to incorporate this extended cognition as a key element in human cognitive evolution. The cognitive neuroscientist Merlin Donald (1991) views the evolution of human cognition as stages in which new memory representations emerged; the final stage is marked by the use of material culture as a way to externally store symbolic information. The cognitive archeologist Steven Mithen (2000) argues that the emergence of modern human behavior during the past 100,000 years was not so much due to intrinsic changes in brain organization as to the emergence of cultural practices that incorporate artifacts into reasoning processes, like the use of representational art as memory storage devices. The cave paintings of Lascaux (Dordogne, France, about 18,600 BP), for instance, can be seen as mnemonic devices that display animals with their feet turned toward the spectator, which allowed the artists to depict the shape of the hoof prints of particular prey species, such as bison and horse (Mithen, 1988). In this way, future hunters could learn the connection between spoor and prey. To Mithen (2000, 214), artifacts are especially suitable to represent ideas that have "no natural home within the mind," such as religious beings. Since religious agents are not obviously physically present, thinking about them is often structured by artifacts, like paintings, masks, or sculptures. The next sections will examine how humans also rely on their external environment to complement their evolved capacity for mental time travel.

8.4 Extending the mind to increase memory capacity

As we have seen, future events are rarely replicas of past ones—a constructive episodic memory, which retains a gist of what has happened is therefore more flexible than a hypothetical memory that would store rote records of the past. But this means that mental time travel falls short of accurately predicting long-term cyclical occurrences. Annual phases in the life cycle of animals and plants, such as spawning migrations of fish or the fruiting of trees occur reliably in the same seasons. Being able to predict these events would have dramatically improved foraging success in prehistoric hunter-gatherer communities. A clear example is Late Pleistocene Europe, where humans primarily relied on animal protein for their diet. Fatty meat is much higher in caloric content than lean meat, but wild mammals are lean most of the year and only store fat during specific phases in their life cycle. Reindeer, an important prehistoric food-source, store fat during the late summer and early autumn. During the rutting season (in the late fall), they quickly lose this fat and only regain it by next summer (R. D. Guthrie, 2005, 74). Cave paintings in Lascaux, Niaux, and other Late Pleistocene Franco-Cantabrian sites indicate that hunter-gatherers were sensitive to these seasonal changes, as they frequently depict reindeer with exaggerated humps of fat (Delluc & Delluc, 2006). Hunter-gatherers who tuned their migrations to coincide with those of the reindeer during early autumn could maximize their energy intake by hunting this prey species.

Moving away from high latitudes, the arid Australian inland, which was colonized by humans as early as 50,000 years ago (R. G. Roberts et al., 1990), provided dramatic challenges in terms of seasonal availability in food, water, shelter and artifact-making materials. Rainfall is sparse and seasonal, and the onset of seasons is highly variable. As a result, Australian nonhuman vertebrates have developed a wide variety of adaptive responses. For example, the freshwater turtle *Chelodina rugosa* lays eggs in low-lying areas during the wet season. The embryo only begins to develop once the egg is exposed to the air which permits a synchronization of the organism with external conditions (Shine & Brown, 2008). Humans do not have such specialized physiological adaptations to variable events; their internal memory likewise seems insufficient to allow storing fine-grained details like co-occurrences of subtle seasonal changes with phases in animal life cycles. Humans equipped with nothing but their naked brains are thus unable to reliably predict such cyclical occurrences. Since distorted retellings corrode episodic memories, and narratives can induce false memories, sharing reminiscences with a wider audience does not increase their dependability. Caspari and Lee (2004) have explained the Upper Paleolithic symbolic revolution mainly as a consequence of increased human longevity. They argue that intensified oral intergenerational transmission of complex cultural information may have contributed to the innovations associated with behavioral modernity. Some computational models (e.g., Di Paolo, 1997) indeed indicate that increases in communication improve the transmission of skills. However, as we have seen, experimental psychological evidence strongly suggests that episodic memories are susceptible to distortion through retelling, leading to the prediction that distributing cognition through oral communication alone may be insufficient to transmit some forms of complex cultural information. Especially if information is transmitted over many generations, it may get distorted through retelling, or may simply be lost through gaps in the transmission process. Thus, one can expect that the use of epistemic artifacts markedly improved the conceptual stability of transmitted representations.

Anthropological investigations of recall in non-literate societies provide evidence for this crucial role of externally stored information. Australian aboriginals use multiple strategies to remember and transmit knowledge of the local geography, such as the presence of water-sources, which are crucial for their survival. They associate oral narratives with particular places in the landscape, the Dreaming[24]—their natural environment thus becomes an epistemic aid. Crucially, several of these stories are recorded as dot paintings on bark (Sharifian, 2003) or as rock paintings. In this way, collective memory can stretch far back indeed. For example, a relatively recent Australian engraving in the Weaber Range of the Keep River (Northern Territory) features the track of *Genyornis newtoni*, a large emu-like bird that went extinct by about 40,000 BP (Fig. 8.1a) (Ouzman, Taçon, Mulvaney, & Fullager, 2002). Given that humans colonized Australia at least 50,000 BP (R. G. Roberts et al., 1990), humans and *Genyornis* co-existed for thousands of years. Australian aboriginals may well have hunted these flightless birds to extinction, as they did with many other large species like giant kangaroos and marsupial carnivores in the period between 46,000 and 40,000 BP (R. G. Roberts et al., 2001). Other examples include an ochre rock painting of a marsupial lion (*Thylacoleo carnifex*), as shown on Fig. 8.1b (Akerman & Willing, 2009), and the depiction of a hitherto unknown species of extinct giant stripe-faced flying fox in the Kimberley Region (northwestern Australia), shown on Fig. 8.1c (Pettigrew, Koerner, McPhee, & Wallman, 2008). The Dreaming teems with zoomorphic ancestors, many of which have the shape of members of the Australian megafauna that went extinct during the Late Pleistocene. Ouzman et al. (2002) speculate that interactions with these animals have been passed down through oral history, with the aid of imagery such as the engraved bird track. The continuity of Australian megafauna in Dreaming stories today indicates that this tradition emerged between 50,000 and 30,000 BP. It seems unlikely that such recollections would have been kept vivid without external memory storage (*in casu* rock art), which helped to bring to mind the physical properties of these beings. In stark contrast, the memory of Australian aboriginal forebears is notably shallow: people tend to remember ancestors only as far back as their grandparents. An important reason for this brief recall is that information about persons is not stored materially, but only orally recounted. During retellings, this information is habitually edited and reformulated to match the fluid social relationships between different families within these small-scale communities, where coalitions are often shifting (Sansom, 2006). By contrast, in nonliterate cultures where genealogical recall is vital for the local political and social order, material culture serves to store genealogical knowledge. The Luba from Congo use flat wooden boards studded with pins and beads to teach neophytes about historical events, such as migrations and royal genealogies. The shape, colors and spatial configurations of the pins and beads help them to accurately remember and transmit these events. Interestingly, many of the elements presented in their oral history are also found in the archeological record of Luba kingdoms which stretches back to more than 1500 years (Nooter Roberts & Roberts, 1996).

8.4.1 Material anchors and epistemic artifacts

In disparate cultures, people keep track of cyclical events by extending their evolved internal timing mechanisms into the world, i.e., they use cyclical natural events as material anchors. Obvious candidates are the phases of the Moon. They are easy to observe, but synodic (phase cycle) lunar years are about 11 days shorter than solar years, which would

Figure 8.1: Australian rock art depictions of extinct species that are still part of the Dreaming today. (a) Track from an extinct bird, *Genyornis newtoni*, undated engraving, Northern Territory, from Fig. 1, p. 104, Ouzman et al. (2002); (b) extinct marsupial lion, *Thylacoleo carnifex*, undated ochre painting, Kimberley region, from Fig. 1, Akerman and Willing (2009); (c) extinct giant flying fox of unknown species, sub-order *Megachiroptera*, undated ink painting, Kimberley region, from Fig. 2, Pettigrew et al. (2008).

soon lead to an accumulation of errors rendering lunar calendars useless for the purpose of tracking seasons. The epistemic role of material anchors is aptly illustrated by the Borana lunar calendar and its calibration to prominent star clusters (Bassi, 1988). The Borana from northern Kenya and southern Ethiopia use synodic lunar months to construct their calendar. This calendar is of vital importance to their subsistence and ceremonial activities, and is regulated by *ayantu*, experts on sky observation. To calibrate it, the *ayantu* add an intercalary month approximately every three years. Their decision to add an extra month is solely based on astronomical observations, namely when the Moon rises in conjunction with a particular succession of reference stars on successive nights. Borana astronomers make multiple night sky observations, formulating hypotheses about the future behavior of celestial bodies and testing them on observations the following nights. The star clusters play an important epistemic role, as they are the sole guides in the *ayantu*'s decision to add the extra month. By using astronomical observations, the Borana can oversee a period spanning three years, which would otherwise be impossible within this nonliterate society.

Horticulturalists from the Torres Islands of Vanuatu (Melanesia) traditionally calibrate their lunar calendar to seasonal events. The appearance of a ubiquitous sea-worm, *palolo*, in October marks the planting of yam and other garden crops. The metamorphosis of a local species of ant into its winged phase, *vühoro*, in January serves as a marker for the end of the planting cycle (Mondragón, 2004). Next to this, many aboriginal groups associate the ripening of particular fruits or occurrences of specific animals with the arrival of particular constellations. For example, in Arnhem Land, Australia, the harvesting of reeds to make fish-traps commences when Arcturus is seen in the eastern sky at sunrise (Haynes, 1992). Material anchors need not be restricted to the visual modality. Aboriginal inhabitants of Queensland, Australia, know that when the black beans are ready to eat, it is time to hunt jungle fowls (Clarke, 2009). The Andaman Islanders knew a calendar of scents: the distinct succession of odors in the densely covered jungles was used to mark different periods of the year (Radcliffe-Brown, 1922). The Yanyuwa from the southern Gulf of Carpentaria, northern Australia, use a wind calendar to identify their five seasons: changes in intensity, humidity and direction of local winds are used to optimally time fishing, and gathering eggs, buds and nuts (Clarke, 2009). In all these cases, the timing of cyclic activities (such as hunting, weeding and harvesting) is rendered more optimal and reliable by tying it to cyclical occurrences in nature.

Next to natural material anchors, humans across the world draw on especially designed artifacts to keep track of cyclical events. Artifacts have the advantage that they are less constrained by processes in nature, thereby further enhancing the stability of the representation of cyclical events. The Mandan (a Native American Great Plains culture) recorded lunar phases as rows of crescents onto sheets of paper. Some of these are accompanied by plant symbols, indicating a record of planting and harvesting (Thornton, 2003). The stick-calendars in the shape of hexagonal prisms of the Yakut, a subarctic Siberian culture subsisting on hunting, gathering and herding reindeer, show two months along each edge, incised with day units (Marshack, 1991b). Several days on the Yakut calendar bear signs to mark seasonal events (e.g., the flowering of certain plants), astronomical observations (e.g., the appearance of the Pleiades, important in their shamanic rituals), as well as Christian (Orthodox) holidays. In Chankillo, Peru, a megalithic calendar of 2,300 years old, consisting of 13 aligned towers, was calibrated to the winter and summer solstices. The towers and gaps in between enabled tracking the progress of the Sun to within an accuracy of two or three days (Ghezzi & Ruggles, 2007), which was vital for agriculture in this arid region that lies in the rain shadow of the Andes.

8.5 *Evidence for the extended mind in the archeological record*

Artifacts like shell beads, notched bones and ochre plaques represent the earliest concrete evidence for storage of symbolic information outside of the human brain. Here, we discuss direct and indirect evidence that suggests that during the Late Pleistocene humans started to use material culture to store cyclical events externally, and that this was one of the factors that had a significant impact on human foraging success. As reviewed above, the human brain is not naturally equipped to recall cyclical events. Cross-cultural evidence from non-literate societies shows that people rely on material anchors to remember such events accurately. On the basis of this, one can expect the appearance of artifacts that were used to keep track of time to coincide with improved foraging success. The next sections will discuss several material devices that were used by Pleistocene hunter-gatherers to keep track of time, focusing on incised bone and antler objects, and rock art. Next, we indicate changes in human behavior during the same period that suggest an improvement in foraging efficiency.

8.5.1 Incised bone and antler objects

Upper Paleolithic bone and antler objects with regular incisions have been recovered since the 1860s. The fact that they have ordered sets of notches or incisions indicates that these artifacts were used to represent numerical information. Marshack (1972) proposed the influential hypothesis that many of these objects were lunar calendars. His conclusion that notched bones represent the first human notation systems has gained general acceptance in the cognitive archeological community. However, he assumed that these notched artifacts always reflected a long term, cumulative, sequential notation, a view that is now called into question. Based on microscopic analysis, the cognitive archeologist Francesco d'Errico (1998) developed a theoretical framework and an explicit methodology for evaluating the manufacturing process of incised bone objects. When morphologically resembling tools were used and abandoned subsequently, the accumulation of the engravings was probably gradual, similar to a tally-stick. If, in contrast, morphologically distinct burins were used simultaneously (like on the antler plaque from Abri Blanchard, see below), one can infer that the artifact was conceived as a whole, representing different items with different symbols, as is the case in a calendar. The code for the symbols is lost, as we do not have enough information about these prehistoric societies to find out what they meant. However, from ethnographic parallels we can infer plausible functions of these objects.

One of the oldest probable lunar calendars is an antler plaque from Abri Blanchard, France, dated to about 32,000 BP. This object was more than a simple tally (counting a number of past nights); it was made with the intention of being a time-keeping device: a recent detailed formal analysis of the artifact (Jègues-Wolkiewiez, 2005) reveals that its maker prepared the surface carefully with a set of notches at the edges, forming a rough coordinate system, to plot his or her inscriptions. One of its sides is engraved with some 70 morphologically differentiated cavities that resemble successive phases of the Moon, the serpentine trajectory of the notches reflecting the actual position of the spring Moon in the sky in the Dordogne region upon setting. In this way, the Abri Blanchard plaque is a hybrid representation, depicting both the phases of the Moon and its position in the sky (Fig. 8.2): the differently shaped notches indicate phases of the Moon, as well as its position. The dates on Fig. 8.2, (based on current astronomical observations in the region) are those corresponding to the current position of the Moon. Four cavities to the left and two cavities to the right of the serpentine are separated from the other cavities by fine lines. Jègues-Wolkiewiez (2005, 57–58) speculates that these are probably mistakes that have been noticed by the engraver, hence separated from the main drawing.

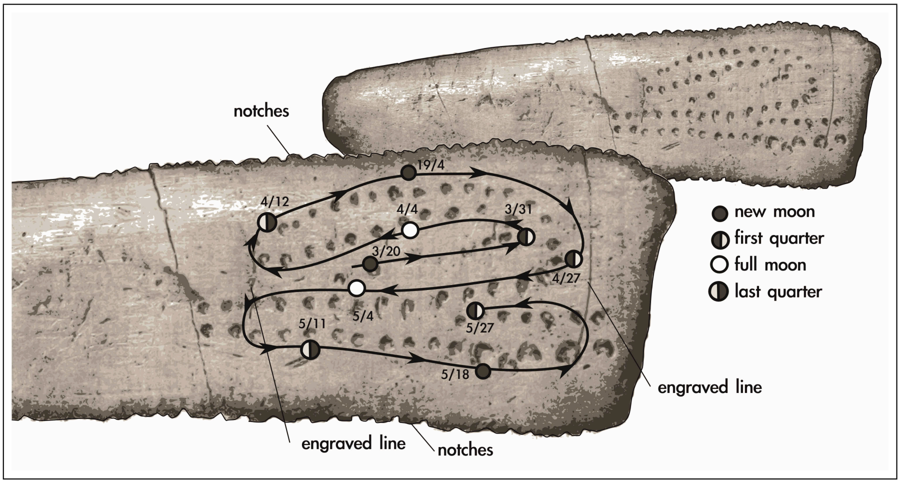

Figure 8.2: Antler plaque from Abri Blanchard. Note the notched edges, which provide the coordinate system. Drawing based on Figs. 1 (p. 44), 3 (p. 46) and 13 (p. 54) from Jègues-Wolkiewiez (2005).

Some Paleolithic notched artifacts show pictorial images, which may hint at the meanings associated with the notations. The antler baton from Cueto de la Mina (Fig. 8.3), Spain, dated to the Late Magdalenian (about 12,000 BP), presents several sets of notches, which are made with different angles, pressures and directions, suggesting a code based on morphological differentiation. Each of these sets is accompanied with a different image: two schematic ibex or chamois heads and at least four kinds of plants in different stages of growth (Marshack, 1972). Many hunter-gatherer cultures use plants to predict seasonal changes in rainfall and temperature (see e.g., Clarke, 2009, for a discussion of plant-based calendars in Australian aboriginal societies). Pleistocene hunter-gatherers may also have used plants in this way, recording their different stages of growth as a means of time keeping (see 1-4 and 7 on Fig. 8.3). Like in the Mandan and Yakut calendars, these icons were probably used to mark seasonal events. Interestingly, archeological analysis of the site (Baxter, 2001) suggests that Cueto de la Mina was an aggregation locale, a place where hunter-gatherer groups annually came together to exchange food, sexual partners and technological skills—the temporal animal and vegetative clues (when did these animals migrate, when were these plants in these particular stages of growth) on this antler piece may have facilitated this.

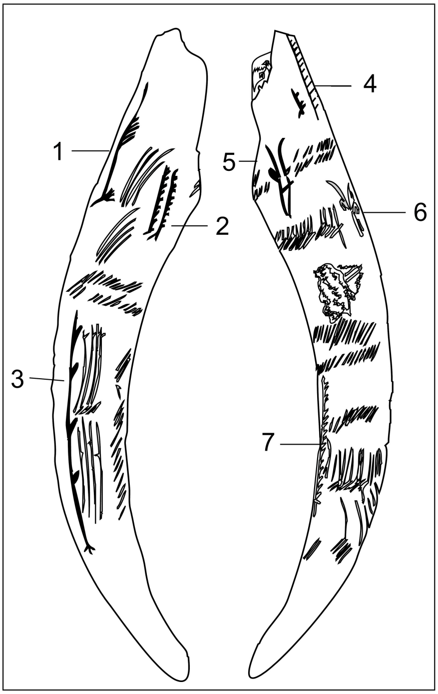

Figure 8.3: Antler baton from Cueto de la Mina. It has several sets of notches that are associated with images of plants (1–4, 7) and two animal heads, probably ibexes or chamois (5, 6). Redrawn from Marshack (1972, p. 456, Fig. 15).

8.5.2 Rock art

Next to incised bone and antler objects, Paleolithic rock art also served as artificial memory system for storing ecologically relevant information about seasons. Rock art often emphasizes information useful to hunters, such as the exaggerated representation of fat deposits on horses and aurochs, or the depiction of footprints of prey species in lieu of hooves (Mithen, 1988). As a detailed analysis by Delluc and Delluc (2006) shows, rock art from well-known Franco-Cantabrian sites like Chauvet, Lascaux and Niaux is rich in seasonal information. Lascaux and Niaux (French Pyrenees, about 12,890 BP) have depictions of horses in different seasons. Horses in summer dress are heavy, with short, light fur, whereas those in winter pelage are typically leaner, with a longer tail and manes, and darker, scruffier fur (Fig. 8.4). Most large herbivores are pictured in their specific winter or summer appearances; for instance, reindeer are shown in summer dress, with large antlers and fat deposits. Additionally, some rock paintings in Lascaux show mating behavior that is restricted to early spring, such as two bison bulls intimidating each other and a stallion closely following a mare. We are not claiming that these paintings were used as calendars; rather, we argue that one of their functions was probably mnemonic, by visually representing what prey species look like in specific seasons.

Next to large terrestrial herbivores, Upper Paleolithic artists also depicted birds. In historical times, the mating and migration behavior of geese, ducks and sea mammals served as cues for seasonal changes to Northwest Coast Native Americans and Inuit (Freeman, 1967). The use of these animals as temporal cues by contemporary hunter-gatherers suggests that their representation served as external storage of cues for seasonal changes. d'Errico's (1994) detailed analysis of a scene depicting three birds identified as great auks (*Pinguinus impennis*) at the Cosquer cave (Bouches-du-Rhône, France) supports this interpretation (Fig. 8.5). The pigments of this rock painting were directly dated to about 26,400 BP (Clottes et al., 1992), but recent developments in C^{14} calibration methods push this back to 32,000 BP (recalibrated using Fig. 2, p. 932 in Mellars, 2006). These large, flightless, now-extinct birds seasonally flocked to form large breeding colonies on offshore islands. This behavior was restricted to early summer, when mating occurred, eggs were hatched and chicks raised.

Figure 8.4: Horse in summer pelage from Lascaux (left): note the light fur, thin mane, and heavy underbelly. Also note the grass in full seed, which gives an additional indication of summer, from `http://www.elissa.weichbrodt.org/wp-content/uploads/2007/12/lascaux_horse.jpg`; horse in winter pelage from Niaux (right): this animal is leaner, has noticeable thick fur and scruffy manes and tail, from `http://www.theartsdesk.com/images/stories/TV/ismene_brown/Niaux_horse.jpg`.

The scene shows three individuals, two facing each other with wings outspread, and a third, lying down with wings folded. As in all *Alcidae*, the great auk's wings were useless for flight; they were only used during swimming or in combat for mates, when they were vigorously flapped. d'Errico (1994) interprets the opposing pair as males in combat, the third bird as a female they are disputing. A less gladiatorial interpretation (McDonald, 1994) is that the upper individuals are foraging underwater (swimming is indicated by their outspread wings), and that the lower individual represents their single chick (auks laid only one egg per season and both parents raised the offspring). Whichever interpretation one favors, it is important to point out that the scene shows gregarious behavior in auks which was seasonally restricted to early summer. The conspicuousness of large breeding colonies on nearby islands may have been useful for prehistoric hunter-gatherers as a material anchor for seasonal events related to the beginning of summer. Rock paintings depicting this behavior may thus have served as artificial memory systems to recall and communicate its significance as a temporal marker. A rock engraving with a comparable function (Fig. 8.6) has been identified in the

Figure 8.5: Scene depicting three auks at the Cosquer cave. This scene shows gregarious behavior, which was seasonally restricted to early summer. Figure from `http://www.bradshawfoundation.com/cosquer/cosquer2.php`.

Elvina track engraving site at Ku-ring-gai Chase National Park, 20 km north of Sydney. This engraving of a large bird represents the *Emu in the Sky*, a common Australian aboriginal term for the cloud of interstellar dust close to the Southern Cross. Interestingly, the engraved bird only aligns with that constellation during early autumn, at just the time of year when real-life emus are laying their eggs (Norris & Hamacher, 2009). Great auks went extinct around 1844. Because they usually returned to the same location to breed, they easily fell prey to sailors and fishermen who captured them in large quantities during their breeding season for meat, fat and feathers. Auk bones are also present in numerous Upper Paleolithic Mediterranean sites, indicating that prehistoric hunters also regularly included these birds in their diet.

Contemporary and historical small-scale societies often rely on star clusters as an aid to keep track of time. The Iroquois and the Algo-

Figure 8.6: Emu in the sky, rock engraving from Ku-ring-gai Chase National Park, Australia, figures from `http://www.atnf.csiro.au/research/AboriginalAstronomy/Examples/emu.htm` (left) and `http://www.freerepublic.com/focus/chat/2591889/posts` (right).

nquians (both Native American peoples) used the Pleiades to time the cultivation of their staple food, maize, which was grown at the northern fringes of the range in which it is possible to cultivate it. The appearance of the Pleiades coincides with the then limits of the frost-free periods of sowing and reaping (Ceci, 1978). The pervasive role of the Pleiades in folk astronomy (in places as widespread as East-Africa, Melanesia, North America and Siberia) can be explained by their visibility: to the naked eye they form the most visible cluster of stars in the night sky with a marked cyclicity. The archeoastronomer Michael Rappenglück (2001, 2004) has recognized the Pleiades on paintings of the caves of La-Tête-du-Lion (Ardèche, France, 21,000 BP) and Lascaux, indicating that Paleolithic people used this easily recognizable star cluster, probably also for calendrical reasons.

8.5.3 Improved foraging success

In what ways does the use of epistemic artifacts extend human cognition? Although cognition itself does not fossilize, one can infer changes in cognition through changes in behavior which leave their marks in the fossil and archeological records. Many archeologists (e.g., Klein, 2001) observe a discontinuity in subsistence patterns and other forms of behavior during the Late Pleistocene. In the archeological record, there is evidence for behavioral innovations in diverse domains during this period. Technological innovations included the invention of highly specialized weaponry, such as harpoons and spear throwers, and improvements in lithic technology, such as the invention of microliths, which had a much higher ratio of cutting edge versus tool weight compared to earlier stone technology (Leroi-Gourhan, 1993, 136). In the European archeological record, there is also clear evidence that Middle Paleolithic (MP) hominids hunted and gathered less efficiently than those of the Upper Paleolithic (UP). Improvements in technology can partly account for this increased efficiency. However, there is also evidence that the increased effectiveness in foraging was due to a better recognition of cyclical events. Take the transition from MP to UP in the southern Russian plains. In marked contrast to the earlier (MP) occupations, later (UP) sites show fewer species of prey and less variability in the concentration of fossil bones across seasons. This is taken as evidence for higher selectivity in the choice of prey and time of occupation, indicating specialized hunting and seasonal occupation of sites tuned to animal migrations (Soffer, 1989).

The Aurignacian site of Vogelherd (Lone Valley, Germany) dated to 33,000-30,000 BP, provides a good illustration of seasonal occupation. The main sources of food for these Pleistocene hunters were reindeer and horses. Both species were highly seasonal in birthing and mating, and they migrated seasonally through the Lone Valley, using the natural routes that dissected it. As present-day wild horses and reindeer are quite predictable in their migration patterns (not following exactly the same route, but approximately so), it would have been advantageous for the Aurignacian inhabitants of southwestern Germany to be able to predict these migrations. An analysis of the tooth eruption patterns of reindeer remains at Vogelherd indicates that these animals were primarily hunted during the fall migration. The horse bones, likewise, indicate that horses were hunted when they migrated in large family groups consisting of mares and maturing foals during late summer and fall. Indeed, evidence for occupation of Vogelherd at other times of the year is lacking (Niven, 2007, 377). Niven (2007) infers from these patterns that Vogelherd was not occupied all year round, but seasonally during the annual fall migrations of large herbivores—the density of the archeological material moreover suggests that it was used multiple times. Given that hunter-gatherers inhabit extensive ranges (between 314 to 2500 km^2 (Mandryk, 1993), probably closer to the high value in the Ice Age Aurignacian), and taking into account the presence of exotic lithic material (i.e., stone tools made from cores that originated over one hundred kilometers away), this seasonal occupation suggests that the inhabitants of Vogelherd could anticipate these migration events. Unlike reindeer, whose migratory behavior is regulated by the secretion of hormones like melatonin as a function of exposure to daylight hours (Paul et al., 2008), humans do not have physiological adaptations to time their migrations. A plausible explanation of their accurate, long distance travels to Vogelherd is their access to calendrical devices.

The African archeological record shows a similar pattern: Later Stone Age (LSA) sites indicate an increased foraging efficiency compared to Middle Stone Age (MSA) locales. These improvements are not caused by changes in climate or prey availability as the South African Last Interglacial and the Present Interglacial are climatologically very similar. Yet LSA sites from the Present Interglacial show improved foraging efficiency, such as an increase in bird and fish bones compared to MSA sites (Klein, 2001). The failure of earlier humans to record cyclicity accurately in their environment could explain this difference. Material culture allowed the recording of cyclical patterns, enabling hunter-gatherers to time their visits to sites according to patterns in animal migration and plant growth. The capture of Cape fur seals (*Arctocephalus pusillus*) in southwestern African coastal sites presents a pertinent case study (Klein, Cruz-Uribe, & Skinner, 1999). Fur seals breed on offshore islands, the majority of births occurring during late November and early December. About nine months later, adult seals force their young from the rocks into sea. Large numbers of these young seals wash ashore, exhausted or dead—an ideal time for mobile hunter-gatherers to visit these sites. Like in the European archeological record, only humans from Later Stone Age sites appear to recognize this cyclical pattern: fossil remains from seals in LSA sites indeed mostly represent individuals of about nine months old, implying that these people timed their visits to the coast to fall within the August-October peak in juvenile seal availability. In contrast, Middle Stone Age sites do not show such a fixed pattern. The bones of seals recovered from these sites are commonly older, ranging from sub-adults to adults, not showing any cyclicity at all, a pattern remarkably similar to that found in dens of fossil hyenas.

Recognizing cyclicity not only had an impact on hunting success, but also resulted in a substantial broadening of the human diet. Fish bones are notably absent in the MP archeological record—exceptions include the opportunistic and occasional exploitation of marine shellfish by Neanderthals at Mediterranean coastal sites. In contrast, numerous archeological sites indicate that coastal UP people relied heavily on fish for their diet. These sites show patterns of seasonal and specialized fish exploitation. The relative proportion of aquatic resources in the diet of prehistoric foragers can also be directly inferred through analysis of the stable isotope values of carbon (δ^{14}C) and nitrogen (δ^{15}N) in their bone collagen. These data provide direct information about average dietary protein intake by prehistoric consumers over a period of ten years prior to their death. Richards, Pettitt, Stiner, and Trinkaus (2001) found that fish only became incorporated in European diets by the middle UP (about 30,000 BP). Prior to this time, the principal sources of animal protein were large herbivores. The trend of including fish in the diet coincides with elaborations in material culture, such as lavish burials, personal ornaments, portable art and notched artifacts. Likewise, at the African LSA site of Ishango, Congo, along the Upper Semliki River, dense concentrations of fish remains, together with hundreds of barbed points used to spear the fish, dated at about 25,000 BP, have been recovered (Stewart, 1994). More than 30% of these remains belong to the genus *Barbus*, a large minnow-like fish. Their size range represents primarily mature individuals, probably caught on their spawning migration, the only time of the year when fish are truly fat. This implies that the fishers at Ishango timed their capture to the rainy season, when large quantities of *Barbus* congregate in river mouths on their yearly spawning migration. The repeated rainy season occupations at Ishango indicate the predictability of these. Interestingly, two incised bones dating to the same period have been recovered at Ishango. The spatial distribution of their notches (Fig. 8.7) almost certainly indicates that they are artificial memory systems. One reason why MSA people neglected such a stable and abundant food source may be that the systematic exploitation of fish requires recognizing cyclical patterns of spawning and migration. In historical times, the Northwest Coast Native Americans planned and prepared for the capture of salmon months in advance (Ames, 1994).

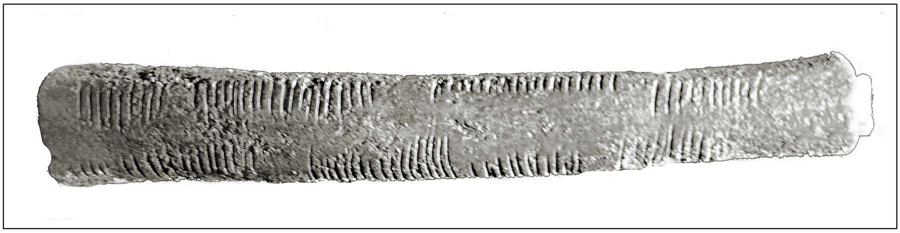

Figure 8.7: Incised bone from Ishango, Congo, dated to 25,000–20,000 BP, Museum of Natural Sciences, Brussels, Belgium (author's photograph). Marshack (1991a) interpreted this object as a lunar calendar, each row representing 60 days (approximately two observational lunar months).

Recognizing cyclicity has an impact on many aspects of human life. Traditional human diets in which plants are rare, such as those of the Inuit, show a strong relationship between physiological stress, group size and dietary fat. The human body's ability to metabolize energy from protein is limited; a critical ratio of protein to fat must be maintained to prevent starvation. As mentioned earlier, the animals that Late Pleistocene humans hunted—as indicated by bone collagen analysis and archeological remains—provided mostly lean meat, which contains mainly protein and little fat. Hunting animals with high fat content requires the detection of cyclical patterns, as animals only accumulate fat during specific phases of their life-cycle: fish are only fat while returning upstream to spawn, terrestrial herbivores only accumulate fat prior to migration, mating or giving birth. A comparative study of traditional Inuit diets with differing protein to fat ratios (Cachel, 1997) indicates that groups with high protein/low fat diets are smaller and have less complex social structures with little social stratification. Their members suffer more physiological stress, such as bone fractures.

Applying these observations to Late Pleistocene Europe, it becomes apparent that Neanderthals (associated with MP industries) consumed less fat than anatomically modern humans (associated with UP assemblages). Although Neanderthals were highly successful hunters, focusing on prime-age individuals (Steele, 2003), they had relatively low population densities and suffered many traumatic injuries—T. Berger and Trinkaus (1995) aptly compare them to rodeo veterans. Their burial patterns do not suggest social stratification. In marked contrast, the population density of anatomically modern humans as indicated by site density was higher, and their fossil remains show less traumatic injuries. Their burial patterns hint at more complex social structures as is indicated amongst others by grave gifts of exotic origin at the Saint-Germain-la-Rivière burial dated at about 15,600 BP (Vanhaeren & d'Errico, 2005). Moreover, detailed study of the processing of carcasses of reindeer and other large mammals by anatomically modern humans (e.g., Niven, 2007) indicates that modern humans invested considerable time and effort in exploiting fat-rich parts of those carcasses (such as the extensive processing of lower hindlimbs). The failure of earlier humans to recognize cyclicity in their environment could explain these behavioral differences.

8.6 Concluding remarks

This chapter has examined anthropological and archeological evidence for the use of the external environment as an extension of human mental time travel. The anthropological case studies indicate that humans use a variety of naturally occurring objects and especially designed artifacts for this purpose. Because only a tiny fraction of material culture survives in the archeological record (i.e., only objects that are in a suitable context, and that are made of hard materials, such as stone and bone), the Late Pleistocene artifacts discussed here are probably only a fraction of the calendrical systems that were being used. Nevertheless, when such artifacts begin to consistently appear in the archeological record, one can see an improvement in foraging success, especially in the exploitation of cyclical resources. The invention of calendrical systems can be seen in the broader context of technological and behavioral innovations that occurred during the MP to UP transition.

The fragmentary nature of the archeological record makes it at present difficult to model the claims put forward in this chapter. However, recent computational models that have examined the evolution of communication (e.g., Di Paolo, 1997) and the role of population dynamics in the emergence of culturally modern behavior (e.g., Powell et al., 2009) could be adapted to model the role of external media in human behavior during the Upper Paleolithic. Current analytic models (e.g., Henrich, 2004b) examine relationships between population size and technological and behavioral innovation. However, to date such models do not take into account the role of externally stored knowledge in cultural evolution. As we have seen, the ethnographic and archeological record strongly indicate that storing knowledge outside of the brain increases the reliability of representations and protects them against various memory biases. Therefore, future computational and analytic models should incorporate this reliance on externally stored knowledge as a factor in the transmission of information and skills.

Some philosophers of mind have raised criticisms against an interpretation of the extended mind where cognition actually takes place outside the brain. Giere (2004) considers the Hubble telescope, which uses the star cluster Abell 1689 as a gravitational lens: if Hubble is involved in cognitive (epistemic) processes, does it follow that cognition extends 2.2 billion light years into space? Does cognition exceed the speed of light? Adams and Aizawa (2001, 46) compare distributed cognition with non-cognitive instances of tool use: if a person uses lopping shears to chop thick branches from a tree, shears and arms can be considered as a single system. However, there is little reason to suppose that the muscular processes inside the arms extend into the lopping shears. If their interpretation is correct, there is little reason to suppose that the cognitive processes that take place within the brain extend into our epistemic artifacts, or that our innate timing capacities are radically altered or replaced by the use of calendars and other timing devices. We are all familiar with situations such as holidays or periods of illness in which we are removed from our time-keeping devices like agendas and calendars, and where we quickly lose track of the days of the week as a result. Therefore, the extended mind can only be properly understood in terms of a coupled system in which the brain holds a privileged position. In the case of calendrical systems, it seems that mental time travel is a necessary prerequisite. Without our ability to mentally travel in time, we could not foresee future imagined events, and calendars would be useless. Archeological evidence for episodic future thinking in hominids dates back to at least 2.6 million years BP. At this time, hominids began to make stone tools (Semaw et al., 1997); they regularly cached these for future use (Potts, 1994), indicating sensitivity to future needs. However, it seems that mental time travel alone was not sufficient to allow them to accurately predict cyclical events. Evidence for this is only archeologically attested since the Late Pleistocene.

The co-occurrence of epistemic artifacts with improved foraging techniques and increased dietary breadth suggests that material culture was necessary to recognize cyclicity in the environment, a capacity that humans do not naturally possess. The changes in behavior during the Late Pleistocene can be understood as a result of an increased use of epistemic artifacts, making humans part of distributed cognitive systems with computational capacities extending their evolved cognitive abilities. Calendars and interpreting humans constitute coupled cognitive systems that enable humans to predict cyclic events far more accurately than their evolved cognitive abilities for keeping track of time allow.

PART III

RELIGIOUS REFLECTION

Religion in human experience

Since the 18th century, philosophers, social scientists and political theorists, such as Freud, Weber and Marx, have repeatedly spelled the end of religious belief in the light of modern science and culture (Stark, 1999). They identified religion with primitive thought and behavior. For example, Auguste Comte (1896, 52$^{\text{ième}}$ leçon), when tracing the evolution of human culture, termed the most primitive stage *l'état théologique*, where human culture is in the grip of hallucinations and passions. As these authors see it, as individuals acquire a more rational understanding of their world, informed by science, they would all gradually come to abandon this view in favor of a purely scientific conception of the world. Despite these forecasts, nothing of the sort has happened. This is especially the case when we cast our glance away from western Europe, where religion is mainly a matter of state churches that typically enjoy low attendance rates, and focus on more entrepreneurial religious institutions in America, Asia and Africa. When current sociologists of religion refer to 'secularization' (e.g., Stark, 1999), they do not mean a process of religious decline, but rather one of change: religious believers can freely choose their religious affiliation, or draw religious meaning outside of institutionalized contexts (adherents to Jediism, for example, get their inspiration from a fictitious religion from the *Star Wars* franchise).

Religion is a cultural phenomenon that can be traced back to the late Pleistocene archeological record. Although religious behavior in itself does not fossilize, many religious practices leave material traces, including burials if they contain grave gifts, and representational depictions of supernatural beings. Although burials were already an established practice by *Homo sapiens* and *Homo neanderthalensis* by 120,000 BP, it is a matter of continuing debate whether or not these burials provide compelling evidence for belief in an afterlife. Neanderthal burials do not contain uncontested grave gifts or other signs that warrant inference to such beliefs. Moreover, some archeologists (e.g., Gargett, 1989, 1999) argue that unintentional burial cannot be ruled out for the Middle Paleolithic skeletons of anatomically modern humans and neanderthals in the Levant, 120,000–80,000 BP. Starting about 27,000–26,000 BP we see more definite evidence of intentional burial, including grave gifts in the double child burial at Sungir, Russia (Kuzmin, Burr, Jull, & Sulerzhitsky, 2004), see Fig. 8.8. A plausible explanation for grave gifts is that the donors actually believed that the deceased could use them, presumably in an afterlife. Next to this, depictions of supernatural beings provide strong evidence for religious thought. Therianthropic figures can be found in the shape of sculptures and cave-paintings since about 32,000 BP. The so-called lion man from Hohlenstein-Stadl (Fig. 7.5a) is a 28 cm tall mammoth ivory figurine that can best be described as a half-human half-feline hybrid of undetermined sex. Recently, a second, smaller lion man has been excavated (Conard, 2003). This figurine was found in Hohle Fels, and is dated to 33,000–31,000 uncalibrated ^{14}C years, making it part of the same Aurignacian Swabian cultural complex as the better-known specimen from Hohlenstein-Stadl. The two objects combined suggest that these therianthropic figurines were not products of individual fancy, but had a well-defined cultural, probably religious, meaning. Other therianthropic figures include more recent cave paintings from the Magdalenian Trois-Frères cave, one a human-animal hybrid, the other a bipedal bull playing a musical arch. More indirect evidence for ancient religious practice can be obtained when relying on ethnographic parallels like shamanic art from the San (Kalahari desert) and the Shoshone (Coso Range, eastern California). Lewis-Williams and Dowson (1988) have argued that the imagery in Franco-Cantabrian rock art bears evidence of shamanic rituals. To Clottes and Lewis-Williams (1996), the frequent depictions of dots and lines indicate that the artists were experiencing altered states of consciousness (where one sees entoptic images, i.e., geometric patterns, and eventually hybrid creatures) which led them to conclude that the Paleolithic artists had a shamanic religion.

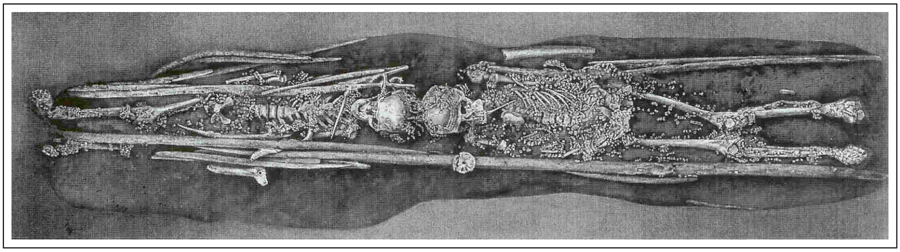

Figure 8.8: Sungir double child burial. Note the lavish grave gifts (spears and clothing studded with beads). From `http://www.evolution-of-man.info/children.jpg`.

It seems safe to assume that religion is a universal human phenomenon. Is it also uniquely human? Darwin (1871) already observed that the belief in one or a few gods is a result of cultural evolution and is not universal, but that animism (the belief that natural objects are imbued with agency) may be far more phylogenetically ancient, and can be found in all cultures. Since the late 19th century, in particular since the anthropologist E.B. Tylor (1871 [1920]) included Australian aboriginal beliefs as religious beliefs in his *Primitive cultures*, anthropologists have broadened their definition of religion so that it not only includes practices that involve interaction with one supreme being, but also with ancestors, spirits, and other supernatural agents. Darwin used a similar inclusive sense when he argued that religion is not uniquely human, but that it can be found in nonhuman animals:

> My dog, a full-grown and very sensible animal, was lying on the lawn during a hot and still day; but at a little distance a slight breeze occasionally moved an open parasol, which would have been wholly disregarded by the dog, had any one stood near it. As it was, every time that the parasol slightly moved, the dog growled fiercely and barked. He must, I think, have reasoned to himself in a rapid and unconscious manner, that movement without any apparent cause indicated the presence of some strange living agent, and no stranger had a right to be on his territory. The belief in spiritual agencies would easily pass into the belief in the existence of one or more gods. For savages would naturally attribute to spirits the same passions, the same love of vengeance or simplest form of justice, and the same affections which they themselves experienced (Darwin, 1871, 64–65).

The anthropologist Stewart Guthrie (1993) has developed this argument more fully, arguing that religious beliefs are a byproduct of our ability to detect agents, in particular conspecifics, an ability we share with many other animals. According to Guthrie, our specialized agency detection system sometimes leads us to observe false positives (i.e., observing an agent where none is present). The evolutionary rationale for this is that a false positive is less costly than a false negative, as the latter can result in a failure to detect a dangerous predator, a prey, or a potential mate, and the former only results in a small waste of time and energy. Using a mathematical model, Godfrey-Smith (1991) indeed found that cognitive systems that generate an excess of false positives can evolve if the costs or payoffs of false positives (detecting a signal in the environment where there is none) and false negatives (failing to detect a signal that is present in the environment) are asymmetric. In those cases, natural selection will tend to promote beliefs that yield the highest payoffs or incur the least costs (Stephens, 2001, see also sections 10.4 and 12.4). It is a kind of wager that is similar to Pascal's wager, and it can easily be explained in game theoretical terms, as follows: as long as $c_1 < c_2$, and $b > 0$, we can expect hyperactive agency detection to occur (table 8.1). Some animals exploit this proneness to detect agency in other species, for example in mimicry: most species of hawk moth (*Sphingidae*) caterpillars have a final abdominal segment with spots that have an uncanny resemblance to a snake's head, thereby deterring predators from eating them (causing a false positive). According to Darwin and Guthrie religion is a form of animism, and one can see something that can be interpreted as animistic behavior in the behavior of other animals. Guthrie talks about horses that shy away from bags and leaves that move in the wind, as if they interpret them as agents, and about chimpanzee rain dancing, i.e., the display of hooting and swaggering that chimpanzees often exhibit at the start of rain storms. To S. E. Guthrie (1993, 52) "the display is indeed a threat against the storm and [. . .] the chimpanzees do perceive the storm as animate." If religion can be reduced to a form of hypersensitive agency detection, it is not uniquely human.

Table 8.1: Costs and benefits of agency detection

	agent present	agent absent
detect	benefit b	false positive c_1
do not detect	false negative c_2	no cost or benefit 0

A problem with Guthrie's model is that it does not provide a detailed causal account of how the detection of living things can result in sustained, costly religious practices. As the psychologist of religion Joseph Bulbulia (2004, 659) puts it: "While it is understandable how Darwin's dog could have responded to a moving gate [sic] by barking, it is not obvious why we would respond to vague reality with a Sistine Chapel, or a Mecca, or with painful rituals?—'I detect an agent, therefore, off with my foreskin."' Bulbulia rightly observes that religion has particular elements, such as ritual, prayer, costly signaling, that are absent in nonhuman animals. It is not surprising that Jesse Bering (2001) is therefore skeptical about the possibility that religion has precursors in nonhuman animals, and argues that it is uniquely human. Our ability to conceptualize unobservable mental states, such as beliefs and desires, our capacity to engage in pretend play and other forms of counterfactual reasoning, and a psychological death concept are, according to Bering (2001), necessary conditions for the development of religious ideas. As we saw in section 1.2.3, the positing of unobservable mental states and counterfactual reasoning seem to be outside the purview of chimpanzee cognition. We might agree with Guthrie (1993) and Darwin (1871) that animism is an important aspect of religion, but in this dissertation I will assume that religion is a far richer and more complex phenomenon, which has no clear parallels in nonhuman animal cognition.

Is religious belief a biological adaptation?

The question of whether religious belief is a biological adaptation remains unresolved. While some authors working in the field of cognitive science of religion (CSR) think that religion is a byproduct, for example Pascal Boyer (2002), Justin Barrett (2004), and Paul Bloom (e.g., 2007), there are others like Richard Sosis (e.g., Sosis & Alcorta, 2003), Jesse Bering (e.g., Bering, 2006) and Ara Norenzayan (e.g., Norenzayan & Shariff, 2008) who regard it as an adaptation. In the following sections, we will briefly review a selection of byproduct and adaptationist accounts of religion. It is important to point out that CSR is not really a research program[25], but rather an umbrella term for philosophers and scientists from diverse disciplines who examine the cognitive basis of religion. Despite its methodological diversity, there are a few features that underlie most CSR research. CSR investigates beliefs (such as beliefs in gods or ancestors) and behaviors (such as rituals, prayer and meditation), and it does so in a fairly specific way. Religious beliefs are examined in terms of ordinary cognitive biases and constraints, and religiously-motivated behaviors are examined in terms of ordinary human behaviors, subject to cognitive and bodily biases and constraints. In this way, CSR naturalizes religion: it provides naturalistic explanations for beliefs and behaviors that are traditionally associated with the supernatural. Another underlying unifying assumption of CSR is that religious convictions and practices are not solely the result of culturally contingent processes. This does not imply that culture would be unimportant—to the contrary, many CSR researchers explicitly investigate the effects of culturally variable features on beliefs. For example, Boyer and Ramble (2001) studied the effects of memory biases in the cultural transmission of religious concepts in Gabon, France and Nepal, and Knight, Sousa, Barrett, and Atran (2004) examined how Maya children represent beliefs in the Christian God and in indigenous spirits. Rather, CSR scholars think that the architecture of the human brain constrains and guides the development of religious beliefs within specific cultures.

Religion as byproduct

CSR researchers adhere to a massively modular conception of the mind (as outlined in section 2.2.3). According to the cognitive anthropologist Dan Sperber (1994), modules are domain-specific computational devices that are highly specialized in the processing of particular computational problems. The evolutionary relevant domain to which a module responds is its *proper domain*. The term 'proper' is closely related to the way the term is used in teleosemantics (e.g., Rowlands, 1997): it is the evolutionary function the module has acquired, which enhances the fitness of its owner. However, a module can also respond to input that is not part of its proper domain, but that resembles it—in Sperber's (1994) terminology the *actual domain* of the module, i.e., the sum of all stimuli that fall in the proper domain and those that fall outside it, but to which the module responds. The large array of cultural stimuli to which a module responds is its *cultural domain*. An example can illustrate this distinction. The proper domain of the face recognition module is the human face. This is because the evolved function of this module is to facilitate the recognition of conspecifics. However, our face recognition module (anatomically located mainly in the fusiform face area) also responds, albeit somewhat less strongly, to faces of monkeys and even to those of other animals such as cats (Tong et al., 2000). Clearly, our face recognition system does not have the evolved function of recognizing the face of a cat, but this is part of its actual domain. The cultural domain of the face recognition module, as we have seen in section 5.4, is the vast array of cultural stimuli that have face-like depictions, including masks, cartoon faces, and portraits.

Byproduct accounts of religious belief similarly see religious concepts as part of the cultural domain of specific computational modules. As mentioned earlier, Guthrie (1993) regards religion as a consequence of an evolved agency-detection system. Guthrie (e.g., 1996) stresses that his account focuses on our ability to recognize conspecifics, i.e., religion is a byproduct of anthropomorphism. However, later authors such as Justin Barrett (e.g., 2004) have argued that the agency-detection system is specialized in detecting agency in general, not just human agency. According to this view, the proper domain of the modules that give rise to religious beliefs are agency detection and intentionality detection. If our reasoning about everyday (nonreligious) agents has indeed given rise to religious belief, we can expect that when people draw spontaneous inferences about their gods, they will model these inferences on their expectations about how everyday agents behave, and not on theologically correct concepts, which in the case of the Christian god include omniscience and omnipotence. As predicted, Barrett (J. L. Barrett & Keil, 1996; J. L. Barrett, 1998) found that both Christian and Hindu believers tend to reconstruct stories about their gods in ways that are theologically incorrect, i.e., gods are bounded in their knowledge and actions: subjects tend to think about their gods in terms of normal agents. Like normal agents, gods and other supernatural beings have beliefs, desires and emotions, and they act in the world in order to fulfill goals and desires.

The developmental psychologist Paul Bloom (2005, 2007) has argued that religion arises out of an intuitive mind-body dualism. As we have seen in section 2.3.1, humans make an intuitive distinction between causation in the physical and psychological domains, a distinction that is already present in infants. A striking experiment by Kuhlmeier et al. (2004), for example, reveals that five-month-old infants simply do not treat humans as if they are physical objects. In this looking time experiment, infants were shown walking humans and inanimate objects that travelled in continuous paths, disappearing behind one screen, appearing again, and then disappearing behind a second screen. The infants were surprised when an inanimate object, such as a rolling ball, violated their expectations about continuity of objects: if a second ball was visible behind one of the screens after it was lowered, they looked longer at the display. However, when the same thing happened with an agent (a human), the infants' looking time did not increase, which shows that they were not surprised, implying that infants initially do not apply their intuitive physics to humans. Adults and older children also use different inference mechanisms for bodies and for minds (intuitive physics versus folk psychology). As a result, the physical death of a person does not prevent them from thinking that that person's mind would continue to exist. Indeed, people often refer to the mental states of deceased persons and how they would react to a current state of affairs, as in 'grandpa would never have approved of that (and therefore, we should not do this)' (Hodge, 2010). We can imagine disembodied minds and this may lead to religious concepts like ancestor worship (where one can still perceive the agency of a deceased forebear). However, Bloom's hypothesis of psychological dualism does not seem to be the default position in all religions, as judged from afterlife beliefs. In many religions (e.g., ancient Egyptian religion; taoism), humans have not one but several souls (Hodge, 2008). Moreover, several religions (e.g., Christianity, Islam) hold that people will have a body in the afterlife. The Fourth Lateran Council (1215) states that God will "judge the living and the dead [. . .] All of them will rise with their own bodies, which they now have,"[26] reiterating what Christian theologians have written since the second century. The resurrection of the body has been a central belief in Christianity for centuries, see e.g., Fig. 8.9 for a typical illustration. Many religions practice the giving of grave gifts, which would be unintelligible if belief in disembodied minds were universal.

The cognitive anthropologist Pascal Boyer (1994, 2002) has argued that religion is not a byproduct of one specific intuitive ontology, but rather, that religious ideas are a product of an interplay between cultural transmission and evolved propensities of the human mind. His byproduct account of culture draws on Sperber's (1985) theory of the epidemiology of representations. This theory aims to explain the stability in cultural representations. Acquiring a new cultural concept, like CAPITALISM or PLATYPUS requires that a learner reconstruct this representation in her own mind. Given this, we can expect that not everyone has identical mental representations. Fortunately, humans do not start out from scratch: they can build upon pre-existing knowledge, including that supplied by intuitive ontologies. For example, a toddler who learns that a PLATYPUS is an ANIMAL can infer that it is self-propelled, needs food to sustain itself, and has offspring that resembles it. Cultural transmission presupposes that a learner supplements already acquired knowledge. Some ideas are

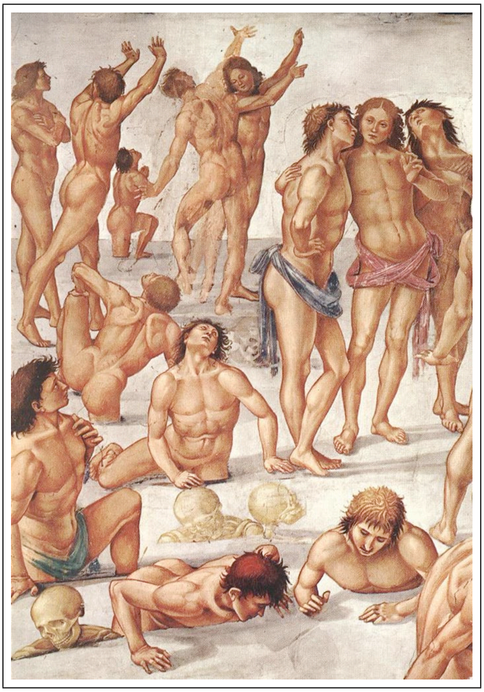

Figure 8.9: *Resurrection of the flesh* (fragment) by Luca Signorelli, 1499–1502, from `http://casasantapia.com/images/art/orvietolsignoresurr700.jpg`.

easier to learn and recall than others because they rely on knowledge that is already present. Intuitive ontologies constrain and guide the acquisition of concepts. We can therefore expect that concepts that have a very poor fit with intuitive ontologies will be harder to reconstruct, and thus harder to remember and transmit. On the other hand, concepts that are more in tune with our intuitive ontologies are easier to remember and transmit. According to Boyer (1994, 2002), religious ideas strike a cognitive optimum, because they are minimally counterintuitive: they violate a few of our intuitive ontological expectations, which makes them interesting and attention-grabbing, but they conform to most other intuitive ontological expectations, which makes them easy to remember and transmit. For example, ghosts violate our basic expectations of how physical objects behave in their ability to walk through walls, and to appear and disappear at will. But the psychology of ghosts is conform to our basic ontological expectations about agents: they have beliefs, desires and a distinct personality. In this case, only the properties that violate our intuitive ontologies need to be transmitted when we acquire the concept GHOST; the elements that are conform to intuitive ontologies are tacitly assumed, as they are the default position.

Implicit in Boyer's theory are two testable predictions: (1) minimally counterintuitive ideas are easier to transmit than others, and (2) minimally counterintuitive are typically religious. There is considerable empirical support for the first prediction. J. L. Barrett and Nyhof (2001) gave participants stories to reproduce that contained intuitive, bizarre or counterintuitive elements. After a delay, their participants were much more accurate in their recall of the minimally counterintuitive elements. Boyer and Ramble (2001) had comparable results with a study that probed recall of similar stories in Gabon, Nepal and France.

However, it is less clear whether minimally counterintuitive ideas are specific for religious concepts. Pyysiäinen, Lindeman, and Honkela (2003) presented subjects with imaginary beliefs with varying levels of counterintuitiveness. They showed that counterintuitive representations in general, and counterintuitive representations involving a conscious agent in particular, are more likely to be considered religious. Next to this, studies indicate that minimal counterintuitiveness is also typical of nonreligious folklore, including fairy tales. Norenzayan, Atran, Faulkner, and Schaller (2006), for instance, found that stories recorded by the Grimm brothers that had a limited number of counterintuitive elements (e.g., *Little red riding hood*) are still beloved fairy tales today compared to those that have too many counterintuitive elements (e.g., *The magic table, the gold donkey, and the cudgel in the sack*) or none at all (e.g., the story of the trickster *The little peasant*). Thus, it is not at all clear why counterintuitiveness should be a defining feature of religious concepts.

Boyer's theory as he originally formulated it in 1994 is also vulnerable to the so-called Mickey Mouse problem[27]: Mickey Mouse is minimally counterintuitive, yet we do not feel compelled to worship him. Boyer (2002) attempted to solve this problem by arguing that not all minimally counterintuitive concepts are interesting, but that specifically agents that have special, strategic knowledge of our actions (especially those that are morally relevant) are compelling. We are thus not much impressed by a god who only exists on Wednesdays (counterintuitive but uninteresting), whereas a god who knows when you are good or bad is more interesting. More recently, Gervais and Henrich (2010) have proposed the Zeus problem. Zeus has all the features that we can expect of a successful god: he is minimally counterintuitive, and he has access to strategic information. Yet Zeus is no longer an object of religious devotion[28]. Gervais and Henrich (2010) argue that a successful evolutionary account of religious beliefs should not only take cognitive biases about the content of religious beliefs into account but also transmission biases, in particular conformist bias: people usually do not worship religious beings from the past, or even gods from neighboring groups, because they tend to follow the religious affiliation of their parents or peers. On the other hand, conformist bias can lead people to accepting a different religion when they perceive that a number of their peers adhere to a different religious movement. This is how the sociologist of religion Rodney Stark (2005) explains the rapid spread of Mormonism in the USA: it is not so much by active proselytizing, but by having Mormons as friends, neighbors or colleagues. Cognitive biases may explain how people mentally represent gods, but context-based cultural evolutionary models are necessary to explain why people come to believe in particular gods.

Religion as adaptation

Some theorists propose that religion is an adaptation, evolved in response to problems faced by humans living in large groups. Humans are a prosocial species, but there is always a risk of defection. To counter the risk of defection, members of a group can impose punishment. Indeed, theoretical models (e.g., Fehr & Gächter, 2002) and psychological experiments (e.g., Henrich et al., 2006) indicate that cooperation can flourish in groups where altruistic punishment occurs, i.e., punishment that is costly to the punishers and that does not always give them a direct material gain. However, for people living in large-scale societies direct punishment is not always possible. Policing institutions are a solution, but they are liable to corruption and even in the best of cases they are not always able to catch or even to spot freeriders. According to Norenzayan and Shariff (2008) human societies would therefore benefit from belief in one or more beings who are omniscient or have special knowledge, next to the capacity to reward or punish. Most adaptationist approaches to religion take this point of view, arguing that belief in supernatural punishment provides a solution to the free-rider problem. Schloss and Murray (in press) remark that adaptationist theories of religion rely on two diverging explanatory strategies. The first group of theories argues that religion enhances cooperation, amongst others through costly signaling (the cooperation enhancement model), whereas the second places more emphasis on the avoidance of punishment (the punishment avoidance model).

The cooperation enhancement model of the anthropologist Richard Sosis (e.g., Sosis & Alcorta, 2003) proposes that religion is a form of costly signaling. It is a well-observed phenomenon in the sociology of religion that strict churches have more success in terms of membership and attendance than loose congregations (Iannaccone, 1994). This is intriguing, given the wide range of seemingly arbitrary behaviors and taboos these churches impose, such as abstaining from coffee, sigarettes, dancing, and even some types of music. Iannaccone (1994) speculates that strict churches are more successful, precisely because they require greater commitment from their members than lax ones. People may be attracted to strict churches because their members are less likely to cheat. The costly religious customs (e.g., dress codes, food taboos), which often result in exclusion from or reduced opportunity of interaction with other groups provide an honest signal: “if I go through all this trouble to signal my religiosity, this means I am a sincere believer.” For example, dressing as an orthodox Jew will provide the benefits of increased altruism from other orthodox Jews, but may expose one to ridicule and ostracism of the population at large. Indeed, even wearing a simple skullcap has this effect, as the use of ‘decoy Jews’ by the Dutch police illustrates[29]. Thus, it seems unlikely that someone (other than a trained policeman) would dress up as an orthodox Jew without having the religious beliefs to match. The costliness of the signal makes it honest. Empirical support for Sosis’ predictions comes from a literature study on the viability of 19th-century American communes—given that communes tend to fall apart due to a high percentage of freeriders, one can take the lifespan of a commune as an indirect proxy of levels of cooperation within it. Sosis and Bressler (2003) found that religious communes had on average a lifespan that was four times longer than that of secular communes. Using games such as the anonymous dictator game, where donors can choose to anonymously give as much as they like to an unknown recipient within their community, Sosis and Ruffle (2007) found that members of religious kibbutzim are more cooperative than those of secular ones. Next to costly dress-codes and taboos, moral emotions can also serve as reliable signs of commitment, which are reinforced with costly sacrifices and ritual observances (Teehan, 2010).

In order for the costly signaling theory of religion to work, the cost for the honest signaler must be smaller than for the dishonest signaler. For example, the cost of a fancy tail is easier to bear for a healthy peacock than for an individual of less quality, thus it is a reliable signal. But it remains unclear whether this is the case for religion. Perhaps religious individuals *perceive* the cost as less high, because they expect greater benefits (e.g., in an afterlife), which makes it easier for them to abide by religious dresscodes and taboos. Another problem with the cooperation enhancement model is that it does not explain why the costly signals should be religious. As we saw in chapter 6, dialects and art may also be capable of generating group cohesion. Another potential difficulty is that cooperation enhancement models rely on freedom of religious choice, which places severe limits on their explanatory scope. Thus, they cannot explain why hunter-gatherers or medieval villeins would be religious, since there is little point in costly signaling one's membership of a religious community if there is no freedom of religious choice. After all, a 'free market' of religious groups (Finke & Stark, 1989) is a relatively recent and not globally widespread phenomenon, mainly restricted to northern America. Many European countries have state-funded churches with low levels of expected commitment, which makes competition by smaller high-commitment religious groups harder. Prior to the 18th century, religious choice was quasi nonexistent, as the treatment of religious minorities in Europe exemplifies—one need but think of the massacre of the Cathars in southern France, or the historical persecution of Protestants. There is still no freedom of religion for the present-day Iraqi housewife and many others (De Cruz & De Smedt, in press c).

Several authors have proposed that religion is adaptive not by fostering cooperation, but rather by helping people to withstand the temptation to cheat, thus aiding them to avoid the costs of being punished. On a population level, the constant imminent threat of supernatural punishment makes groups with religious beliefs less vulnerable to subversion from within than non-religious communities. In this way, Norenzayan and Shariff (2008) explain how belief in supernatural punishment can be maintained through cultural group selection. There is a considerable body of empirical research that is in favor of punishment avoidance theories.

Shariff and Norenzayan (2007) confronted participants with a sentence that they had to unscramble and remove an extraneous word from, such as ‘felt she eradicate spirit the,’ which should become ‘she felt the spirit’. Some of these sentences contained only neutral words, others contained secular primes (e.g., police, judge) and a third group contained religious words (e.g., God, spirit). Afterwards, the subjects played a dictator game with a 10 $ stake, where they could freely choose how much money they kept and how much they gave away. They found that participants who got religious primes gave more money than those who received neutral primes (mean 4.6 $ versus 2.6 $), an effect that actually only held for theists. However, participants who got secular primes did not significantly differ from those who received religious primes (mean 4.4 $ versus 4.6 $). Bering, McLeod, and Shackelford (2005) found that students were less likely to cheat at a computer game where they could win money, if they had been informed prior to the experiment that the ghost of a deceased graduate student had been observed in the room that the experiment took place in. Several problems remain unresolved in the punishment avoidance account. First, there is a problem of cause and effect: if the effect Shariff and Norenzayan (2007) observed was entirely due to the presence of theists in their sample, how can the model explain the belief in supernatural punishing/rewarding agents? Second, why should the observer be a supernatural and not just a natural observer? After all, experimental studies show that even a picture of a pair of eyes on a box increases prosocial behavior: people are more likely to put money in a donation box in a canteen when two staring eyes are put on it (Bateson, Netttle, & Roberts, 2006). As Norenzayan and Shariff (2008) themselves point out, the presence of large, cooperative and not very religious groups (e.g., agnostic Scandinavian countries) indicates that secular institutions like the police can be equally successful in instilling cooperation. Thus, people in at least some societies can withstand the temptation to cheat when effective punitive mechanisms are present without belief in divine punishment. In sum, the two adaptationist models for religion (cooperation enhancement and punishment avoidance) each have experimental evidence in their favor but leave many questions unanswered. At present, there is no compelling evidence to suggest that religious belief would be a biological adaptation.

The role of universal cognitive biases in theological thinking

As this brief survey of evolutionary approaches to religion indicates, there is at present no satisfying overarching explanation for why humans, and not other animals, have religious beliefs. Despite this lack, CSR has provided compelling explanations for specific aspects of religiosity, in particular the widespread occurrence of minimally counterintuitive agents (Boyer, 2002), the focus on agents, rather than non-agents as objects of religious worship (S. E. Guthrie, 1993; J. L. Barrett, 2004), and the strong connection between religion and moral norms in particular cultural settings (Shariff & Norenzayan, 2007). Interestingly, CSR has to date mainly focused on folk religious beliefs. This makes sense, because theological reflection is only a tiny part of religious experience, since it is performed by specialists in specific highly-institutionalized contexts like universities and monasteries. Through this neglect of theology, CSR has not yet addressed the question of whether theological reflection is continuous with everyday cognitive processes—it has naturalized religion, but it has not yet naturalized theology. In the following two chapters, we shall look at some arguments from natural theology in the light of CSR. Throughout I will take the position that Rowe (1979, 340) has described as 'friendly atheism': "The atheist may believe that some theists are rationally justified in believing that the theistic God exists." In the context of this dissertation, I assume a naturalistic (nontheistic) picture of the world, a view that includes an evolutionary origin of human cognitive capacities as given. I will defend the view that theists may be justified in holding the beliefs they do, and that the cognitive basis of theological reflection may provide a basis for rational disagreement between theists and atheists.

CHAPTER 9

PALEY'S IPOD: THE COGNITIVE BASIS OF THE DESIGN ARGUMENT WITHIN NATURAL THEOLOGY

This chapter is a revised and expanded version of De Cruz, H., & De Smedt, J. (2010b). Paley's iPod: The cognitive basis of the design argument within natural theology. *Zygon: Journal of Religion & Science*, *45*, 665–684.

For many scientists and philosophers, Hume's critique (1779) and Darwin's theory of natural selection (1859) have definitely undermined the idea that we can draw any analogy from design in artifacts to design in nature. Yet the argument from design stands as one of the most intuitively compelling arguments for the existence of a divine creator. It enjoys an enduring appeal, going back as early as Plato's *Timaeus*, Cicero's *De Natura Deorum* and Aquinas' *Summa Theologiae.* Although it garnered particular attention around the turn of the 19th century, with Paley (1802 [2006]) as the best-known example, recent formulations can be found in the work of Swinburne (1968), Plantinga (1991) and proponents of Intelligent Design. Some (e.g., Wattles, 2006) have argued that the appeal of the design argument can be explained by Aristotle's pervasive influence on western philosophy and theology in his concept of nature as inherently purposive. Although cultural factors undeniably played an important role, this chapter proposes that the popularity of the design argument runs deeper, and that its argumentative structure can be traced back to evolved properties of the human mind.

In what follows, we will examine empirical studies from developmental and experimental psychology to investigate the cognitive basis of the design argument. The focus will be on two aspects: the tendency of humans to discern teleology in nature, and the way they intuitively assess probabilities. A better understanding of these aspects not only elucidates the lasting popularity of the design argument, but can also help theists and atheists to construct a rational basis for disagreement. From this it becomes clear that humans spontaneously discern purpose in nature, but that the inference to a designer is not automatically made. When constructed theologically and philosophically correctly, the design argument is not presented as conclusive evidence for God's existence, but rather as an abductive, probabilistic argument. This chapter examines the cognitive basis of probabilistic judgments in relationship to natural theology. Placing emphasis on how people assess improbable events, we clarify the intuitive appeal of Paley's watch analogy. We conclude that the reason why some scientists find the design argument compelling and others do not lies not in any intrinsic differences in assessing design in nature, but rather in the prior probability they place on complexity being produced by chance events or by a creator. The chapter begins by outlining an analysis of the epistemic properties of the design argument. Next, it examines the cognitive basis of teleological reasoning and the design stance in children and adults. We then discuss the probabilistic aspects of the design argument. Finally, we explore why theists and atheists disagree on the plausibility of the argument.

9.1 The argument from design

The argument for the existence of a divine creator, based on evidence of design in nature, has recently enjoyed a revival in theology and philosophy. Biologists (e.g., Dawkins, 1986, 4–5) praise the argument for its explanatory coherence and intuitive appeal. William Paley's image of the watch on the heath was certainly not the earliest formulation of the design argument, nor even of the watch analogy, but its familiarity makes it a suitable starting point. The argument Paley presented in *Natural theology* can be summarized as follows: if one encounters a watch, the complexity of this artifact and the interrelations of its parts lead to the inference that it is the product of purposive design. From this Paley concluded that complexity in nature is also the product of a Designer, because proposing that it could have been brought about by chance would be absurd (Paley, 1802 [2006], 7–15).

This argument has interesting epistemic properties: it is both an analogy and an inference to the best explanation. Analogies map the structure of a well-known domain (the source domain) onto a lesser-known problem (the target domain). In distant analogies the structures of source and target domains greatly differ in their basic ontological properties. The design argument is a distant analogy in that it maps the artifactual domain (source domain) onto the natural world (target domain). Artifacts exhibit goal-directedness in their design: they are intentionally created by designers who have their function in mind. As organisms exhibit goal-directedness in their design, they must also be the product of a purposeful designer. Although this analogical structure has often been attacked on the ground that it is inconclusive (e.g., Hume, 1779; P. Frank, 2004), it is worth noting that distant analogies are well-established in scientific practice as a way to gain insight into new problems (De Cruz & De Smedt, 2010c). When the conceptual structure of the target domain is relatively unknown, as in the case of scientific discovery, scientists often resort to analogical reasoning of this sort as an epistemic action. Historical examples include Johannes Kepler's mapping of the properties of gravity onto the properties of light (i.e., the fact that sunlight dissipates with increasing distance between the Sun and the planets it is cast upon) to explain why planets further from the Sun move more slowly, in this case, caused by a weakening of the gravitational force with increasing distance from the Sun (D. Gentner et al., 1997), and Charles Darwin's analogy of a hundred thousand wedges to examine the force of natural selection (Millman & Smith, 1997). A more recent example is the Swiss army knife analogy as a way to conceptualize the evolved structure of the human brain in evolutionary psychology (Cosmides & Tooby, 1994a, 88). The analogical structure of the design argument is thus epistemic; it is performed to gain insight into an unfamiliar domain (God's creation). In many early versions, the design argument served a heuristic, rather than a strictly argumentative purpose, as in the works of 17th-century natural philosophers like Bernard Nieuwentijt and Antonie van Leeuwenhoek, who perceived design as a source of wonderment about nature.

Traditionally, design arguments had an inductive argumentative structure. They began with the empirical observation that all complex, functional objects of known origin were products of intelligent design. Then came the inductive step, in which one infers that what is true for some members of a class is true for all members. Hume (1779, part II, 56–60) dispensed with this way of reasoning by arguing that artifacts and biological organisms are too dissimilar to be classed together. When we see a house, we can reasonably infer that it has an architect or builder, because we know from experience that this particular effect flows from that particular cause. But we have no guarantee that the universe bears such a resemblance to a house as to invoke a Designer; we do not know in how far our analogy is reliable. Indeed, because an object resembles other objects in that it has property p does not imply that it also resembles them in other respects. To suppose that it does is affirming the consequent, which is a logical mistake. Although Paley did not mention Hume explicitly, the structure of his watchmaker analogy escaped this criticism by adopting a different strategy. It is an inference to the best explanation (IBE), which has the following structure:

> **IBE** Given evidence E and a pool of plausible, potential explanations $H_1, \ldots, H_n$ of E, if H_i explains E better than any of the other hypotheses, infer that H_i is closer to the truth than any of these others (Douven, 2002, 359).

IBE enables us to probabilistically infer that a given hypothesis is closer to the truth than other hypotheses because it explains the available evidence better than rival explanations. In this probabilistic aspect, the design argument differs from deductive proofs for the existence of God, such as Anselm's ontological proof. IBE escapes Hume's critique, because it does not rely on induction, as it simply argues that there is no better explanation for order and complexity than design (Gliboff, 2000). This fundamental probabilistic aspect of the design argument has received relatively little attention in the philosophical literature (but see Sober, 2002). Having established apparent design and probabilistic inference as two key properties of the design argument, we will now examine the possible cognitive bases for its rational acceptability.

9.2 How we infer design

9.2.1 The design stance

To Paley, the conclusion that a watch is purposefully designed was self-evident. Our perception of its interrelated parts, formed and adjusted to each other—the coiled elastic spring, the flexible chains, the cogwheels —each fashioned out of the material that suits their intended function best, should lead us to infer that the watch must have had a maker who formed it for a specific purpose. Yet Paley acknowledged that such seemingly spontaneous inferences require contextual knowledge about the artifact under consideration: “it requires indeed an examination of the instrument, and perhaps some previous knowledge of the subject, to perceive and understand it” (Paley, 1802 [2006], 8). In the case of the watch, Paley could infer the intent of the designer, as he was familiar with the class of artifacts to which the watch belongs. But what would happen if he pitched his foot against an unfamiliar object, such as an iPod? Would he have inferred design as automatically as in the case of the watch? Its sleek shape, carefully integrated buttons and intended function would have presented a puzzle to him. Unfamiliar artifacts can be so outlandish that people can be led to believe that they are not the work of human designers. From the 19th-century wave of European colonization onward, and especially during World War II, the indigenous inhabitants of Papua New Guinea were confronted with a cornucopia of western goods. They believed that these were gifts of the ancestors. This led to the emergence of cargo cults, whose adherents are still trying to ritually lure airplanes into dropping more cargo, more western goods (Trompf, 1995; P. Frank, 2004). And what to think of people who observe UFOs? Often these alleged spaceships are no more than military reconnaissance airplanes, crashing weather balloons, or even bright planets. Nevertheless, people do infer that the objects are intentionally designed by supernatural agents and by extraterrestrials respectively. To gain a better understanding of the design argument, it is therefore useful to examine how humans infer design, what constitutes necessary and sufficient conditions for something to be a product of design, and how creator and artifact are causally linked.

Evidence from developmental psychology suggests that design is not a feature we can objectively infer. Remarkably, neither complexity nor order are necessary and sufficient conditions to decide whether an object is purposefully created. For example, Gelman and Ebeling (1998) showed two-year-olds a stain vaguely resembling a bear (Fig. 9.1). They told some subjects that the spot was created accidentally, by kicking over a bottle of paint, whereas another group learned that the shape was painted intentionally. Only the children in the latter group called it ‘a bear’. Thus the perception of the stain as accidental or representational depends critically on the prior information the children received on how it was brought about. In a similar experiment (Gelman & Bloom, 2000), adults saw a variety of artifacts, but were given two diverging accounts of how the objects came into being. In the unintentional version a strip of cloth was accidentally caught in a machine, resulting in holes being

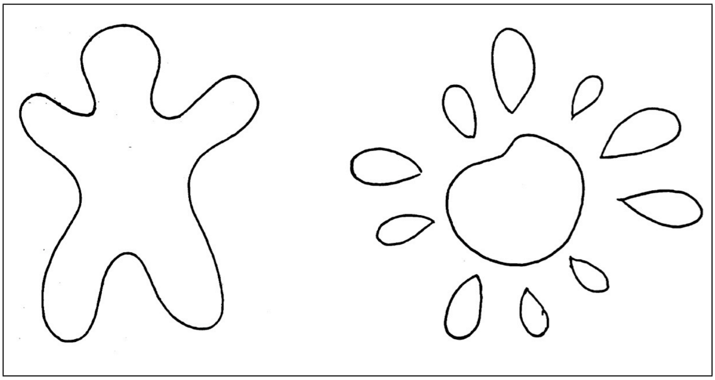

Figure 9.1: Are these pictures a bear (left) and a sun (right) or just some spots? Our intuitions are influenced by background information about the genesis of these images. Stimuli from Gelman and Ebeling (1998), Fig. 1, p. B37.

punched at regular intervals. In the intentional version, a person took scissors and carefully cut holes at regular intervals. Subjects were more prone to call the object a 'belt' if they believed it was intentionally created. Apparently, design is in the eye of the beholder: our judgment that something is an artifact depends on our foreknowledge that the artifact was intentionally created. Once we are familiar with specific classes of artifacts, we can reasonably infer that a particular member of a class was created with the intention of belonging to this class. When we see a chair in a pile of rubbish, we conclude that the object was created to fulfill a specific function (to sit on) and to be of a specific class (chairs). This stance also provides useful inferences when we have to identify classes of non-utilitarian objects, such as ships in bottles: although these boats will never sail, we still call them ships, because the designer intended them to belong to this class of objects. The intimate relationship between design and intention was noted by Dennett (1987, 16–17) and Bloom (1996) who argue that humans take an intuitive design stance: we use the designer's intention to infer the class the object belongs to. It was on this inference that Paley relied in his assertion that the watch was a product of intentional design (see also section 7.2.1).

Conversely, knowledge of the designer's intention can help us to infer an object's intended function or identity. Take as an example Bloom and Markson's (1998) experiments in which three- and four-year-olds were shown featureless ovals that were purportedly drawn by a child with a broken arm that because of this could not draw well. The young subjects were told that these were drawings of chickens (three vertical ovals) and a pig (one horizontal oval). When prompted, the preschoolers effortlessly identified the pig, because they reasonably inferred that the artist would draw objects from the same category in the same way. Young children intuitively regard the creator of an artifact as having privileged knowledge about both its name and its intended function. This was illustrated by an experiment (Jaswal, 2006) in which preschoolers saw objects that were given an anomalous label, e.g., the experimenter showed the child a key-shaped object and said 'you are not going to believe this, but this is actually a spoon'. Children were only willing to adopt the anomalous name if the experimenter referred to the object as something he had created, not as something he had merely found. Recognizing that the creator of an artifact has the prerogative to name it marks an important step in the development of the design stance.

The intended function and identity of an object thus inextricably link the creator with the created object. This aspect of the design stance is particularly interesting in the case of broken objects: although broken watches and fragile chairs cannot perform their intended function, we still name these objects watches and chairs because they were originally created to fulfill the intended function of their artifact class. When nine-year-olds and adults are presented with broken artifacts, they still label them according to their intended function, except if the transformation has changed the object beyond recognition (Gutheil, Bloom, Valderrama, & Freedman, 2004). Paley voiced this intuition aptly when he stated:

> neither [...] would it invalidate our conclusion, that the watch sometimes went wrong, or that it seldom went exactly right. The purpose of the machinery, the design, and the designer, might be evident, and in the case supposed would be evident, in whatever way we accounted for the irregularity of the movement, or whether we could account for it or not. [...] If by the loss, or disorder, or decay of the parts in question, the movement of the watch were found in fact to be stopped, or disturbed, or retarded, no doubt would remain in our minds

> as to the utility or intention of these parts (Paley, 1802 [2006], p. 8–9).

The human propensity of inferring design may be due to the distinct evolutionary history of our species (see also section 4.4.2). Humans rely to a unique extent on tools for their survival. Whereas other primates use mostly unmodified objects as tools, archeological evidence for stone-knapping in hominids goes back as far as 2.6 million years BP (Semaw et al., 1997). By adopting the design stance, hominid children might have learned to use and fashion tools more efficiently. Indeed, comparative studies of social learning in children and chimpanzees reveal stark contrasts in the way new tools are used: whereas children take the intention of the person who demonstrates these tools as guidance, chimpanzees rely more extensively on the physical properties of the tools to figure out how they work (Horner & Whiten, 2005). The design stance provides children with a useful heuristic to learn about their environment. It allows them to "ignore the actual (possibly messy) details of the physical constitution of an object, and [relying on] the assumption that it has a certain design, predict that it will behave as it is designed to behave under various circumstances" (Dennett, 1987, 16–17). Without the design stance, we would not possibly learn to use and name hundreds of tools and other artifacts, but would perhaps be limited to the less than ten tool types a typical community of wild chimpanzees entertains (Whiten et al., 1999). The hypothesis that the design stance is a product of natural selection, rather than the cultural product of Aristotelian teleology, finds support in the fact that it also occurs in nonwestern cultures, even those where material culture is relatively sparse, like the Shuar, an Andean Native American culture (German & Barrett, 2005), and that infants and young toddlers rely on it to learn the names of novel objects and how to use them (Casler & Kelemen, 2007).

9.2.2 Intuitive teleology

Whereas the design stance might have evolved in response to the regular use of artifacts throughout human evolution, with the function of rapidly categorizing and using artifacts, humans also possess a natural propensity for teleological reasoning. This propensity is most marked for biological entities, but it can apply to almost all categories of objects. Across cultures (e.g., H. C. Barrett, 2004), humans have the intuition that animals and plants possess adaptations that are self-beneficial, such as claws for defense or thorns for protection against being eaten. Young children, however, not only attribute purpose to artifacts and biological adaptations, but also to entire organisms (what are lions for? 'to go in the zoo') and nonliving natural kinds like clouds ('for raining')—a tendency termed promiscuous teleology (Kelemen, 2004). Moreover, when given a choice between teleological and non-teleological explanations, preschoolers and elementary school children prefer teleological accounts. For example, when asked whether rocks are pointy because of natural processes (e.g., 'bits of stuff piled up for a long period of time') or because of teleological functions (e.g., 'so that animals could scratch on them when they got itchy'), children typically endorse the latter (Kelemen, 2003).

At around ten to twelve years of age, the preference for teleological explanations lessens, probably because adolescents acquire elaborate coherent mechanistic explanations through schooling. Although mountains can be climbed, few adults would claim that mountains are there to climb on. This is because our learned knowledge that mountains are formed by tectonic activity or volcanism is incompatible with teleological explanations, where the function provides a sufficient reason for why the structure exists. Remarkably, patients with Alzheimer's disease show a re-emerging preference for teleological explanations. For example, they think that rain is there so that plants and animals could have water to drink and grow, rather than the acquired explanation that rain occurs by water condensing into clouds and forming droplets (Lombrozo, Kelemen, & Zaitchik, 2007). An increased tendency for teleology is also observed in people with little schooling such as Roma adults (Gypsies from central European descent). Formal education seems to reduce a preference for teleological explanations, but cannot eradicate it. Indeed, when educated adults are forced to make speeded judgments, they too, show a heightened acceptance of teleological explanations: when judging at a glance whether a statement is correct or not, they tend to endorse teleological, incorrect explanations, such as 'the Sun radiates heat because warmth nurtures life' (Kelemen & Rosset, 2009). Reasoning strategies observed in children persist into adulthood, but may be masked by secondary explanatory strategies. Once these become impaired (in the case of Alzheimer patients) or are unavailable (in the case of speeded judgments or lack of education), the intuitive, evolved strategies of childhood re-emerge. Although scientific education tends to lessen teleological reasoning, the tendency to apply teleology is not absent even among trained scientists. As will be expounded in section 11.5.1, analysis of the paleoanthropological literature reveals that early theorists relied on extra-scientific intuitive explanatory strategies—until the late 1970s, many paleoanthropologists thought that separate lineages of human races evolved toward an idealized endpoint (modern humans), a process denoted as orthogenesis, which is now uniformly rejected (De Cruz & De Smedt, 2007).

Today, teleology is no longer considered a valid scientific principle in biology. It is hard to refrain from thinking that the eyes' function is 'for seeing,' whereas it is more in tune with evolutionary theory to say that the eyes' function can be described in terms of the effects it had for reproduction and survival in past organisms in which this structure evolved. The philosopher of biology David Papineau (2005), for example, believes that teleology should be excised from biological discourse, because the function of a trait is not a result of its purpose, but a consequence of the fitness advantages it bestowed on ancestral organisms. Nevertheless, teleology is a useful heuristic to make sense of our everyday artifactual and biological environment—it enables us to see at a glance what a tool is for (e.g., a sharp edge for cutting) or to categorize animals as dangerous or not (e.g., presence of claws or fangs). As Kant (1790 [1987], part II, §66) had already argued in his *Critique of Judgment*, we use teleological explanations because the concept of purpose makes living things and artifacts more intelligible to us.

The central place of teleology in human cognition can perhaps explain why it remains an important philosophical and theological principle, despite its lack of scientific plausibility. Note that the fact that our psychological propensities are sometimes at odds with scientific knowledge does not necessarily affect the rationality of our judgments. Not only are they often indispensable in everyday reasoning (our understanding of artifacts would be seriously compromised without the design stance), concepts like 'design' or 'purpose' would be meaningless without them. Whether or not such concepts are also scientifically meaningful, is a property that is to be empirically discovered or philosophically elucidated. The biologist *cum* philosopher of biology Francisco Ayala (1970), for example, argues in favor of teleology as a result of blind design—even though natural selection is blind, biological traits have acquired purposes.

9.3 Are humans intuitive theists?

Does the tendency to infer design also entail an inference to a Designer, as Paley and others have suggested? At this point, developmental and experimental psychological data do not present a unified picture. Lombrozo et al. (2007) found that although Alzheimer patients reasoned more teleologically, they were not more likely than healthy control subjects to invoke God as an explanation. In a study that probed Dutch primary school children's intuitive theories on the origin of species (Samarapungavan & Wiers, 1997), the answers clustered together in different categories, including spontaneous generation, Lamarckism and pure essentialism (i.e., animals and plants have always existed in their present form). Although many children made teleological inferences, only about 10% made explicit reference to God or intelligent design. On the other hand, a comparable experiment by Evans (2001) in the United States, found that the majority of 10-year-olds endorsed creationist accounts of the origin of species, regardless of their religious background. Kelemen and DiYanni (2005) obtained comparable results with British elementary school children, although the percentage of creationist accounts was significantly lower than with American subjects.

Several possible explanations might account for these findings. A strong position holds that humans are intuitive theists. In this view, creationism is a natural mode of reasoning which is only altered when children acquire explicitly non-religious beliefs from their cultural environment. Bering (2006) defends this position, arguing that religious beliefs are biological adaptations that were directly selected to enhance cooperation, altruism and group cohesion. A weaker position (e.g., Bloom, 2007) holds that religious belief itself is not innate but a byproduct of other cognitive adaptations such as agency detection and theory of mind. In this view, children acquire culturally transmitted religious beliefs easily because these key in on evolved propensities of the human mind. Here the step from design to Designer is not automatically made, but needs to be made explicit, as Paley and others in fact did. Support for this latter view comes from experiments where Hindu (J. L. Barrett, 1998) and Christian (J. L. Barrett & Keil, 1996) college students had to recall stories about God. In doing so, they unconsciously distorted the stories to fit God into intuitive expectations they had about normal people, such as only attending to one person or one event at the same time. This indicates that representing an omniscient, omnipresent being is cognitively demanding and that expectations about normal agents structure reasoning about divine agents. Another view, suggested by Taede Smedes as he read the paper on which this chapter is based, holds that intuitive theism might be an evolved module, but that it depends on external cultural circumstances for its development, in the same way as the language faculty requires appropriate linguistic input to develop properly. In this, he echoed John Calvin's *sensus divinitatis*, an innate propensity to form a belief in God that needs to be triggered by environmental (cultural) factors (Helm, 1998, see also section 10.5). We think that the experimental evidence does not support the view that there is an intuitive theism. What is still required is an assignment of a probability to the existence of a Designer. The next section will look in more detail at the probabilistic aspects of the design argument.

9.4 Intuitive probability: Can chance events produce order and complexity?

9.4.1 The Annales and the Boeing

The theologian and philosopher Joseph Butler (1736) already observed that all human reasoning is probabilistic: Because we are finite beings with knowledge that is restricted in time and space, we cannot claim absolute knowledge. From imperfect observations we regularly draw far-reaching conclusions. Humans are naturally endowed with the ability to detect statistical frequencies in their environment. This ability is not restricted to humans; it occurs in a wide variety of animal species, including those with relatively simple nervous systems such as bumblebees (Real, 1991). Human infants use probability inference to learn about their environment, such as the statistical detection of recurring sound patterns to chunk streams of continuous speech into words which is crucial for word learning (Aslin, Saffran, & Newport, 1998). The design argument draws on our evolved ability to assess posterior probability, the probability that is assigned after the relevant evidence is taken into account. From the age of five onward, humans are fairly accurate in making such assessments (Girotto & Gonzalez, 2008). For example, if preschoolers are shown that more red than green chips are placed in a bag, they will correctly state that there is a higher chance that the experimenter will draw a red chip. However, if the experimenter says 'I can feel that the chip in my hand is round' and proportionally more round chips are green, children will update their probabilistic judgments in favor of green. How likely is it that the apparent design in nature was intentionally created or, alternatively, that it happened by chance? Early proponents of the design argument have taken their intuition that chance does not produce order as a starting point:

> He who believes this may as well believe that if a great quantity of the one-and-twenty letters [...] were thrown upon the ground, they would fall into such order as to legibly form the *Annales* of Ennius. I doubt whether fortune could make a single verse of them. How, therefore, can these people assert that the world was made by the fortuitous concourse of atoms? (my translation) (Cicero, 45 B.C.E., book 2, §93)

Cicero discarded the atomists' idea that chance collisions of elementary building blocks (atoms) formed the material world on the basis that chance has a low probability of producing order. Assuming that the 21 letters of the Roman alphabet are equally distributed into his "great quantity," the chance of the first letter falling in the correct place is 1/21, the chance that the first two letters are correct is thus $1/21 \times 1/21 = 1/441$ (if the space is also treated as a letter, it would be $1/22 \times 1/22 = 1/484$). The chance that the letters would produce the approximately 7,000 characters of the 600 lines that survive of Ennius' *Annales* (a now fragmentary epic poem on the history of Rome) is vanishingly small, being $1/21^{7000}$. Cicero's intuition has been reiterated many times, including astronomer Fred Hoyle's image of hurling around scrap metal at random and happening to assemble a Boeing 747 (Anon., 1981)[30]. Although all arrangements of the scrap metal are, with hindsight, equally improbable, very few of them will fly; similarly, although all combinations of 21 letters are equally unique, very few of them will produce a legible text, let alone the *Annales*.

William Dembski (1998) has developed this inference as the basis for his defense of Intelligent Design. Although it is intuitively compelling, rejecting chance as an explanation for complexity and design is problematic because, as Elliott Sober (2002) notes, there is no probabilistic equivalent of modus tollens. In other words, we cannot state that

> If hypothesis H were true, observation O would be highly improbable.
> But O.
> Therefore, H is not true.

The lottery paradox aptly illustrates this. Assume a fair lottery in which only 1 of 1000 tickets is the winner. The probability of winning this lottery is very low. Yet winning the lottery does not cast doubt on its fairness. The law of likelihood in statistics stipulates that it is not the absolute value of the probability of data under a single hypothesis that is to be considered but rather how the probability values compare under different hypotheses. The intuitive idea that improbability strengthens the existence of God is problematic in that it tacitly relies on an analogy between human and divine agency. When deciding whether human design or chance is responsible, we rely on empirical knowledge of what human agents in fact do. In an example from Kenneth Himma (2005), adapted from Dembski (1998), suppose a political candidate's name appears first on the lists of voting ballots 40 out of 41 times. The probability of such an event's occurring by chance is very small. But when we suspect that a county clerk rigged the list, we rely on two pieces of tacit knowledge: that undecided voters are more likely to choose the first on the list, and that the county clerk wants a particular candidate to win. Being an intelligent agent, it is not unlikely that he rigged the list. We also know of cases in which ballots were tampered with to win an election. Hence the hypothesis that the name was placed first 40 out of 41 times by design rather than mere chance becomes very plausible indeed.

In the case of divine action, however, we do not have empirical knowledge to draw upon, and thus no assumptions can be made about what God would or would not do. It is not possible to accord prior probabilities to the existence of God on the basis of empirical evidence. Without the necessary background data to make the design argument an IBE, this argument relies on an analogy between human and divine agency. Again, this version of the design argument becomes an argument from analogy. As we have seen, this was successfully attacked by Hume (1779), and it was precisely for this reason that Paley (1802 [2006]) recast the argument from design into an IBE.

9.4.2 Probability and inference to the best explanation

The reliability of IBE as an abductive strategy depends on the amount and quality of the data and the relevance of the data to the conclusion. If insufficient evidence is available, IBE may well lead us to choose "the best of a bad lot" (van Fraassen, 1989, 143). In fact, the bad-lot argument even applies if one has all the possible evidence, because one may simply have failed to conceive of the true theory with this evidence in hand. If each letter that falls correctly is selectively retained, we need at most $21 \times 7,000$ trials to complete what is now left of the *Annales*. Cicero, being unacquainted with the principle of cumulative selective retention, did not envision this possibility. Richard Dawkins (1986, 46–48) uses a similar analogy to illustrate this point: whereas one monkey could not possibly type a sentence from Hamlet, selective retention of keystrokes by many typing monkeys would solve the problem.

When using an IBE strategy, however, most modern versions of the design argument do not take natural selection and its principle of cumulative selective retention into account as a viable explanation. Dembski (1998), for example, holds that regularity, chance, and design exhaust the possibilities, thereby sidestepping the combination of chance and regularity that is natural selection. To be sure, in 1802 natural selection was not in the pool of possible explanations. However, as Sander Gliboff (2000) demonstrates, Paley did have a range of alternative materialist explanations, of which we mention three. First, necessity: because everything has to have some form, it may as well be the present form; for example, the eye is the actual realization of the possible ways to fill an eye socket. Second, he considered infinite trial and error: given an infinite time and universe, every possible configuration of matter could be produced, some of which turned out to be viable life-forms that persisted and reproduced—an interesting precursor to the concept of natural selection, and an idea first proposed by Lucretius (ca. 50 B.C.E [2007]) in *De rerum natura*. Third, he discussed the claim that parts of organisms could arise before their function was determined, a forerunner of exaptation theory (Paley, 1802 [2006], 38–41). These alternatives were being explored and hotly debated in Paley's time by early evolutionists such as (Georges-Louis Leclerc Comte de) Buffon, Denis Diderot, and (Paul-Henri Thiry Baron) d'Holbach. Paley seems familiar with these authors, as he mentioned Buffon explicitly and others implicitly. Next to these, he briefly discussed the special biological forces or 'organizing principles' proposed by the Göttingen school of German biologists, such as Johann Friedrich Blumenbach, Carl Friedrich Kielmeyer, and Johann Christian Reil (Paley, 1802 [2006], 218–225). Although now rejected, the latter's Newtonian approach to biology in which they stipulated forces acting on biological entities (analogous to physical forces acting on physical entities) was conceivable and widely accepted at the time (Larson, 1979). The idea proposed by atomists such as Lucretius that very improbable things may happen in an infinite universe has its modern statistical formulation in Diaconis and Mosteller (1989, 859), who write that "with a large enough sample, any outrageous thing is likely to happen."

What led Paley to reject these alternatives? His answer was that the purported natural propensities required intelligent design:

> I am unwilling to give to it the name of an atheistic scheme [. . .] because, so far as I am able to understand it, the original propensities and the numberless varieties of them [. . .] are, in the plan itself, attributed to the ordination and appointment of an intelligent and designing Creator (Paley, 1802 [2006], 224–225).

One could dismiss this as a circular argument in that he rejected naturalistic explanations because they point to a Designer, the proposition that had to be proven. We want to argue that it can likewise be seen as arising out of the high probability Paley accorded to the existence of God. As will be argued in the next section, the likelihood of data can be meaningfully assessed only in relationship with hypotheses, which are accorded a prior probability.

9.5 A rational basis for disagreement

If humans are prone to discern design and teleology in nature, why do some find the design argument more compelling than others? This may be due not to intrinsic differences in the way design and teleology are discerned but to differences in the prior probability people place on the existence of a Designer. An interesting way to approach this problem is through an examination of how humans regard coincidences. For Griffiths and Tenenbaum (2007), an event is a coincidence if it is judged to have a lower probability of occurring under our current theory of how the world works than under an alternative hypothesis. Coincidence plays an important epistemic role in scientific discovery: the meteorologist Alfred Wegener (1912) noted that the coastlines of West Africa and South America fit into each other like puzzle pieces, that their geological strata matched, and that the distribution of species on both sides of the Atlantic was highly correlated. He thought that this pattern was not a mere coincidence but that these continents were once joined and had drifted apart. The nineteenth-century physician John Snow (1855) noted that cholera outbreaks in London tended to cluster at public water pumps and inferred that this was not a coincidence but provided evidence for his theory that cholera was transmitted through polluted water (rather than bad air, the then favored theory).

These examples suggest an intimate connection between coincidence and evidence. A coincidence occurs when the likelihood ratio in favor of an alternative theory is insufficient to overwhelm the prior odds against it. A coincidence becomes evidence when the likelihood ratio in favor of an alternative theory overcomes the prior odds against it and leads us to accept that alternative theory. Because people differ in the prior probabilities they assign to alternative hypotheses, what is a coincidence to one person can be considered compelling evidence by another.

In the case of the design argument, the competing hypotheses are H_{mat} (purposive and complex structures arose strictly through natural, material causes) and H_{deo} (design as the result of a Designer). In the framework of H_{mat}, the occurrence of ordered complexity and apparent design presents a coincidence. Given that chance events tend to produce disorder, the probability of this occurrence is extremely low. Darwin's theory of natural selection has successfully solved this dilemma, because it relies on a combination of chance and lawlike processes. Indeed, no other naturalistic theory can explain why living things are improbably complex, why the interrelationships between their parts are highly functional, and why they exhibit features that enhance their probability of surviving and reproducing in their environment. Proponents of H_{mat} can find epistemic justification in Darwin's explanation of design. To justify why they favor their view rather than H_{deo}, they can cite examples of maladaptedness and appeal to ontological parsimony because their explanation is restricted to observable, causal physical processes. In H_{deo} the occurrence of design is not improbable, because this theory explicitly proposes a Designer who made the universe orderly and purposeful.

Under these epistemic circumstances, but not under H_{mat}, design in nature becomes corroborative evidence for the existence of a Creator. Next to this, natural theologians can also appeal to ontological parsimony, because it reduces many kinds of explanation to one under H_{deo} (Swinburne, 1968).

This model of prior probabilities explains three puzzling facts. First, it explains why evolutionary thinkers writing before 1859 did not accept natural theology's design argument. Even in Paley's time, not everyone was led to accept H_{deo}, although the arguments in favor of natural theology were widespread. Early evolutionists, including Erasmus Darwin and biologists of the Göttingen school, sought to describe biological forces that could assemble complexity in the same way as Isaac Newton had done for mechanics (see also section 12.6). These authors had a strong commitment to a physicalist worldview leading them to adopt the view that H_{deo} was unlikely, even though they did not have a compelling causal explanation for the apparent design. Second, it explains why the design argument, despite its intuitive appeal, fails to convince nonbelievers. As long as plausible naturalistic explanations for design in nature are available, the design argument will fail to overturn their prior beliefs. Third, it may elucidate why well-established scientific data do not persuade believers of design of the opposite. This is shown paradigmatically in the United States, where everyone has access to scientific education, yet creationism and Intelligent Design are widespread, and many express severe distrust of evolutionary theory (see J. D. Miller, Scott, & Okamoto, 2006).

The epistemic force of the prior probabilities we accord to competing hypotheses is an important element in scientific and other formalized ways of reasoning. It can explain why scientists are unwilling to let go of a cherished theory even in spite of overwhelming evidence against it, as already described by Thomas Kuhn (1962). For theists, design in nature provides compelling circumstantial evidence for the existence of a Creator. Take as an illustration the Thomistic tradition, which emphasizes the role of understanding and knowledge (*scientia*) in belief. In this view, a successful natural theology would start out from self-evident premises, proceed by valid arguments, and reach the conclusion that there is a person such as God (Plantinga, 1991). As we have seen, humans are prone to discern design and teleology in nature. Within the epistemic context of H_{deo}, the perceived design in nature that is a universal feature of human cognition can be taken as a self-evident premise from which the existence of a Creator can be argued. It is not a stand-alone argument that can convince those who do not believe in God (see also Himma, 2005), especially since plausible naturalistic explanations have become available.

9.6 Is there still a place for the design argument?

Undeniably, the power of the design argument as an inference to the best explanation has been seriously weakened since Charles Darwin and Alfred Wallace independently came up with natural selection as a naturalistic explanation for design. Given that the combination of random events and selective retention can explain most of the apparent design around us, can theologians still reasonably invoke design? Misrepresenting or altogether neglecting natural selection is the strategy most commonly adopted by Intelligent Design proponents (e.g., Dembski, 1998). Intelligent Design is not a very desirable position for theologians to take, however, because it makes scientific claims that need to be evaluated by scientific standards. As a scientific research program, it fails because its hypothesis of a Designer is too vague and too general to count as a scientific hypothesis; it cannot be used as a basis for empirical testing. Even concepts such as irreducible complexity (Behe, 1996) are too broad and too vacuous to be investigated by biologists; to date, there are no satisfying models of complexity that allow for investigation by empirical, quantitative methods. Moreover, using scientific standards to argue for divine action is a category mistake, because under the received theistic worldview, God is not an immanent cause like other natural causes (Smedes, 2008).

The most productive way for theologians and scientists to look at the argument from design is to treat it as a metaphysical rather than a scientific principle. Within this perspective, there are at least two cases in which a design position is still defensible. A first case is presented by a position that endorses evolutionary biology but argues that God intervenes occasionally to fashion structures that could not have arisen through natural selection. In this position, one endorses intelligent design as a philosophical position but not as a scientific research program that conceptualizes evolution and design as competing scientific explanations. Theologically, it follows a distinction that is commonly made between God's general actions (which pertain to the universe as a whole and can be seen in the laws that govern physical, chemical, and biological processes) and special actions (which lie beyond normal physical processes). Whereas natural selection and other evolutionary processes belong to the former category, occasional design or intervention in these belongs to the latter.

Johnson and Potter (2005) propose that human natural language may be the product of purposive creation. They base their argument on the fact that adaptationist explanations require a plausible reason for why the adaptation evolved. Adaptations evolve in response to specific selective pressures and enhance the survival and reproduction of their bearers. For language, there are as yet no persuasive adaptationist explanations (see also section 3.2). We do not know what language is an adaptation for or how and when it evolved. Despite the proliferation of adaptationist stories on the origin of language, such as social grooming, technological intelligence, cooperative hunting, and sexual selection, none of these hypotheses has been able to substantiate itself into a theory. This leads Johnson and Potter (2005) to infer to the best explanation that purposive design brought language into being. Their position is distinct from Intelligent Design in that they explicitly endorse evolutionary theory as the best explanation for complexity in the living world.

A second, perhaps stronger, case (because it does not rely on a God of the gaps) is found in scientists and theologians who regard design and evolution as complementary rather than mutually exclusive explanatory frameworks. Watchmakers do not build watches from scratch but rather rely on the gradually accumulated innovations in timekeeping technology, which we can trace back to sundials and waterclocks, to the introduction of the spring, to the modern digital watch. Upon close scrutiny, very few inventions appear *de novo*; most are the result of a gradual and cumulative retention of favorable variations (Basalla, 1988). For instance, the streamlined design of Polynesian canoes, which is close to optimum, can be traced through archeological and historical data as the gradual and unconscious retention of favorable variations, with the perilous ocean as the selecting agent (D. S. Rogers & Ehrlich, 2008).

These insights on the origin of artifacts can be extended to divine design. The nineteenth-century botanist Asa Gray defended the view that natural selection is an

> a-fortiori extension to the supposed case of a watch which sometimes produces better watches, and contrivances adapted

> to successive conditions, and so at length turns out a chronometer, a town clock, or a series of organisms of the same type (Gray, 1888, 57).

Cell biologist Kenneth Miller argues that God has initiated natural selection and other natural evolutionary processes as an indirect way to create complexity and design. For him, the undetermined nature of evolution through natural selection and other natural processes enabled the evolution of truly free, truly independent beings (K. R. Miller, 1999 [2007], 213, 238, 253). Theodosius Dobzhansky, one of the founding fathers of the modern synthesis, wrote, "The organic diversity becomes [...] reasonable and understandable if the Creator has created the living world not by caprice but by evolution propelled by natural selection [...] Evolution is God's, or Nature's, method of Creation" (Dobzhansky, 1973, 127). This position is stronger than Intelligent Design, because proponents of the latter—who see natural and supernatural causes as competing explanations for complexity in the living world—in many cases need to acknowledge that natural selection is the better explanation. This problem is avoided when one allows for the possibility that evolution and design are not mutually exclusive.

On the basis of modern evolutionary theory it is not possible to reject either H_{mat} or H_{deo}. Both positions depend on prior probabilities that are assigned on the basis not of scientific evidence but of metaphysical principles. It is interesting that both positions, physicalism and naturalistic theism, already existed in the earliest stages of evolutionary theory. Whereas Charles Darwin and Thomas Huxley did not provide room for God in their explanatory frameworks, Alfred Wallace and Asa Gray were theists who treated divine action as complementary with a scientific worldview, not as a competitor. Wallace, while continuing to endorse natural selection as the chief principle guiding the evolution of plants and animals, invoked intelligent design for the human mind: "The brain of pre-historic and of savage man seems to me to prove the existence of some power, distinct from that which has guided the development of the lower animals through their ever-varying forms of being" (Wallace, 1871, 343). Martin Fichman (2001) aptly argues that Wallace's theism, rather than an about-face, was an integral part of his evolutionary thinking. Today, both schools of thought continue to exist side by side, with Richard Dawkins and Daniel Dennett as examples of strict materialists and Kenneth Miller and Simon Conway Morris as proponents of theistic evolution.

To summarize, the argumentative structure of the design argument can be traced back to evolved biases of the human brain. It relies on the design stance, which leads us to treat complex and purposive structures as the product of design, and on intuitive teleology, the propensity of humans to discern purpose in nature. These cognitive biases are universal, although they can be masked by formal education or strengthened by religious upbringing. The step from design to Designer is perhaps more explicit, and relies on an inference to the best explanation. The plausibility of this inference relies on the prior probability one places on the existence of God. By making these differences in prior probability more explicit, theists (natural theologians, biologists, and philosophers) and physicalist scientists and philosophers have a rational basis for disagreement.

CHAPTER 10

THE COGNITIVE APPEAL OF THE COSMOLOGICAL ARGUMENT

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10.1 Introduction

The cosmological argument has enjoyed and still enjoys substantial popularity in various traditions of natural theology. This chapter investigates the cognitive basis of the cosmological argument. It proposes that its enduring appeal is due at least in part to its concurrence with human cognitive predispositions, in particular intuitions about causality and agency. These intuitions seem to be a stable part of human cognition. We will consider implications for the justification of the cosmological argument from externalist and internalist perspectives. The cosmological argument infers the existence of God from the existence of the universe. It has been developed in various traditions of natural theology (Christianity, Judaism, Islam) since the Middle Ages (Fig. 10.1). Early examples include the Kalām (Islamic theological) cosmological argument, formulated by amongst others Ibn Rushd (Averroes) and al-Ghazāli, the second and third of Thomas Aquinas' five ways, Duns Scotus' argument from contingency, and cosmological arguments based on the principle of sufficient reason by Gottfried Leibniz and Samuel Clarke. Despite an equally distinguished list of critics (such as David Hume, Immanuel Kant, Bertrand Russell, and C.D. Broad), it still enjoys a widespread popularity in contemporary philosophy of religion (e.g., Craig, 2003; Koons, 1997; Swinburne, 2004). Cosmological arguments can be usefully categorized in three classes (see e.g., Craig, 2003; Oppy, 2009). The first, exemplified by Thomas Aquinas' second and third way, relies on the observation that causes stand in relation to their effects as chains. As an infinite regress

Figure 10.1: God the creator of the world was a popular theme in Medieval imagery, as in this miniature from a French bible (1252–1270). From `http://www.wga.hu/art/zgothic/miniatur/1251-300/03f_1251.jpg`

of causes is deemed impossible, this leads to the inference of an uncaused cause, i.e., something that has itself as a sufficient cause. The second, exemplified by the Kalām cosmological argument, contends that all objects that have a temporal beginning must have a cause, and that since the universe has a temporal beginning, it must have a transcendent cause. The third, Leibnizian cosmological argument says that the totality of the world is a contingent being, which requires a sufficient explanation for its existence (Craig, 2003).

This chapter does not provide an analysis of the formal properties of the cosmological argument, but rather, focuses on the intuitions that lie at its basis. We propose that the enduring appeal of the cosmological argument is due at least in part to its concurrence with human cognitive predispositions, in particular intuitions about causality and agency. Intuitions about causality underlie the inference of an external cause of the universe (section 10.2), whereas predispositions towards agency make God a natural candidate for this cause (section 10.3). Even modern versions of the cosmological argument that are couched in sophisticated modal terms are based on and ultimately stand or fall with the soundness of these intuitions. The link between the cosmological argument and the structure of human reasoning was first proposed by Kant (1781 [2005]), who claimed that arguments from natural theology are unavoidable given the structure of human reason. To Kant, the intuitions that underlie the cosmological argument (such as our propensity to look for explanations or to seek necessary causes) are regulative ideas of human reason, which bring "systematic unity into our cognition" (Kant, 1781 [2005], A616/B644). The crucial difference between his and the present account is that Kant could only rely on introspection when considering causal intuition, whereas present-day philosophers can also draw on empirical data from cognitive science that, as we shall see, are very relevant for the debate. The case of cognitive origins of the cosmological argument is better informed than it was more than two centuries ago.

We also examine the implications of cognitive science for the cogency of cosmological arguments. Section 10.4 explores an externalist argument that is based on evolutionary considerations: our natural capacities for causal inference have evolved in response to selective problems related to everyday experience. However, this may cast doubt on their reliability in the domain of metaphysical inquiry. A second externalist line of reasoning (section 10.5) is based on Reformed epistemology: cognitive science shows that our beliefs about causality and agency are properly basic, and therefore at least *prima facie* justified. Section 10.6 examines an internalist approach where cosmological arguments fulfill an epistemic need. Answering the question of why there is a universe by positing an agent may afford an epistemic sense of satisfaction, provided that one already accords a high prior probability to the existence of God. In this way, the cosmological argument can contribute to a coherent worldview for theists.

Before proceeding, a caveat is in order. The central issues of this chapter are on the one hand a meta-causal question (what are the causes for our causal reasoning?) and on the other hand a question of justification (how do causal intuitions figure in the justification of the cosmological argument?) A familiar philosophical metaphor to distinguish between these two questions is the Sellarsian dichotomy between the space of reasons and the space of causation (e.g., Sellars, 1956). The cosmological argument as formulated by theologians and philosophers of religion is situated in the space of reasons and justification: it is motivated by propositions (reasons or candidate reasons) that present themselves to our judgment and that guide our inferences. These reasons cannot be reduced to the fact that cosmological arguments are appealing—after all, as Davidson (1963) observed, there are many things that may hold a certain appeal but that we would not subscribe to. What can be a compelling reason for accepting the cosmological argument is that it concurs with basic human intuitions about causality and agency. The cognitive origins of these intuitions can be located in a space of lawlike processes, such as regularities in cognitive development. When examining the cognitive origin of intuitions that underlie the cosmological argument, we are in effect proposing a causal factor that impinges upon the space of reasons—such a factor would not strictly speaking be a move within the space of reasons and therefore, according to Sellars (1956), would lack justification.

Nonetheless, from a methodologically naturalistic point of view, there is no unbridgeable gap between causes and reasons, but a fundamental continuity in the causal natural order: human minds and the thoughts they form do not stand outside this natural order (Blackburn, 2001). Consequently, naturalists have attempted to bridge the gap between causes and reasons. As we have seen in section 2.1.4, Susan Hurley (2003) has argued that animals can make flexible decisions within specific contexts (e.g., in their social interactions with conspecifics) that are driven by cognitive adaptations. According to Hurley (2003), we can say of these animals that they have reasons for their actions, even though these reasons are never made explicit (by the animals themselves), and even though these reasoning processes only work under quite specific, ecologically relevant conditions. John McDowell (1996) has developed the notion of *Bildung* (upbringing and education), the process in which we acquire habits of thought and action through experience, such as an ability to make ethical or normative judgments. To McDowell (1996), these habits would be sufficient to constitute an individual's competence in the space of reasons.

However, *Bildung* naturalism still requires an account of how these habits, which together constitute our rational capacity, are acquired. Such an account has not been outlined yet. Bill Pollard (2005, 76) has suggested that "developmental psychology could assist us in this endeavor." As we have seen in section 2.2.4, developmental psychologists (e.g., Spelke & Kinzler, 2007) have proposed that humans are equipped with a set of core principles that regulate their knowledge acquisition, amongst others in the domains of physics and agency. As we saw in section 2.3, humans are equipped with intuitive ontologies concerning psychological, biological, artifactual and physical events. They are phylogenetically old, emerge early in development, and remain stable throughout adult life; they are elaborated and enriched through experience and education, but not fundamentally revised (Carey & Spelke, 1996). As will be argued further on (sections 10.2 and 10.3), intuitions about causality and agency that are present in young children are still regulative in the formulation of the cosmological argument. In other words, the habits that underlie our reasoning about causation are partly based on early-developed intuitions that are enriched but not overturned through experience or education. If developmental psychologists are correct in proposing that core knowledge still "guides and shapes the mental lives of adults" (Spelke & Kinzler, 2007, 89), these intuitions can continue to play a role in shaping the reasoning that guides human inferences, including those in philosophical and theological reflection. Thus, our examination of origins of the intuitions that underlie the cosmological argument can be seen within a methodological naturalistic framework that seeks to relate causes and reasons.

10.2 Causal cognition and the cosmological argument

Most cosmological arguments proceed in two steps: first, they establish that the existence of the universe must have a cause, and second, they identify this cause with God. In this first step, historical versions of the cosmological argument (e.g., the Kalām and Thomistic versions) rely on the causal principle: every contingent state of affairs has a cause of its existence[31]. To illustrate this, here is a contemporary formulation of the Kalām cosmological argument (see Shihadeh, 2008, for an extensive treatment):

1. *Causal premise*: Whatever has a temporal origin (i.e., begins to exist), has a cause of its existence.
2. The world has a temporal origin (from the *hāḍith*[32]).
3. Therefore, the world must have an originator (from 1 and 2).
4. This originator must be eternal, otherwise it too must have an originator (from 1).
5. *Identification of God*: The originator is God.

Contemporary versions of the cosmological argument proceed in a similar way, although they attempt to replace intuitions with more rigorous logical argumentation. For example, Joshua Rasmussen (2010) provides an updated version of Duns Scotus' argument from contingency: necessarily, for all contingent concrete objects or their duplicates, it is possible that they have a causal origin, i.e.,

> $\Box$(Normally, $\forall S$ ((S is a contingent state of existence)$\Diamond$(S's obtaining, or the obtaining of a duplicate of S, is causally explained))).

Using this causal principle, Rasmussen (2010) derives the existence of a necessary being wielding S5 modal logic. To justify the causal principle, however, he draws upon his causal intuitions in everyday experience of objects:

> Consider, for example, your favorite armchair. Surely the armchair's existence can be the result of causal factors, such as a craftsman or factory machine piecing together materials. (Indeed, it certainly was.) [. . .] The principle seems to apply to very small objects, too: neutrinos, for example, can be produced from proton collisions in a particle accelerator. *It's natural to generalize*: necessarily, any contingent concrete object can have a cause (Rasmussen, 2010, 185, emphasis added).

Humans habitually generalize from their intuitions about causes in everyday objects to causes about any contingent concrete object. To proponents of the cosmological argument, the causal principle is a self-evident principle that hardly requires justification. The philosopher of religion

William Lane Craig (2003, 117), for example, argues that it "seems obviously true—at least more so than its negation." However, critics of the cosmological argument have called this into question. Kant (1781 [2005], A609/B637) contended that "the principle of causality has no significance at all and no mark of its use except in the world of sense; here [in the cosmological argument], however, it is supposed to serve precisely to get beyond the world of sense." Although we perceive the world in terms of causes, we cannot be sure that causes exist in the observer-independent world. At best, one can justify the causal principle by induction, for example, by arguing that it is constantly being confirmed in our experience, and that it holds a central place in modern scientific practice and in contemporary analytic philosophy (Koons, 1997). For Hume (1779, IX, 167), an explanation of the world in causal terms may be epistemically satisfying, but such an explanation is only "an arbitrary act of the mind." By this, Hume (1748, section 4, part 1) meant that the causal principle is not metaphysically necessary, but rather, that it results from a psychological disposition, where cause and effect are joined in the imagination of the observer through repeated experience. Although Hume's ideas on causal cognition are no longer followed in cognitive science[33], his assertion that causal reasoning has a psychological origin, and that such causal reasoning lies at the basis of the cosmological argument is still sound. As will be shown in more detail below, our causal intuitions in everyday domains closely match those employed by the cosmological argument.

From an early age onward, humans seek causal explanations in every sphere of their lives, such as why water expands upon freezing or why a relationship has failed. We have an intuitive feel for whether or not an explanation is satisfying. Satisfying explanations are often those that invoke generative causes (Ahn, Kalish, Medin, & Gelman, 1995). To put it in a different way: our intuitive understanding of causation is not only in terms of events that covary or that are contiguous, but is also in terms of causes that can be plausibly thought to generate their effects (T. R. Shultz, 1982b). People tend to infer causes spontaneously, without conscious deliberation and in the absence of instructions to do so (Hassin, Bargh, & Uleman, 2002). To explain states of affairs, we frequently invoke unobservable causes such as internal mental states, or invisible forces and properties like gravity or metal fatigue. This preference for unobservable, nonobvious causes is already present in young children. Preschoolers invoke unobservable mental states to explain the behavior of agents: they spontaneously attribute beliefs, desires and intentions to them, and realize that mental states can differ from the actual state of the world (Callaghan et al., 2005). Young children posit unobservable physical forces and properties to account for the motion of inanimate objects. They have, for instance, the intuition that unsupported objects fall downward due to gravity, and that one object can set another in motion when in direct contact (T. R. Shultz, 1982a). From about three years of age, children posit invisible biological properties to account for the growth and behavior of biological organisms. Such hidden properties are invoked to explain why apple seeds, planted in a flower pot, will still grow out to be apple trees, or why caterpillars turn into butterflies (Gelman & Wellman, 1991). In sum, humans typically posit unobservable causes in many domains of reasoning.

Pace Hume, adults as well as young children tend to interpret physical causation in terms of mechanistic causes rather than simple co-occurrences, even if both types of clue (mechanism and temporal covariation) are equally available to them (T. R. Shultz, 1982b). That is, they believe that causes actually generate or produce their effects. Indeed, adults find causal explanations that invoke a plausible mechanistic causal link more convincing than those that are only closely associated in space and time (Ahn et al., 1995).

The ability to figure out causes has also been demonstrated in nonhuman animals, such as apes that can use causal cues to find the location of hidden food (Bräuer et al., 2006). Next to this, human children of four years and older as well as adults are able to infer causes of events that they never experienced before, involving objects that they are totally unfamiliar with. In a classic series of experiments, the developmental psychologist Thomas Shultz (1982b) showed Malinese children from a horticultural society who were unfamiliar with western technology a variety of causal events involving flashlights and tuning forks. In these experiments, the participants were more likely to say that a tuning fork that was struck caused a box to resonate, rather than a tuning fork that was closer to the box but that was not struck. Similarly, western children and adults preferred a generative account of causality to explain why the propeller of a Crookes radiometer (an instrument for measuring electromagnetic radiation that none of the subjects had ever seen) began to spin when a flashlight was turned on. Cosmological arguments postulate a cause for the existence of the universe, a unique state of affairs that cannot be compared with other events. From a psychological point of view at least, such a view is not problematic or unintelligible, as humans spontaneously make causal inferences concerning events with which they had no prior experience. Such causal inferences are, to use a phrase by McDowell (1996, 84) "habits of thought and action" that constitute a "second nature." We have a rudimentary sense of causality that allows us to infer plausible causes of unique events.

As discussed earlier, humans routinely posit unobservables as underlying causes. One set of experiments that compared the behavior of human children and adult chimpanzees indicates that preschoolers, but not chimpanzees, attempt to seek a cause for their failure to perform a task (Povinelli & Dunphy-Lelii, 2001). In this study, the participants were taught to place an oblong L-shaped block in an upright position. When the block had been visibly tampered with, so as to make the task impossible, both preschoolers and chimpanzees examined it extensively. However, when the block showed no external signs of manipulation, only the children explored it from different angles to attempt to find a reason why the task could have failed. This apparent inability of nonhuman animals to attribute invisible causes has been demonstrated in other domains as well. Human children, from an early age onward, routinely represent false beliefs of other agents. Apes, by contrast, fail to attribute false beliefs (Call & Tomasello, 1999). The primatologists Jennifer Vonk and Daniel Povinelli (2006) propose that humans may be unique in their ability to conceptualize unobservables, such as God, ghosts, gravity, and other minds. The early emergence of this ability suggests that it may be a stable feature of human cognition. The attribution of an unobservable cause for the universe in the cosmological argument is made possible by a universal human cognitive disposition to readily infer unobservable causes.

Most proponents of the cosmological argument also argue for the necessity of a cause for the existence of the universe. This part of the cosmological argument may also be informed by cognitive predispositions. When we think about causes, we intuitively think about deterministic rather than stochastic causes. When preschoolers get the choice between an observable, stochastic cause, or an unobservable, deterministic cause that both explain a given event, they prefer the deterministic cause—they are, in the words of Schulz and Sommerville (2006), intuitive determinists. This bias toward deterministic causal factors persists until adulthood. For example, Metz (1998) compared the ability to infer stochastic causes of physical events in kindergartners, school-age children and adults. She found that the ability to recognize stochastic causes increased with age, probably an effect of education. Nevertheless, like the children, the majority of adult participants continued to infer deterministic causes for some stochastically caused events. It seems that the causal reasoning that lies at the basis of the cosmological argument is not an arbitrary act of the mind, but rather a way of reasoning that is both obvious and intuitive to humans: we readily infer generative causes for events, we routinely deal with unique states of affairs, we habitually infer unobservable causal mechanisms, and we have a preference for deterministic causes.

10.3 Intuitions about agency in the identification of God

The second step of most cosmological arguments consists of an identification of the necessary, external cause of the universe with God. This second step is important, because, as Hume (1779, IX, 164–165) already observed, one could simply argue that the material universe is metaphysically necessary. Moreover, even if we grant that the universe has an external cause, what reason do we have to identify that cause with the God of traditional theism, i.e., an infinitely powerful, all-knowing, eternal and perfectly good being? It seems reasonable to suppose that if there is an external cause to the universe, it must be a powerful entity. This does not mean that it is a person, let alone God. To justify the identification of God, Craig (2003) proposes an argument of the following form:

1. The cause of the universe is timeless and immaterial.
2. The only entities we know of which can be timeless and immaterial are minds and abstract objects.
3. Abstract objects cannot cause something to come into existence.
4. Therefore, the cause of the universe is a mind, i.e., a person.

As Rowe (2005, 114–115) rightly observes, this argument as it stands is invalid. In order to be valid, the conclusion should be:

> [4a] The only entity we know of which can be the cause of the universe is a mind.

Also in this revised form, the argument relies to an important extent on our finite, human intuitions about causality, where a person is regarded as the cause for any occurrence—in this case the universe. Craig's (2003) characterization of minds as timeless and immaterial entities is akin to folk psychology. Even young children conceive of minds as immaterial entities that survive physical death—they believe, for instance, that a young mouse eaten by an alligator will nonetheless keep on feeling sad and missing its mommy (Bering et al., 2005).

Richard Swinburne (2004) distinguishes two kinds of causes (physical and personal), which require two types of explanation, scientific and personal. To explain the existence of the universe as a whole, we cannot posit physical causes since there are no physical causes expect for the universe itself and its parts. Therefore, the universe is either a brute inexplicable fact, or it is explained in personal terms. Swinburne (2004, 142–145) argues in favor of the personal explanation: he invokes a person, God, who freely chooses to create and sustain the universe. Given that the physical universe is extremely complex, whereas God is simple (in the sense of undivided, not composed of parts, etc.), Swinburne (2004, 147) argues that the theistic explanation is more likely, as it is the more parsimonious: "The need for further explanation ends when we postulate one being who is the cause of the existence of all others, and the simplest conceivable such—I urge—is God."

The identification of God as the necessary cause of the universe can be traced back to human intuitions about agents as causes. Swinburne's distinction between physical and personal causes has parallels in the cognitive psychological literature: humans draw an intuitive distinction between events that are caused by purely physical processes and those caused by agents (Gelman & Gottfried, 1996). One of these distinctions that arise already in infancy is that agents, but not inanimate objects, are able to influence the behavior of objects from a distance (Spelke et al., 1995). Preverbal infants seem to appreciate that only agents can create order: they exhibit surprise (as measured by a longer looking time) when a rolling ball apparently causes a disorderly heap of blocks to become nicely stacked, but not when an unseen agent (hidden behind a screen) performs the same thing (Newman, Keil, Kuhlmeier, & Wynn, 2010). This intuitive distinction between objects and agents as two types of causes is a core principle of human reasoning that persists into adulthood. Neuroimaging studies of adult volunteers indicate that the perceptions of mechanical and agent-based motions are subserved by distinct and largely non-overlapping brain areas (Martin & Weisberg, 2003). In particular, only motions performed by intentional agents activate areas reliably involved in the attribution of mental states to others. The universe exhibits a high degree of order. Our attribution of its origin to an intentional agent is furthered by these stable intuitions about agents as causes.

Purposiveness is a decisive cue to favor agency. When adults watch simple geometric objects moving about on a screen, they interpret those motions as agent-like and explain them by reference to internal mental states if the objects appear to move in a goal-directed manner (Scholl & Tremoulet, 2000). Experimental studies suggest that the ability to identify an agent as the cause of an event arises early in development. Twelve-month-olds witnessed a beanbag landing on a stage; subsequently an object appeared on stage that could be interpreted as the cause of this event (Saxe, Tenenbaum, & Carey, 2005). The infants looked least long when a human hand appeared, and significantly longer when a toy train or toy animal was shown, indicating that they expected the hand, but not the toys, to be the cause of the event. This implies that infants assume an agent to be the cause of a contingent event. This preference for agents was also shown in other studies. Gelman and Gottfried (1996) showed preschoolers different kinds of objects (animals, wind-up toys, other artifacts) that, under some conditions, moved without any apparent external cause. In the case of the animals, the children mostly referred to internal, biological features. However, for the artifacts, they were much more likely to attribute the motion to a person. They expressed their surprise when they saw artifacts moving by themselves, and frequently appealed to invisible agents, e.g., "I think another invisible person did that again" (Gelman & Gottfried, 1996, 1980). Children appeal to agents as causes when they have to explain the origin of artifacts, and even plants, animals and natural kinds. This led Kelemen (2004) to call young children intuitive theists, because they discern design and purpose in nature, regardless of whether or not they were brought up in a religious environment (see also section 9.3).

Explanations that postulate agents as causes of contingent events are intuitively appealing and epistemically satisfying. Humans have the intuition that beliefs, desires and intentions directly cause actions. They regard them as generative causes that bring about actions (e.g., one forms the desire to lift a hand, and the hand is lifted) although the actual cognitive processes that underlie human actions are far more complicated. As social psychologist Daniel Wegner (2003) observes, personal accounts do not require further causal explanations. By contrast, an infinite regress of causes does not provide epistemic satisfaction—infinite regress may be rejected out of hand in many versions of the cosmological argument because it is unintelligible from the perspective of stable causal intuitions about persons.

Although the step to an agent is intuitive, the step to a single omniscient and omnipotent creator seems somewhat far-fetched from a cognitive psychological point of view. Why might proponents of the cosmological argument favor God? Are they mainly motivated by background beliefs that are specific to their culture, i.e., because theologians and philosophers of religion who have developed cosmological arguments stem from monotheistic religions? More cognitively interesting is the following explanation: agents that are all-knowing and very powerful are intuitively more appealing than normal agents. A large empirical literature on false belief reasoning (e.g., Callaghan et al., 2005) indicates that an explicit understanding of mental states as distinct from the state of the world emerges somewhere between four and five years of age. From this age onward, humans realize that an agent's internal mental states may differ considerably from the actual state of the world or from one's own mental states. By contrast, in the case of an omniscient agent, mental states always correspond to the state of the world. If such an agent believes that p, then p is simply the case. Consequently, such mental states are easier to represent than mental states of normal agents, because the latter require that one keep both the state of the world and their mental states in mind. In line with this, cross-cultural psychological studies (e.g. J. L. Barrett, Richert, & Driesenga, 2001; Knight et al., 2004) indicate that an understanding of God's mental states arises earlier in development than that of other agents, typically around the age of three. Toddlers start out attributing omniscience to all agents (e.g., their parents), but later in cognitive development they restrict this to God. Children come to realize from their experience that their parents do not know everything, but as they constantly receive testimony that God is omniscient, they have no reason to scale down that expectation. From a cognitive point of view, the inference to an omniscient creator of the universe is not an unlikely step.

How do early-developed intuitions about causality and agency precisely figure as reasons for holding the cosmological argument? There are two ways in which reasons for developing or endorsing the cosmological argument can be articulated. The first, which an agent can do retrospectively, corresponds most to the commonsense notion of reason. It consists of a reconstruction of an agent's subconscious states when she was formulating the argument. Such states could include, for example, habitual modes of making inferences that cohere with the agent's worldview. A second conception is quite different. Not only the agent, but also others, such as friends, family or other people who know the agent well, can try to make those reasons explicit. Such persons have what Pollard (2005, 80) terms "second person authority" about our reasons. Experts on the human mind (such as developmental psychologists and cognitive neuroscientists), if they are worth their salt, also have second person authority about our reasons: they can formulate informed ideas about how the mind draws certain conclusions and what cognitive stable intuitions may underlie these.

As outlined earlier (section 2.2.4), many developmental psychologists (e.g., Carey & Spelke, 1996) subscribe to the view that early-developing principles of human reasoning do not get fundamentally revised over time. Rather, they get enriched and sophisticated through experience and education. Obviously, the causal inferences that scholars trained in philosophy and theology formulate are far beyond the rudimentary causal understanding of young children. Yet, if developmental psychologists who articulated the notion of core knowledge turn out to be correct, there are good reasons to assume that philosophers and theologians are still guided by these early developed, cognitively stable intuitions about causality and agency. These intuitions can be explicitly articulated, addressed and challenged in philosophical and theological discourse as, for example, in the discussion between Grünbaum (2000) and Craig (2001) on intuitions that underlie the cosmological argument. The fact that philosophers can do this is compatible with our claim that these intuitions have their origin in normal cognitive processes. As the philosopher Timothy Williamson (2007, 3) remarks: "Neither their content [of intuitions in philosophy] nor the cognitive basis on which they are made need be distinctively philosophical." Instead, one should not be surprised that reasoning skills that are used in philosophy and theology are what Williamson terms

> cases of general cognitive capacities used in ordinary life, perhaps trained, developed, and systematically applied in various special ways, just as the cognitive capacities that we use in mathematics and natural science are rooted in more primitive cognitive capacities to perceive, imagine, correlate, reason, discuss (Williamson, 2007, 136).

In the case of causal cognition, we have indicated continuities between commonsense causal reasoning and causal inferences that underlie the cosmological argument, such as the inference of causes to unique events, the preference for a necessary cause, and the favored postulation of an agent as cause.

10.4 Evolutionary debunking arguments

Given that intuitions about causality and agency play an important role in the formulation and acceptance of the cosmological argument, what are the implications for its cogency? In what follows, we consider implications for the justification of the cosmological argument from externalist and internalist perspectives. According to one externalist view, cognitive accounts of religion cast doubt on religious beliefs (e.g., Dennett, 2006). This can be placed within the broader context of evolutionary debunking arguments (a term coined by Kahane, in press): since evolution is not a truth tracking, but a fitness-enhancing process, beliefs that have an origin in the evolved structure of our minds are unreliable. This casts doubt on their epistemic justification. Evolution can lead our cognitive faculties to produce false beliefs or suboptimal decisions. In some cases, cognitive processes might deviate from the truth due to a fitness trade-off between accuracy and efficiency: given that animals have limited time and resources, they will sometimes be better off with fast heuristics than with faculties that are slow and always truth-preserving, for example, there is little point in deliberating the most optimal escape route when faced with a hungry predator. In this view, the propensity to attribute causes may be a useful heuristic rather than an accurate reflection of the structure of the world. Sometimes natural selection will promote cognitive faculties that err on the side of safety, especially when one has little information, and when the costs of false positives and false negatives are asymmetric. This asymmetry can lead to the evolution of cognitive predispositions that are triggered easily and give rise to many false positives (S. E. Guthrie, 1993; Stephens, 2001). Arguably this is the case for causality and agency detection. Suppose one hears a noise in the night: assuming that the sound is uncaused when in fact it is caused by an intruder, a false negative is potentially a lot more costly (being murdered in one's bed) than the cost of a false positive, where one investigates in vain and goes back to sleep.

Other authors (e.g., Stewart-Williams, 2005) maintain that our cognitive faculties work reliably under normal circumstances, but not in situations that are remote from the conditions in which they evolved. Accordingly, the evolutionary origin of causal intuitions provides *prima facie* evidence against the soundness of the cosmological argument, as it applies causal intuitions to a domain that is not ecologically relevant, namely the universe as a whole rather than states of affairs in our everyday life. Steve Stewart-Williams (2005, 801) presents the following evolutionary debunking argument:

> We should be extremely cautious about accepting that there must be a causal answer to the question of why there is something rather than nothing. One popular answer to this question is to posit God as First Cause. However, we cannot rely on the intuition that there must be an ultimate cause for the universe as a whole. [...] [This] weakens the First Cause argument for the existence of God.

A problem with this line of reasoning is that we simply do not know whether the attribution of a cause for the existence of the universe is off-track. Our causal intuitions are often correct (e.g., the sound at night was caused by the cat), and there is no *a priori* reason to assume that they are off the mark when we apply them to the universe as a whole. Arguing that causal cognition does not work in the case of theism begs the question, i.e., it already assumes that there is no God. Should we doubt either the causal principle itself or its applications outside of the domain of commonsense reasoning, we would be faced with the unwelcome consequence that causal cognition is unreliable in the domain of science. After all, science has only developed in the last few hundred years, and therefore does not constitute an ecologically relevant domain for our cognitive faculties. Moreover, holding erroneous scientific beliefs (such as that the Earth is some 6,000 years old) does not seem to have a negative impact on human fitness (fundamentalist families tend to be large). Yet causality is an important metatheoretical assumption of science that cannot be proven. It therefore seems that rejecting the causal principle outside of the domain of commonsense reasoning comes at a high price. The soundness of our intuitions in the cosmological argument remains an open question.

10.5 Properly basic causal intuitions?

A second externalist line of reasoning could go like this: perhaps our causal intuitions are warranted, because they are properly basic. They are basic because one does not need to ground them in arguments or in evidence from other propositions, and they are properly so in virtue of their truth (or probable truth) being obvious and transparent to the subject. Examples of basic beliefs include belief in an external world and in the existence of other minds. According to Reformed epistemologists like Alvin Plantinga (2000) some religious beliefs are properly basic; they derive their warrant from the view that God designed the human mind in such a way that it spontaneously forms these beliefs under a wide variety of circumstances. According to this model, the human mind has a *sensus divinitatis*, an innate cognitive disposition that produces belief in God under a diverse range of conditions.

The cognitive science of religion has remarkably converged on this basicality of religious beliefs, by indicating that they arise naturally and spontaneously without deliberation or instruction (K. J. Clark & Barrett, 2010). In the case of causal intuitions, humans are cognitively predisposed to think that every contingent object or event must have a cause, so the assumption that God is the cause of the universe seems plausible. God is perceived as a good explanation for the universe, because human intuitive notions of causality favor personal over impersonal causes. In this view, our causal intuitions do not figure as premises in an argument, but rather, they are spontaneously elicited when we consider the universe and its origin. Although strictly speaking in this case, there is a brief inference, the inference would be very quick, obvious and elementary—Reformed epistemologists (e.g., Plantinga, 2000, 170) include such beliefs in the category of basic beliefs. It may seem surprising to include causal theistic intuitions in the category of basic beliefs. After all, traditionally, Reformed epistemologists have drawn a sharp distinction between belief in God as properly basic and belief in God as a consequence of argumentation, i.e., natural theology. Some (e.g., Plantinga, 1983, 63–73) have argued that the idea of properly basic theistic belief motivates opposition to natural theology. However, such a sharp dichotomy may be overstated. Michael Sudduth's (2009) historical examination indicates that natural theology was widely endorsed within the Reformed tradition up until the latter 19th century. In some cases, basic belief and natural theology are more part of a continuum than direct opposites. For example, considerations about the complexity or fine-tuning of the universe might start out as an unreflective sense of wonderment, but it can form the starting point of explicit arguments from design. Similarly, a sense of fascination about the world's existence can form the beginning of a more formalized cosmological argument.

The warrant of our causal intuitions depends on the externalist position one adopts, namely a Reformed epistemological account of causal intuitions or an evolutionary explanation. In both cases, a belief is only warranted if it is produced by cognitive processes that successfully aim at the truth. As Plantinga (2000, 187) argues, a false belief can have warrant, provided that the cognitive processes that produce it are typically truth-preserving. This can happen, for example, when the cognitive faculty that produces the belief is working at the limit of its capacity. Applying this to an evolutionary point of view, this would mean that in the case of cosmology human causal intuitions would be working at the limit of their capacity, since natural selection has honed these intuitions in such a way that we can successfully interact with our everyday environment. Now suppose that theism is false, then a theist who forms the spontaneous belief that the universe requires a causal origin, and that this origin is God, would be warranted, even though in this case he would be wrong. By contrast, according to the Reformed epistemological model, if theistic belief is false, then there is no *sensus divinitatis* and therefore, the externalist justification of theistic belief (by virtue of a creator who has instilled belief in God) disappears. A surprising consequence of Plantinga's position is that an evolutionary perspective allows for belief in God that is both false and warranted, whereas Reformed epistemology does not. If one does not take theism as a given, the basicality of causal intuitions does not help one decide whether the cosmological argument is true, or whether these intuitions are perhaps false but warranted.

10.6 Epistemic satisfaction

The cognitive science literature on causal cognition can also be incorporated in an internalist position where cosmological arguments fulfill an epistemic need. Religious arguments rarely persuade: people seldom accept or reject religious beliefs on the basis of arguments. This is true for both theist and nontheist religious arguments, for example, the claim that natural evil (such as earthquakes or diseases) is incompatible with a benevolent and omnipotent God, typically does not convince theists to abandon their belief in such a being. Jennifer Faust (2008) argues that religious arguments do not persuade because they beg the doxastic question: the probability one assigns to at least one of the premises depends on whether or not one accepts the argument's conclusion. Such arguments are not strictly speaking circular, since they do not state their conclusion in the premises, but the fact that they require belief in the conclusion to be persuasive makes them question-begging in a doxastic sense.

Take the key premises of the Kalām cosmological argument (whatever begins to exist has a cause of its existence; the world began to exist). It is no coincidence that theists find them more likely than nontheists. Proponents (e.g., Craig, 2001) often appeal to the Big Bang theory as scientific support for these premises. However, the Big Bang theory describes only the expansion and cooling of the universe, but says nothing of its origin. Within the standard interpretation of this theory, the universe inflated from a tiny speck to the size it is today, and will continue to do so. Given that matter cannot be infinitely packed, we cannot trace the universe back to an infinitely packed state (Faber, 2001). This seems to warrant the following inference: the universe is only finitely old, and started out as a singularity (a very densely packed state). According to this picture, it does not make sense to talk about time and space prior to 14–15 billion years ago, since time and space began when the universe began to inflate. This corresponds to the second premise of the Kalām cosmological argument.

Nevertheless, other interpretations could be given. For example, one could argue that in the case of a singularity, every moment of the Big Bang model ($t > 0$) is preceded by earlier moments, so that there is no moment at which the universe began to exist ($t = 0$) (Pitts, 2008). Such interpretations of the Big Bang theory assume a B-theory of time, according to which events are ordered by tenseless relations, and all events are on an ontological par. In this B-theoretical interpretation, it is possible to say that the universe, while it is finitely old, never came into existence. Unsurprisingly, proponents of the cosmological argument (e.g., Craig, 1998) favor an A-theory of time, where the only temporal items that exist are those that exist presently . This indicates that scientific evidence itself is not decisive for the cosmological argument, but rather the way in which it is interpreted, and these interpretations depend on the prior probability one accords to the existence of God. Nontheistic critics do not accept cosmological arguments because they accord an initially low probability to theism. As John Mackie (1982, 100) wrote: "the hypothesis of divine creation is very unlikely." Materialists may find the existence of the universe as a necessary fact appealing, since their worldview favors the metaphysical primacy of the material world. To them, indeed, there is no reason why the universe, as Hume (1779, IX, 164–165), put it, could not be the necessary self-existent being. Theists, on the other hand, accord a high prior probability to the existence of God, and find God an epistemically satisfying explanation. To quote Swinburne (2004, 147):

> [T]he choice is between the universe as stopping point and God as stopping point. In the latter case, God's existence and intention over all the universe's history will provide not merely a full explanation but a complete and ultimate explanation of the existence of the universe.

If the cosmological argument does not persuade nontheists, what does it accomplish? By presenting a justification for beliefs that one already holds on the basis of faith or perhaps weak evidence, religious arguments are primarily aimed at those who already believe (Faust, 2008). Cosmological arguments may fulfill distinct cognitive needs by providing a sense of epistemic satisfaction. Starting from premises that humans find intuitively appealing, such as the causal principle and ideas about agency, such arguments can show that theism is a satisfying explanation for questions like 'why is there something, rather than nothing?' The sense of epistemic satisfaction that arguments from natural theology can provide is perhaps more important than their value as proofs. In other words, while such arguments do not afford a formal proof for the existence of God, they are nevertheless rationally compelling to creatures like us, given our natural cognitive faculties. Kant (1781 [2005]) made a similar claim about natural theology and its link with the structure of the human mind: these intuitions may be misleading because they are subject to the limitations of the human cognitive apparatus, but they are also unavoidable and irresistibly convincing (A624/B652) given the structure of human reasoning (see Byrne, 2007, chapters 2 and 3, for a critical analysis). As discussed earlier (chapter 9), the persuasive force of the argument from design might likewise be a consequence of its concurrence with human cognitive predispositions, in particular a pervasive tendency to see purpose and design in nature which emerges universally in young children and remains stable throughout adult life. However, while Kant assumed that such causal and teleological intuitions are inherently misleading, this remains an open question, as we have pointed out in section 10.4. From an internalist perspective, it is therefore possible to treat the intuitions that underlie the cosmological argument as starting points in explanatory strategies that make theism a more coherent position. The ability to move within the space of reasons, to formulate cogent arguments (including religious arguments) critically depends on such core intuitions that are a stable part of human cognition. These intuitions (in particular, those about causality and agency) make it possible to develop and evaluate cosmological arguments. If humans were unable to posit unobservable causes (as our closest nonhuman relatives seem to be), cosmological arguments would simply be unintelligible.

Experimental evidence from cognitive psychology (Koslowski, Marasia, Chelenza, & Dublin, 2008) reveals an intricate interplay between explanation and evidence: subjects treat information as evidence if they can incorporate it in a causal framework. They are more likely to treat background information as relevant to an explanation for an event when the explanation can incorporate both the event and the background information into a single causal account, which makes the overarching explanation increasingly convincing. Merely saying that God created the universe is not as epistemically satisfying as providing a coherent, explanatory account of why we should believe that He did. The cosmological argument can make theism more plausible by its ability to incorporate background information (e.g., the Big Bang theory) and universal human intuitions about causality and agency into a convincing overarching explanatory account (God as the best explanation for the beginning of the universe). By its ability to unify scientific knowledge, intuitions about causality and agency, and theism, the cosmological argument contributes to a more coherent worldview in theists, for whom the existence of the universe is a fact in need of explanation. As Craig (2001, 379) put it: “Even if the uncaused origin of the universe were natural relative to the Standard Big Bang model, that would not imply that the origin of the universe does not cry out for explanation.”

PART IV

SCIENTIFIC STUDY

The cognitive science of science

Like artistic abilities and religious reflection, science is considered as one of the hallmarks of human-specific cognition and behavior. The world would look radically different without science and its products, such as technology, medicine and the institutions we all work in. Indeed, it is because of our worldwide reliance on science that *Homo sapiens* could have this enormous impact on the planet's climate, ecology, and resources. If we are to obtain a better understanding of human nature, studying the cognitive processes involved in scientific reasoning and practice seems crucial. Since the second half of the 20th century, some philosophers of science like W.V.O. Quine (1969a) have taken a naturalistic turn. Rather than regarding philosophy as an *a priori* discipline, they have begun to accept that human modes of knowledge acquisition and reasoning are natural—i.e., they unfold in accordance with natural laws, and are fully part of the natural order. In this philosophical naturalistic framework, it also became self-evident to see science as a natural phenomenon. As a consequence, philosophers of science have started to look at cognitive science in their quest for an understanding of scientific activity (see for example, the essays contained in Carruthers, Stich, & Siegal, 2002). Indeed, as Kertész (2004, 29) observes, the naturalized philosophy of science and cognitive science share a common background assumption: by using the methods of empirical disciplines, both strive to investigate the way in which we gain knowledge of the world.

However, the cognitive science of science remains relatively underexplored terrain. This is in sharp contrast with, for example, artistic behavior, which, as we have seen in section 5.1, has been a subject of inquiry since the formation of psychology as a scientific discipline in the 19th century. Scientific practice is a relatively recent subject of inquiry in cognitive science. Like the cognitive science of religion, the cognitive science of science has only really started in the 1980s and 1990s, with authors like the philosopher and cognitive scientist Marc De Mey (1992), who applied theories of perception and computer science to philosophy and sociology of science. The complexity of scientific reasoning, and the many processes that seem to be involved in it may be the main reasons why it has not been as actively researched as some other domains of cognition. The cognitive science of science not only investigates the mental processes that come into play when people reason about the content of science, but also specific ways of reasoning that are used in science (e.g., induction, causal reasoning, inference to the best explanation), the creative processes involved in scientific discovery (e.g., the use of metaphors or analogies), the interactions between scientists (e.g., joint lab work, influence from one scientist on another researcher's work), and the nature of scientific understanding. Given the wide range of cognitive processes that are involved in scientific practice, the cognitive science of science is only different from general cognitive science in that it investigates reasoning that has scientific content (K. Dunbar & Fugelsang, 2005).

However, this potential wide scope may also turn out to be one of the strengths of the cognitive science of science. Most of cognitive science is done using an *in vitro* approach: cognitive scientists typically investigate a well-defined phenomenon (e.g., concept formation, memory retrieval) and use especially-designed tasks that are quite remote from everyday cognition (e.g., presenting participants with averaged faces to probe judgments of facial attractiveness). By contrast, cognitive scientists who investigate scientific practice have often adopted an *in vivo* approach (e.g., K. Dunbar & Blanchette, 2001). They have shifted from fairly high-level, idealized approaches to scientific discovery and creativity, to practice within specific settings, attempting to answer questions like 'what enables scientists to make significant contributions to their field?', or 'what explains individual differences between scientists?' To give but one example, the psychologist Dean Keith Simonton (1999b) has shown a clear correlation between the quantity of scientific output by individual scientists and their long-term impact on their respective fields. The most powerful single predictor of reputation (eminence) is a person's sum total of contributions. It is thus primarily the quantity, rather than the quality of individual contributions that influences the reputation of the researcher (or the artist for that matter). In this, Simonton, drawing on Campbell (1960), sees creativity as a blind non-directed process of variation, selection and retention: ideas are similar to organisms, in that there is a strong correlation between number of offspring and lifetime fitness. Animals that have much offspring have a potentially higher long-term fitness compared to those that have very few offspring—the same goes for scientific (or artistic) output: "those who are the most prolific will have the most successful works, but they will also have the most unsuccessful works" (Simonton, 1999a, 316).

Scientists rely to an important extent on cognitive scaffolding. Ronald Giere (2004) and Steven Mithen (2002) have argued that scientists draw extensively on material culture, which records, stores and helps transmit information. Next to this, material culture also extends perceptual capacities, as in the use of a telescope or a microscope, and computational abilities, as in the use of calculators and computers, or even simply pen and paper to work out a difficult equation or a complicated experimental setup (e.g., by drawing diagrams). As we have seen in chapter 8, by the Upper Paleolithic, material culture had begun to extend human cognitive abilities. The earliest art and artificial memory systems such as calendars thus provide the earliest unambiguous evidence that material culture was used as a means for recording, storing and transmitting information. Language also plays an important role in extending human cognitive capacities (Jackendoff, 1996). For example, the use of analogies and metaphors is crucial for successful scientific discovery and creativity. Scientists use both near analogies, where target and source come from the same or a closely related domain, and distant analogies, where target and source come from widely diverging domains. The psychologist Kevin Dunbar (1997) studies creative scientific thought in action in molecular biological labs. He found that near analogies form the most important source of creative insight, such as an analogy from a well-understood virus to a lesser-understood virus in order to predict how the latter would behave in specific circumstances. In this particular scientific setting, distant analogies were less common and served explanatory rather than epistemic purposes. Dunbar (1997, 488) therefore concludes that "creative ideas and novel concepts arise through a series of small changes produced by a variety of cognitive mechanisms [...] Conceptual change, like evolutionary change, is the result of tinkering." However, in a recent paper (De Cruz & De Smedt, 2010c) my co-author and I have argued that this is only the case when scientists study well-understood phenomena. In periods of intense conceptual change or in the invention of radically new technological devices, when scientists cannot rely on established examples to draw near analogies from, distant analogies can play a role in scientific discovery. For example, the use of mechanical analogies in early modern physiology was an effective way to understand the functions of bodily organs. Until well into the 18th century, most of medicine concentrated on the fluids within the body and their equilibrium, the so-called humors, such as blood, gall and slime (Greenblatt, 1995). Organs and their workings were poorly understood. The Renaissance revival of ancient texts on mechanics, such as Vitruvius' *De architectura* (ca. 25 B.C.E.), which contained accounts of hydraulics and water pumping engines, next to Archimedes' seminal works on mechanics, made that knowledge of hydraulics expanded rapidly during the early modern period, enabling, for instance, the draining of the Low Countries. This permitted physiologists of that time to draw from this well-understood domain to unravel blood circulation, an at that time poorly understood phenomenon. For example, the Paduan anatomist Benedetti published a paper in 1502 on the action of the heart valves, which he likened to unidirectional sluice gates in a canal: "three valves are purposefully placed by nature like movable gates which by turns when the heart is contracted in emitting blood do not completely shut off its passage, for these valves close inward" (cited in Novell, 1990, 397). Another Paduan anatomist, Aquapendente, compared the action of the venous valves to a dam or a mill sluice. One of his pupils, William Harvey, used a variety of analogies to reason about circulation. Although his idea that the heart was like a pair of water bellows (not a pump, as is popularly assumed) was not novel, his colorful use of analogies, often from the domains of mechanics or physics, enabled him to make a more precise formulation of how human blood circulated. Next to this, in his lectures to the College of Physicians, he likened the mechanism of an erection to the inflation of a glove, and the working of lungs and thorax to a bladder within a pair of bellows (De Cruz & De Smedt, 2010c, 36–37).

Continuity or discontinuity?

An important question in the cognitive science of science concerns the continuity or discontinuity between science and other forms of reasoning. As we saw in parts II and III, art and religion both date back to at least 32,000 BP. By comparison, scientific practice is a recent phenomenon in our species, even if it is as broadly construed to also include Greek natural philosophy. Moreover, although science has an enormous impact on human lives, the vast majority of humans do not actively engage in science. Indeed, the process of becoming a scientist involves years of dedicated practice and study within the highly institutionalized environment of research-oriented universities. The philosopher Robert McCauley (2000) argues that there is a wide cognitive divide between scientific and everyday reasoning: science is 'unnatural', whereas religion is 'natural'. McCauley uses these terms in the fairly restrictive sense of Boyer (1994).

Accordingly, thoughts can be said to be natural if they emerge without extensive cultural support, or even without any particular cultural support. For example, grammatical rules in natural language arise spontaneously even in newly-invented languages such as home sign languages (e.g., Sandler et al., 2005). By contrast, unnatural abilities are those that need extensive cultural support for their development. If McCauley (2000) is correct, then studying the cognitive basis of science is of academic interest at best, since the cognitive processes that would be uncovered are restricted to the select few who have applied themselves to this unnatural form of reasoning, and is mostly constrained to those living in industrialized nations of the past few centuries (a handful of ancient Greeks notwithstanding).

Although scientific methods are indeed the result of deliberate study and practice, McCauley (2000) may be overstating his case. Without causal reasoning, creativity, and induction, for example, it would be hard to imagine scientific practice. These abilities are crucial to science, yet they are not explicitly taught. This suggests some continuity between scientific and everyday reasoning. Carruthers (2002b) has argued that our ability for hypothesis testing predates the evolution of scientific knowledge, and that this ability has been honed by natural selection through hunting and tracking. Humans have been active hunters for at least one million years (Rabinovich et al., 2008). Whereas predators often hunt by stealth or endurance, human hunters typically proceed by wounding an animal and subsequently tracking it down using cues in the environment before killing the weakened prey. This tracking is a lengthy process that requires the explicit testing, evaluating and confirming or abandoning of hypotheses, often in consultation with fellow hunters, as can be seen on Fig. 10.2.

Although science does require a specific suite of social and economic circumstances for its development, whether one takes the short chronology (Renaissance) or the long chronology (ancient Greeks) of science, scientific practice can only be fully understood if one takes into account both the abilities and constraints of the evolved human mind. As we have seen in section 1.2.3, according to Mithen (1996), the ability for scientific reasoning was already fully in place by the Upper Paleolithic, where we see evidence of cognitive fluidity, a propensity of the human brain that lies at the basis of art, religion and science. Richard Rudgley (1999) has convincingly argued that people from the Late Pleistocene onward show

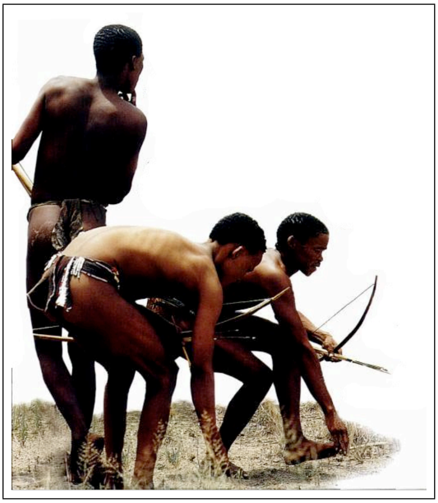

Figure 10.2: Three Kalahari hunter-gatherers use environmental cues to track down a wounded prey, testing and deliberating hypotheses. From Wannenburgh et al. (1999), p. 33.

evidence of sophisticated technology and modes of reasoning, including surgery (e.g., trepanation) and astronomical observations, which are precursors of more recent systematic scientific endeavors.

Some authors (e.g., Gopnik & Meltzoff, 1997) go as far as to say that scientific reasoning has its roots in normal cognitive processes that emerge early in child development. They adhere to the 'theory theory view' of cognitive development, according to which human cognition can be characterized in terms of theories that the mind constructs about the world. Children move through a successive number of stages in which they have different understandings of phenomena around them, including belief-desire psychology, biology or physics. Children are 'scientists in the crib' (Gopnik, Meltzoff, & Kuhl, 2001): they learn about the world by constructing hypotheses and testing these against their growing experience of the world. However, Gopnik and Meltzoff (1997) may be over-emphasizing the role of theory formation in cognition, especially in view of the substantial evidence that a considerable body of our folk intuitions is already present in infants. As we have seen in section 2.3.1, infants already posit unobservables, such as gravity and internal mental states, with very little exposure to the world. Three-month-olds seem to have some understanding of gravity: they expect that unsupported objects will fall downward (Spelke et al., 1995). Seven-month-olds already infer internal mental states (Kovács et al., 2010): they form expectations about the presence or absence of an object not only on the basis of their own mental states, but also on the inferred beliefs of others. It seems very hard to believe that preverbal infants would be able to construct unobservables like gravity or mental states on the basis of external cues alone, and would be able to do this after less than a year of interaction with the world, especially given the fact that they spend a considerable part of this period sleeping.

The educational psychologist David Geary (2007) draws a useful distinction between *primary* and *secondary* forms of cognition, both of which play a role in science and other forms of formal reasoning. Primary abilities are evolved capacities, dealing with evolutionary relevant properties of the world. They include what we have termed intuitive ontologies, namely domains of folk knowledge such as intuitive physics, intuitive psychology, and intuitive biology, and abilities such as the capacity to learn language or to understand the spatial properties of the environment. Secondary abilities are learned skills. An interaction of both types of cognition allows for the creation and maintenance of suites of culture-specific domains, like mathematics, writing or specific scientific disciplines. Mathematics, for instance, is a culture-specific domain that relies on an unlearned number sense and spatial abilities, but that extends these into culture-specific mathematical concepts like negative numbers and Euclidean spaces, often relying on symbolic notation (De Cruz & De Smedt, in press b). Thus, it makes sense to say that scientific practice consists of both unlearned, innate capacities and learned, culturally transmitted skills. Induction, the detection of causality, the ability to make inferences to the best explanation, and intuitive ontological knowledge belong to the former kind, whereas the ability to synthesize DNA or to solve algebraic equations are examples of the latter. In the next two chapters, we will examine the role of intuitive ontologies in scientific understanding (chapter 11) and the role of biased cultural transmission in overcoming these biases (chapter 12). Intuitive ontologies play a prominent role in scientific understanding, and may hamper scientific progress, but interactions between scientists can mitigate their effects, and may provide a solution to the discrepancy between our everyday, commonsense understanding of the world, and the often counterintuitive worldviews that scientists construct.

Chapter 11

The role of intuitive ontologies in scientific understanding—The case of human evolution

This chapter is a revised and expanded version of De Cruz, H., & De Smedt, J. (2007). The role of intuitive ontologies in scientific understanding—The case of human evolution. *Biology and Philosophy*, *22*, 351–368.

11.1 Introduction

Since the advent of modern biology, biologists have strived to give humans a place in their theories. Both Thomas Huxley (1863) and Charles Darwin (1871) stressed that humans are subject to the same evolutionary pressures as other species. However, more than a century later, paleoanthropology is still struggling to give man a place in nature. Paleoanthropology 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 paleoanthropologists on answers to these questions may seem puzzling given the sound theoretical background of evolutionary biology and the ever expanding archeological and fossil record. This chapter proposes 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 chapter begins with a brief overview of the role of intuitive ontologies 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 provides evidence that intuitive ontologies are an integral and stable part of human cognition.

11.2 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 (see section 2.3). 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 (Atran, 1998). 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. Between three and six 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 [2001], part III, §2) 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 in motion by colliding with it. Yet even three-year-olds make such inferences based on an assumed generative transmission of energy (T. R. Shultz, 1982a). Children, laypeople and pre-scientific philosophers rely on framework theories, rather than on perceptual cues to explain a wide range of phenomena. 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. 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). The youngest children (preschoolers) formulate coherent but scientifically incorrect models of the Earth, such as a disc-shaped Earth, similar to folk conceptions in many cultures (e.g., Indian cosmology), see Fig. 11.1. After all, their intuitive physics informs them that the Earth is flat, and that things fall downward. Cultural influence also plays a role: whereas both Indian and American young children make disc-shaped models of the Earth, only the former will state that this disc is surrounded by water, in accordance with Indian folk cosmology (Samarapungavan, Vosniadou, & Brewer, 1996)—this is not unlike the popular image of the Earth in the Middle Ages, when seafarers feared they would sail off this ocean into unknown deeps. Cultural influence can also have a mitigating effect on intuitive ontologies: Australian children are very much aware that they live ‘on the other side’ of the globe compared to children in the United Kingdom. Because of this, they have a much earlier understanding of the shape of our planet compared to British children (Siegal, Butterworth, & Newcombe, 2004). Older children attempt to incorporate scientific knowledge while maintaining a consistent worldview. For example, the hollow sphere takes into account spherical images of the Earth, but still maintains a flat surface for people to live on. It is only in later primary school that children accept a scientifically correct spherical model of the earth (Vosniadou & Brewer, 1992).

11.3 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 scientific lens. How reliable could intuitive ontologies be as a source of knowledge? It is evo-

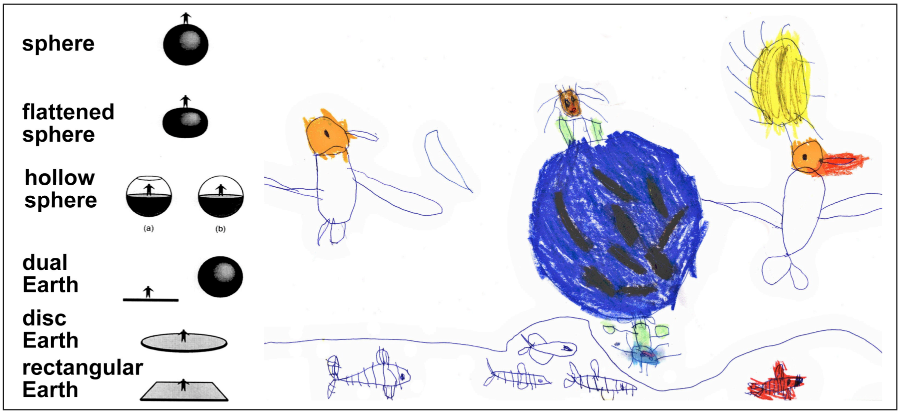

Figure 11.1: Left: mental models of the Earth by children aged 6 to 11. Note that not all children go through every stage, but basically the lower drawings represent models by younger children, and the upper figures represent ideas on the Earth by older ones. From Vosniadou and Brewer (1992), Fig. 1, p. 549. Right: an example of a dual Earth model, spontaneously drawn when the author asked his then four-year-old daughter to depict the Earth. Here the Earth is round and has people on opposing sides, but our planet is then integrated into a flat plane with the usual fauna. It is also a geocentric model, with a small Moon and Sun orbiting the Earth.

lutionarily 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 supported. Newtonian physics predicts a parabolic deviation in the course of the falling object. Yet, an overwhelming majority of people who had a high school course in physics predicts that the ball will fall in a path perpendicular to its point of release, an intuition which systematically distorts their empirical observations, as shown on Fig. 11.2. Even among physics undergraduates over 20% hold this wrong intuition (McCloskey, 1983).

Although intuitive ontologies could be termed theories in the sense that they provide explanations, they are often surprisingly shallow. In-

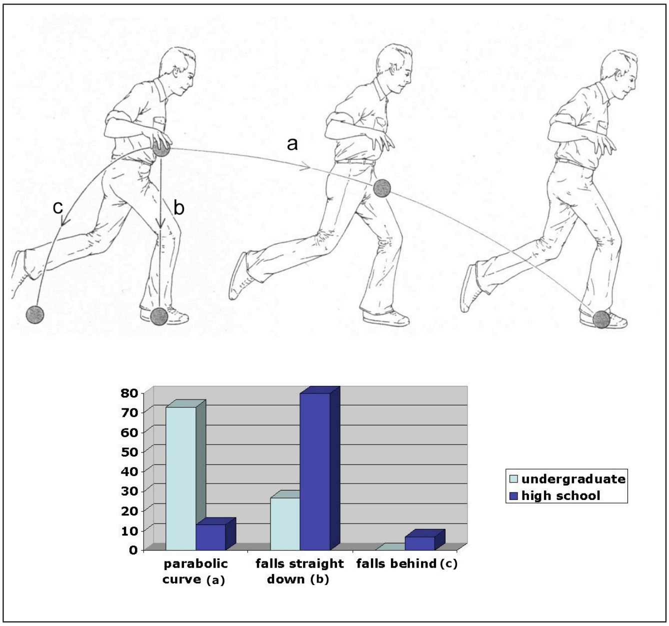

Figure 11.2: Top: What will happen when a running man releases a ball? The correct prediction is (a): the ball will continue at the same speed as the runner; combined with the gravitational force this results in a parabolic curve. From McCloskey (1983), p. 123. Bottom: predictions of the trajectory of the ball. A minority of subjects who had a high school training in Newtonian physics correctly predicted (a). In the physics undergraduates, this number has increased, but a minority of them incorrectly maintained the intuitive model (b).

tuitive 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 developed the evolutionary function of making quick inferences about other agents’ behavior rather than 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 favored fast, shallow inference mechanisms (Gigerenzer & Goldstein, 1996) over epistemologically sound, but slow profound theories.

11.4 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 naive 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. First, let us consider the historical example of physics. 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 three-month-olds (Spelke et al., 1995). 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

> Thus we can and ought to say that in the stone or other projectile there is impressed something which is the motive force [*virtus motiva*] of that projectile. [...] [T]he motor in moving a moving body impresses [*imprimit*] in it a certain impetus [*impetus*] or a certain motive force [*vis motiva*] of the moving body, [which impetus acts] in the direction toward which the mover was moving the moving body, either up or down, or laterally, or circularly. [...] It is by that impetus

> that the stone is moved after the projector ceases to move (Buridan, 14th c. [2009], 88).

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, Caramazza, & Green, 1980, 1140).

Another example of the role of intuitive ontologies in scientific understanding is essentialism in biology. The view of a species essence as underlying causal mechanism for development and behavior 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). Hull (1964) observed that essentialism in taxonomy (and biology in general) resulted in two thousand years of stasis: before Darwin and other evolutionary theorists, biologists like Linnaeus did not make any significant theoretical contribution to taxonomic theory since Aristotle laid its foundations in the fourth century B.C.E. The view of a species essence as underlying causal mechanism for development and behavior has dominated most pre-Darwinian biological thought until well into the 18th century (Stamos, 2005). In questionnaire-based studies (e.g., Samarapungavan & Wiers, 1997), a large percentage of children spontaneously voice essentialist ideas about the origin of species. Their ideas show remarkable similarities to historical theories, including Greek essentialism or accounts of small, micro-evolutionary changes within species' boundaries, as fleshed out by the 18th-century French natural historian Buffon. Perhaps the intuitive appeal of essentialism can partly explain the slow acceptance of evolutionary theory. It took this theory almost a century to take root among professional biologists; even today it is not widely accepted among non-scientists. Shtulman and Schulz (2008) indeed found that adults who hold on to an essentialist conception of species understand the mechanism of evolution through natural selection less well than those who hold less essentialist views.

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 & 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.* Presumably 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.

Scientists exhibit the same cognitive biases and limitations as other human beings. The influence of cognitive biases not only applies to the content of their scientific beliefs, but also to their most fundamental metatheoretical assumptions. Take, for example, the intuition that all contingent states of affairs have a cause for their existence. Scientists rely on this principle, though they cannot demonstrate its reliability. The propensity to infer causes probably has a long evolutionary history, as it has been demonstrated in apes as well (Bräuer et al., 2006). The search for (non-obvious) causes of events arises in very young children, leading some psychologists (e.g., Brewer, Chinn, & Samarapungavan, 2000) to liken children to scientists, engaged in theory formation and hypothesis testing. Others have reversed this analogy, arguing that in fact scientists are like children: Gopnik and Meltzoff (1997), for instance, see science as a byproduct of our universal search for causal explanations, emerging in early childhood. As we have seen in section 10.3, looking time experiments (Saxe et al., 2005) indicate that this search for causes is already present in 12-month-olds, who expect a human hand, rather than a toy animal, to be the cause of an object falling on a stage. Preschoolers readily infer unobservable causes in diverse domains: they invoke unobservable mental states to explain the behavior of agents (Callaghan et al., 2005), unobservable physical forces to account for the motions of inanimate objects (T. R. Shultz, 1982a), and invisible essences to predict and account for the growth of biological organisms (Gelman & Wellman, 1991). This intuition of causality illustrates the continuity between everyday and scientific reasoning.

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 and philosophers of biology disagree on the basic unit(s) of selection (Okasha, 2006), on what a species may be (Stamos, 2003), and on whether evolution takes place in a gradual or a punctuated tempo (Gould, 2002). If intuitive ontologies continue to guide our everyday understanding, there remains the possibility that intuitive ontological ideas may slip unnoticed into scientific discourse.

11.5 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 archeological evidence for the occurrence of hominids outside of Africa at 1.8 million years BP. 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 III et al., 1994). Paleoantropologists 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, paleoanthropology 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 paleoanthropologists depart from those of standard evolutionary theory. If these basic assumptions are more compatible with intuitive ontologies than with evolutionary theory (as will be argued, 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 ontological assumptions: the human-nonhuman distinction and psychological essentialism, both of 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, Frot, Zangl, & Mehler, 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.

11.5.1 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, Waxman, and Medin (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 (Bonatti et al., 2002), but fail to distinguish dissimilar looking artifacts (Xu & Carey, 1996), indicating that they make a fundamental human-nonhuman distinction. 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 of 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 the paleontologist Tim 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 plants and animals, it becomes possible to adopt an essentialist stance on humans as well. As late as the 1920s, for example, the paleoanthropologist 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 paleoanthropologists, 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 paleoanthropology'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 Franz Weidenreich, and endorsed by Theodosius Dobzhansky and Ernst 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 this 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. 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 on 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 paleontologist George Gaylord 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, paleoanthropologists chose to follow Dobzhansky and Mayr, 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 between 90,000 and 18,000 BP (P. 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 (e.g., now-extinct pig-sized hippopotami on Cyprus and Madagascar, Diamond, 1992). Indeed, a recent case of extreme island dwarfism in *Homo sapiens* on the Micronesian island Palau around 3000–1000 BP (L. R. Berger, Churchill, De Klerk, & Quinn, 2008) underscores this. Morphological analysis of stone tools also calls the exaggerated role of culture in human evolution into question. It indicates that human culture prior to the Upper Paleolithic evolved very slowly, with long periods of stasis. For instance, the earliest Oldowan stone tools, dated at around 2.6 million year ago, are morphologically indistinguishable from the youngest African specimens, which are one million years 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 archeological and fossil evidence than by the intuition that humans are unique compared to other animals.

As a result, the paleoanthropological 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*, shown on Fig. 11.3 (R. E. F. Leakey & Walker, 1976). Since this time, paleoantropologists have cautiously started to acknowledge that humans may be like other species after all, subject to the same evolutionary processes, as exemplified in Robert Foley's (1987) *Another unique species*, arguably the first paleoanthropological book to make explicit use of evolutionary theory to interpret details of the human fossil record. A modern offshoot of the single species hypoth-

Figure 11.3: Frontal, lateral and superior aspects from (a) KNM-ER 406 (*Paranthropus boisei*) and (b) KNM-ER 3733 (*Homo ergaster*), the first unequivocal proof that two hominid species lived at the same time as both were found *in situ* in the same archeological layer (the upper member of the Koobi Fora Formation, east of Lake Turkana, Kenya). This effectively ended the single species model, as even a layperson could see that both skulls belong to two different species. From R. E. F. Leakey and Walker (1976), Fig. 2, p. 573, Fig. 1, p. 573 and Fig. 3, p. 574.

esis is the model of multiregional continuity (see e.g., Wolpoff, Hawks, & Caspari, 2000, for an overview). According to this model, all extant human populations descend directly from a single, highly variable species which arose about 1.5 million years BP, 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 toward 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 (e.g., Ingman, Kaessmann, Pääbo, & Gyllensten, 2000) have cast serious doubt on the multiregional hypothesis, since they indicate a very recent common ancestor for all current human populations[34].

The intuitive human-nonhuman distinction may have contributed to the idea that human evolution is somehow exceptional. Paleoantropologists 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 paleoanthropology: since 1994 important discoveries of late Miocene hominid fossils have given rise to four new genera within the hominid lineage: *Ardipithecus* (T. D. White, Suwa, & Asfaw, 1995), *Orrorin* (Senut et al., 2001), *Kenyanthropus* (M. G. Leakey et al., 2001) and *Sahelanthropus* (Brunet et al., 2002)—next to the three widely accepted genera *Australopithecus*, *Paranthropus* and *Homo*. Nonetheless, paleoanthropologists (e.g., Haile-Selassie, Suwa, & White, 2004) and geneticists alike (e.g., Cela-Conde & Ayala, 2003) argue that such a large number of genera is unacceptable, and that we should somehow prune the tree of hominid evolution.

11.5.2 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 that 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 & Ortony, 1989). This enables children and lay adults to override perceptual features when making judgments on category-membership. When three-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 the latter (Gelman, 2004). Children from such dissimilar cultures as Mesoamerican Maya (Atran, Medin, & Ross, 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, for example, 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"[35]. 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 paleoanthropology and molecular biology have dramatically altered our conceptual framework on the relatedness between humans and other apes (see also section 1.2). It was generally believed that the split between hominids (*Hominidae*) and the other apes (the paraphyletic clade *Pongidae*) occurred at least 15 million years BP. As we have seen, Sarich and Wilson's (1967) seminal molecular biological study demonstrated that humans and chimpanzees diverged only 5 million years BP. 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[36].

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, 184–185) 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 & 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, behavior and appearance.

Jared 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, since there are only four nucleotide types, it can be argued that we share at least 25% of our genes with any given species. 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, 2003). As mentioned earlier (section 1.2.2), King and Wilson (1975) have proposed that the differences between human and chimpanzee anatomy and behavior 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 (e.g., Gu & Gu, 2003) have indeed shown that genes have been upregulated in the human brain compared to that of the chimpanzee. 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 program 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, 2000b, for a 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 & 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 behavioral 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. The fact that chimpanzee minds seem ‘suspiciously human’ (Povinelli & Vonk, 2003) may be a reflection of our own mental state attribution. Indeed, as pointed out in chapter 4, the divergent ecological and social circumstances under which humans and chimpanzees evolved make it likely that their psychology is very different from ours.

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 equivocal (see Call & Tomasello, 2008, for a balanced review). Thus, it is conceivable that research programs 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.

11.6 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 epistemically limited. In this chapter, 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 results from specific evolutionary pressures, intuitive ontologies can yield mutually inconsistent pictures of reality; 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 programs in comparative psychology. Intuitive ontologies especially play a role in scientific understanding when it is not underpinned by an explicit ontological 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, Frans 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 behavior within its own ecological and evolutionary contexts (see chapter 4 for an elaboration on this point). 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. This research suggests that intuitive ontologies are an integral and stable part of human cognition.

CHAPTER 12

EVOLVED COGNITIVE BIASES AND THE EPISTEMIC STATUS OF SCIENTIFIC BELIEFS

This chapter is a revised and expanded version of De Cruz, H., & De Smedt, J. (in press a). Evolved cognitive biases and the epistemic status of scientific beliefs. *Philosophical Studies.*

12.1 Introduction

What is the relationship between the evolved structure of the human brain and scientific knowledge? A growing body of empirical evidence from developmental psychology, neuroscience and cognitive psychology indicates that the way humans perceive and conceptualize the world is shaped by evolved cognitive inference mechanisms. These findings can be incorporated in naturalistic theories of mental content that propose that the proper function of our cognitive processes is to promote survival and reproduction (e.g., Millikan, 1984; Rowlands, 1997). The implications of this evolutionary picture for the epistemic status of scientific and other forms of beliefs remains a matter of debate. Does the fact that our cognitive apparatus has an evolutionary origin provide us with a justification for scientifically informed beliefs, or are we to treat them with suspicion? To address these questions, we look at two types of arguments that connect evolution and beliefs: *evolutionary arguments* (EAs) and *evolutionary debunking arguments* (EDAs). Both types of argument agree that evolutionary considerations have implications for the epistemic standing of beliefs. Both are also committed to evolutionary psychology in the broad sense, i.e., they hold that evolutionary pressures, in particular natural selection, are important forces in shaping cognition[37]. They reach contradictory conclusions about the implications of evolutionary psychology for the epistemic justification of beliefs. EAs state that evolution will tend to select for belief-formation mechanisms that are reliable, whereas

EDAs imply that evolution is not a truth-tracking, but a fitness-enhancing process.

This chapter examines the implications of the evolutionary origins of our cognitive faculties for the epistemic standing of science. First, it briefly outlines the role of cognitive biases in human cognition (section 12.2)—as was argued in the previous chapter, these biases also play a role in scientific practice. Next, we discuss evolutionary arguments and evolutionary debunking arguments in relationship to scientific practice (sections 12.3 and 12.4). We show that for any belief that can be plausibly thought to be influenced by evolved cognitive predispositions it is possible to construct both an EA and an EDA. This indicates that evolutionary biological considerations may not be decisive for the epistemic justification of scientific beliefs. We therefore shift our focus to the cultural dynamics of scientific practice, by presenting an analytical model (sections 12.5 and 12.6) that suggests that cultural transmission of scientific knowledge can lead toward representations that are more truth-approximating under a broad range of circumstances, even if human cognitive faculties were further off the mark than they actually are.

Before proceeding, we make explicit two basic assumptions that underlie this chapter. First, evolutionary considerations are only relevant for the justification of beliefs from an externalist perspective. For externalists who favor a causal account, beliefs are only justified if there is a proper causal relationship between a belief and the external world. As we shall see, both EAs and EDAs rely on an externalist, causal account of knowledge acquisition. Second, we assume a form of basic or ontological realism; in other words, we will assume that there is an external and observer-independent reality.

12.2 Cognitive biases and the perception of reality

Is there a limit to what humans can know? Some authors (e.g., Dennett, 1991) are convinced that our cognitive faculties are in principle able to tackle all aspects of nature, whereas others (e.g., Sullivan, 2009) argue that some parts of reality will always remain outside the reach of our cognitive faculties. This skepticism is often motivated by an appeal to the evolved nature of the human brain. Plantinga (1993), for example, argues that

> if our cognitive faculties have originated as Dawkins thinks [i.e., through natural selection], then their ultimate purpose or function [. . .] will be something like *survival* (of individual, species, gene or genotype); but then it seems initially doubtful that among their functions—ultimate, proximate or otherwise —would be the production of true beliefs (Plantinga, 1993, 218).

Several philosophers of mind (e.g., Millikan, 1984; Akins, 1996; Rowlands, 1997) propose that mental content can be understood as a product of natural selection: the proper function of some mechanism, trait, or process in evolved organisms is ultimately relative to fitness, and the brain has as proper function the production of beliefs that are fitness-enhancing.

Faced with a rich environment, and with limitations in time and cognitive resources, animal brains need to be highly selective about the information they process. Information that has potentially large consequences for an animal's fitness needs to be prioritized, whereas cues that are irrelevant for fitness are often ignored. For example, animal visual systems typically pick up only a small part of the electromagnetic spectrum. In contrast to humans and other mammals, pollinating insects can see ultraviolet light. In the co-evolution of flowers and pollinators, many flowers have developed ultraviolet cues that help insects find nectar, such as concentrations of ultraviolet streaks that guide bees into the centre of a flower, thereby promoting pollination (R. Miller, Owens, & Rørslett, 2011), as shown in Fig. 12.1. The human visual system ignores ultraviolet light because it did not play a role in our evolutionary history (e.g., in terms of food or sexual selection). There is little reason to assume that the limited part of reality we perceive represents an objective translation of that reality—animals, including humans, produce simplified approximations of reality that tend to be adaptively useful within their ordinary world. Philip Sullivan (2009) considers deerflies: they conceptualize sources of food like deer, cattle or humans of which they suck the blood as middle-sized objects that are in motion. A deerfly has no cognitive resources that enable it to differentiate between a truck and a large mammal. Human cognitive faculties, too, are not aimed at the disinterested representation of facts, but at representations that are relevant for the organism's fitness. Our sensation of temperature, for instance, is closely related to the skin's starting temperature; rather than detachedly reporting a change in temperature, an already hot skin will register a warm impulse as hotter and more discomforting than a cooler skin (Akins, 1996).

Figure 12.1: A common yellow woodsorrel (*Oxalis stricta*) under normal lighting conditions (left) and photographed using an ultraviolet-sensitive camera (right). Note that the honey guides are only visible under UV light. From R. Miller et al. (2011), Fig. 11, p. 288.

The impact of evolutionary pressures on human mental content can be weak or strong, depending on the model one develops. A weak version (e.g., Rowlands, 1997) restricts the impact to fairly basic representational mechanisms, mainly perception, such as the spectral-frequency band in which the human ear can receive acoustic signals. A stronger version would extend the impact to our conceptual knowledge as well. One reason to adopt this latter version is that it is difficult to make a clear distinction between purely perceptual and conceptual mental content. Higher-order cognitive capacities are almost always involved in simple cases of perception. Even the belief that one has hands is informed by higher-order processes, such as an internally generated body schema. When damaged, this leads to finger agnosia, the inability to recognize one's own hands or fingers in spite of intact visual and tactile perceptual input (Osawa & Maeshima, 2009). Moreover, a burgeoning field of experimental evidence from developmental psychology and cognitive neuroscience indicates that the human mind imposes a variety of conceptual structures onto the sensations it receives. Human cognition is characterized by a host of higher-level specialized inference mechanisms, which we termed intuitive ontologies (De Cruz & De Smedt, 2007, 2010c). In order to interpret the world around us, we make inductive inferences about objects, and categorize them into a relatively small set of classes that are meaningful from an evolutionary point of view, such as 'artifact', 'animal' and 'person'. Categorization is vital for survival and reproduction, because it enables animals to make fast decisions based on limited sensory information—it is therefore unsurprising that even organisms with very small brains, such as insects, perceive the world in terms of high-level concepts and categories (Chittka & Niven, 2009).

From an evolutionary perspective, science is a recent development in our species. Thus, scientists have to draw on the same cognitive resources as other people, and they are subject to the same cognitive limitations. If humans conceptualize and reason about the world in terms of a limited number of intuitive ontologies, one could expect that intuitive ontologies play a role in scientific understanding, as was argued in chapter 11. Also, as we have seen in section 11.4, the influence of cognitive biases not only applies to the content of our scientific beliefs, but also to our metatheoretical assumptions, like, for instance, causality detection.

12.3 Evolutionary arguments

The evolutionary argument (EA) contends that natural selection will form animal brains that tend to produce true beliefs, because true beliefs are essential for adaptive decision making. Cognitive faculties that are widely off the mark would seriously compromise a creature's ability to survive and reproduce. As Quine (1969b, 126) put it "Creatures inveterately wrong in their inductions have a pathetic but praiseworthy tendency to die before reproducing their kind." This position goes back at least to the 18th-century commonsense philosopher Thomas Reid, who considered the consequences of rejecting those beliefs that our cognitive faculties naturally produce:

> I resolve not to believe my senses. I break my nose against a post that comes in my way; I step into a dirty kennel; and after twenty such wise and rational actions, I am taken up and clapt into a mad-house [...] I gave implicit belief to the informations of Nature by my senses [...] I find, that without it I must have perished by a thousand accidents [...]

> I consider this instinctive belief as one of the best gifts of Nature (Reid, 1764, 413–415).

A detailed defense of EAs comes from the philosopher Stephen Boulter (2007), who argues for an updated form of commonsense philosophy. Commonsense beliefs are non-inferential, basic beliefs that do not have to be justified by reasoning or by reference to other beliefs, like our belief in the past, in the existence of other minds, or our reliance on memory. As we have seen in section 2.3, intuitive ontologies furnish us with a wide variety of commonsense beliefs, such as the belief that an unsupported object will fall downward (intuitive physics), that other agents act on the basis of their internal mental states (intuitive psychology), and that tadpoles grow into frogs even though they do not look alike (intuitive biology). To Boulter (2007), these basic beliefs derive their epistemic justification from their adaptive value. His EA can be summarized as follows:

1. Animals that can successfully interact with the world have a higher chance of passing on their genes than animals that do not successfully interact with the world.
2. Beliefs about the world that accurately track those states of affairs in the world are, on the whole, better guides to action than are false beliefs.
3. Therefore, natural selection will favor those animals with reliable sensory and belief formation systems insofar as those sensory systems and beliefs have a bearing on the animals' fitness.
4. Commonsense beliefs have direct bearing on human fitness.
5. Therefore, human commonsense beliefs will tend to be correct.

Similar EAs can be found in Fodor (1981) and Stewart-Williams (2005). This chapter will neither evaluate nor defend the merits of the EA for commonsense beliefs, but only consider whether this argument can be used to justify scientific beliefs. As can be seen in premise 3, the EA has the important qualification that the beliefs will only be reliable to the extent that they have a bearing on an organism's fitness. Defenders of EAs argue that they only hold under conditions that resemble the ones in which our cognitive faculties evolved. The philosopher and evolutionary psychologist Steve Stewart-Williams (2005), for example, argues that causal cognition only yields reliable intuitions in our everyday understanding of the world, but that it may be unreliable in circumstances outside this narrow range, such as when it produces philosophical or scientific beliefs (see also section 10.4)—for instance, we cannot rely on causal intuitions to explain events at the quantum level where the commonsense belief that every event must have a cause has proven unreliable. Most scientific knowledge falls outside of ecologically relevant conditions. Intuitive ontologies may be effective for everyday understanding, but they can go awry in such domains as probability theory, cognitive neuroscience or evolutionary theory. Scientific practice itself cannot have exerted any selective influence on our cognitive systems. The fact that scientific practice as we know it is only a few hundred years old makes it very unlikely that such selective pressures, if any, would have perceptible effects. If the reproductive success of fundamentalists who reject evolutionary theory in favor of creationism is any guide, holding wrong scientific beliefs does not seem to have any negative effects on one's fitness.

12.4 Evolutionary debunking arguments

Does natural selection promote the formation of true beliefs? Evolutionary theorists and philosophers have offered at least four types of situations where it does not. First, many false beliefs, including systematic fallacies, do not compromise fitness, and thus cannot be honed by natural selection. As Steven Pinker (2005) puts it:

> Members of our species commonly believe, among other things, that objects are naturally at rest unless pushed, that a severed tetherball will fly off in a spiral trajectory, that a bright young activist is more likely to be a feminist bankteller than a bankteller, that they themselves are above average in every desirable trait [. . .] The idea that our minds are designed for truth does not sit well with such facts (Pinker, 2005, 18).

More generally, we can expect that beliefs that have no bearing on an animal's fitness are not subject to natural selection. Second, natural selection can favor cognitive faculties that are more often incorrect than correct under specific circumstances. This scenario is explored by the 'better safe than sorry argument' (a term coined by Stephens, 2001), which states that cognitive processes may sometimes err on the side of safety. If the costs or payoffs of false positives and false negatives are asymmetric (see table 8.1 on p. 236), natural selection will tend to promote beliefs that yield the highest payoffs or incur the least costs. Take agency detection: it is less costly to discern an agent when none is present (a false positive) than it is to fail to detect an agent that is present (a false negative)—the first results in a small waste of time and energy, whereas the second may lead one to miss out on a meal or to become one. For the same reason, creatures are expected to be excessively cautious when deciding whether a potential mate is member of the same or of a different species. In this case, the cost of a false positive (mistaking a member of another species for a member of one's own) can be disproportionately high for females, as it might result in investing time and resources in inviable or sterile offspring (Godfrey-Smith, 1991). Third, cognitive processes can deviate from the truth due to a fitness trade-off between accuracy and efficiency: given that animals have limited time and resources, they will sometimes be better off with fast heuristics that may occasionally or even often misfire. There is little point in carefully and elaborately choosing the best escape route when faced with a hungry predator. As the world is too complex to be understood in its entirety by organisms limited in space, time and cognitive resources, animals must resort to heuristics to make the world more tractable. This usually enables them to act adaptively under uncertainty, but it sometimes leads to characteristic biases. Such heuristics and biases have been experimentally observed in humans as well as nonhuman animals (see e.g., Real, 1991, for characteristic biases in foraging bumble bees). Fourthly, and more tentatively, some misbeliefs might confer an adaptive advantage because of their misalignment with reality. McKay and Dennett (2009) cite the 'above average' effect as a case in which it is adaptive to be wrong. This is a well-established tendency in neurologically normal people to overestimate their own positive qualities, to underestimate their negative qualities compared to others, and to value their own children as smarter, kinder and more beautiful. From an evolutionary perspective, one can easily see how this bias can be adaptive, as it leads to increased fitness by compelling one to pay more attention to one's own needs and the needs of one's offspring.

Given that natural selection does not reliably preserve or promote true beliefs, the evolutionary origins of our cognitive faculties can cast doubt on their epistemic justification. The philosopher Guy Kahane (in press) offers a general schema for such evolutionary debunking arguments (EDAs):

1. We believe that p, because we have an intuition that p, and there is an evolutionary explanation of our intuition that p.

2. Evolution is not a truth-tracking process.

3. Therefore, we are not justified in believing that p.

To take a simple example: Thelma believes her children are more beautiful and smarter than average, and there is a good evolutionary explanation for this belief. Her belief is not properly causally connected to facts in the world, namely the objective qualities of her children. Therefore, Thelma's belief is unjustified.

Is science vulnerable to EDAs? As Kahane (in press) has observed, once one allows EDAs, it is difficult to see where they would not apply. In the case of moral beliefs, for instance, EDAs call into question not just a subset of moral judgments (e.g., prioritizing the well-being of one's own children over that of strangers in the developing world) but all moral judgments (e.g., caring about the well-being of other people). If we were solitary animals like tigers, we wouldn't care about our conspecifics at all. Humans have altruistic feelings because such feelings confer an adaptive advantage to animals that live in complex, structured social groups. EDAs that are leveled against religious belief may similarly overshoot their purpose. Studies on the cognitive science of religion indicate that religious beliefs are byproducts of everyday cognitive capacities, such as agency detection or attribution of design (see the introduction to part III for an overview). To some authors the fact that religion is a byproduct of evolved cognitive faculties undermines its epistemic standing. To quote Dawkins (2006, 184): "The irrationality of religion is a byproduct of a particular built-in irrationality mechanism in the brain." But if being a byproduct undermines religious beliefs, one could argue that science, which is also a byproduct of the evolved structure of human cognition, is likewise undermined:

1. We can hold scientific beliefs due to our evolved capacities for understanding the physical, biological, and mental world.

2. Natural selection is not a truth-tracking process.

3. Therefore, scientific beliefs are unjustified.

Note that it does not help much to say that one does not endorse adaptationism, since scientific beliefs formed through cognitive skills that have arisen through drift or other non-adaptive processes would presumably be even less reliable than those formed through natural selection.

Interestingly, it seems that for *any* belief that is plausibly influenced by human cognitive predispositions, one can construct both an EA and an EDA, suggesting that we cannot draw straightforward conclusions from evolutionary origins to epistemic justification. Take theistic beliefs. The philosopher of religion Michael Murray (2008) speculates that God has instilled cognitive predispositions in humans through natural selection which elicit religious beliefs in a broad variety of circumstances. By contrast, Dawkins (2006) claims that the evolutionary origin of religious beliefs provides *prima facie* evidence against the existence of God. Or take scientific knowledge. The philosopher of science David Papineau (2000) asserts that evolution promotes truth-approximating beliefs in scientific practice because of selective pressures that have enhanced human capacities for rational reasoning in the domains of folk psychology and means-end reasoning. On the other hand, the philosopher of science Kathleen Akins (1996) argues that our cognitive faculties are not aimed at a disinterested and objective representation of reality, but rather at forming beliefs that benefit the organism. It seems that evolutionary biological considerations will remain indecisive for the epistemic justification or debunking of scientific beliefs. A single brain cannot test its own reliability without being subject to either circularity (justifying its own working) or debunking (undermining its own reliability). However, if the dynamics of knowledge acquisition in institutionalized environments are very different from those in individual agents, it may be possible for *interacting* brains to do so. In what follows, we consider a pessimistic scenario in which cognitive biases are very influential in science. We will present an analytical model of cultural transmission that shows that interacting scientists are able to overcome these cognitive biases in a broad range of circumstances. Note that, since this is an externalist justification of scientific beliefs, we need not worry about the radically skeptical possibility that our model, like other types of beliefs, might in its turn be subject to cognitive biases. The only thing that is required, from an externalist point of view, is that there *are* mechanisms in the external world that promote the growth of scientific knowledge; scientists need not be aware of these mechanisms.

12.5 The cultural transmission of scientific knowledge: A model

To examine the cultural transmission of scientific knowledge, we develop an analytical model, based on Henrich and Boyd's (2002) work on biased cultural transmission. Cultural transmission takes place in human minds. It is biased by prior beliefs and expectations. In particular, our model focuses on the role of intuitive ontologies in scientific practice. It does not require high-fidelity copying of cultural traits, nor that these traits are discrete. It does rely on the assumption that scientific models can be more or less truth-approximating. There are well-known objections to this assumption, and a discussion of this falls beyond the scope of this chapter. However, given that most defenses of scientific realism seem to require some form of truth-approximation, the assumption seems quite reasonable. As we shall see, the dynamics of cultural transmission are such that science can evolve progressively even when starting out with very low levels of empirical accuracy; even if initial theories are mostly wrong, they can converge toward more accurate representations over time given a large enough population of scientists and a sufficient level of diversity of inferences.

We start out with a range of scientific ideas that attempt to represent some aspect of reality or that attempt to solve a particular science-related problem. It does not matter whether we talk about the evolution of crustaceans, the structure of the atom, or reasons for the fall of the Roman empire. Assuming ontological realism, not all scientific solutions will capture observer-independent reality equally well. Each scientific model has a z value, a positive real number. Higher z values denote better scientific models, i.e., they are more truth-approximating or more efficient at solving a science-related problem. $\Delta\overline{z}$ is the average change in z across the community of scientists, denoted by N, that is concerned with a particular problem. For example, suppose that z stands for the representational adequacy of models of the structure of the atom that were in the running in the early 20th century. N would then be the pool of scientists who investigated the structure of the atom in that period. Of the models of the atom that were circulating then, Dalton's early 19th-century model of atoms as hard billiard balls had a lower z value than Thomson's plum pudding model of electrons floating in a soup of positive charge which in turn had a lower z value than Rutherford's model of the atom as a miniature solar system. Even though Rutherford's analogy is no longer used in contemporary physics, it still had the highest z value of the aforementioned models, since it made a distinction between the positive nucleus and the negative electrons. $\Delta\overline{z}$ is the shift in representational accuracy from the early 19th to the early 20th century. Since the average representational accuracy of models of the atom improved, $\Delta\overline{z}$ was positive. If there had been scientific stasis (no improvement in these models), $\Delta\overline{z} = 0$; if there had been a decline in scientific accuracy (for instance, if scientists during this period had reverted to a form of ancient Greek atomism), $\Delta\overline{z}$ would have been negative.

To model the transmission of scientific practice, we use the Price equation (Price, 1972), which describes changes in the frequency of traits that are transmitted. This equation is widely used in disparate scientific domains, including biology, economics, and anthropology. It models the extent to which transmittable characteristics covary with the effects of selection (first term of equation 12.1), and the rate at which these characteristics change over time (second term). Henrich and Boyd (2002) and Henrich (2004b) have adapted it to study the transmission of culturally acquired skills; here it will be used to examine the transmission of scientific knowledge. In a general form the Price equation states:

$$\Delta\overline{z} = \underbrace{Cov(f, z)}_{selective\ transmission} + \underbrace{E(f\Delta z)}_{noisy\ inference} \tag{12.1}$$

Equation (12.1) describes how the average value of any transmittable trait z changes in a population from one generation to the next. To predict the value of $\Delta\overline{z}$, we need to take into account on the one hand its selective transmission—in this case, the adoption of a specific scientific model based on its perceived empirical adequacy and instrumental effectiveness by scientific peers—and on the other hand distorting influences of cognitive biases. The former is modeled as $Cov(f, z)$ (covariation of z with its cultural success) and the latter as $E(f\Delta z)$ (expected cultural success of z as it changes over time). f gives the relative likelihood that a given scientific model z will be chosen. We will here assume that scientists are able to assess the merits of scientific models. This model is agnostic as to how people assess competing scientific theories; this can be through epistemic values, intuition, experiment, evaluation of empirical adequacy or a combination of these factors. We also suppose for simplicity's sake that members of the scientific community want to adopt the best scientific model, denoted by z_h. Assuming that members of the scientific community attempt to incorporate the most successful representations of reality z_h, we can see that $f_h = 1$ and $f_{not\ h} = 0$. This reduces equation (12.1) to

$$\Delta\overline{z} = z_h - \overline{z} + \Delta z_h \tag{12.2}$$

Due to errors inherent in cultural transmission and the effects of cognitive biases, most scientists of N will end up with lower z values than z_h. Henrich and Boyd (2002) model the newly obtained z value as randomly drawn from a Gumbel distribution[38]. This provides us with a rather pessimistic assumption: there is a greater probability that a scientist who adopts a model will get it wrong, and will end up with a lower z value, typically by an amount α, which represents the systematic biases of our evolved cognitive faculties. However, as in other forms of cultural learning, there are stochastic processes involved, so that some individuals might end up with a higher z value, due to individual learning or even lucky errors. If the new most successful model $z_{h'}$ is accepted by the scientific community, the average z value can exceed the previous mean ($\Delta\overline{z}$ is positive). One could also imagine that members of the scientific community will not end up with a higher z value, or alternatively, that they do not adopt a new model with a high z value. Recall that $\Delta\overline{z}$ can be 0 (scientific stasis), or can even become negative (decline of scientific knowledge). Under what conditions can we expect these scenarios to occur?

Henrich (2004b) derived the following equation (see his Appendix A for technical details on the derivation), which will here be applied to calculate $\Delta\overline{z}$, i.e., the change in z value across time in the population of scientists working on the same problem:

$$\Delta\overline{z} = -\alpha + \underbrace{\beta(\gamma + Ln(N))}_{always\ positive} \tag{12.3}$$

To assess whether scientific progress will be positive, 0 or negative, one needs to take the following variables into account: α, the difference between average z value ($\overline{z}$) and z_h; β, the variability of the Gumbel distribution which represents the degree to which scientists will make different inferences; N, the size of the scientific community. γ is the Euler-Mascheroni constant (≈ 0.577). One can see that the first term of equation (12.3) acts against cultural transmission: α represents the effects of low-fidelity transmission due to cognitive biases. Therefore, it is negative and lowers the value of $\Delta\overline{z}$, except in cases where scientists take over a model without modifying it, in which case $\alpha = 0$. The second term promotes scientific progress. $Ln(N)$ is the natural logarithm of N. We presupposed interaction among the scientific community, so N is the population of interacting scientists. β is a mathematical measure of the tendency of people to make different inferences, in this case, diverging scientific models of the same aspect of reality. For instance, in the early 20th century, there were several competing models of the structure of the atom, yielding a high β value. Interestingly, the larger β, the higher the chance that models will be invented that exceed the mean of previous z values. In other words, the more scientists make *different* inferences, the more likely scientific progress becomes. In contrast to what some Bayesian philosophers of science contend (see Shaffer, 2008, for an overview), this model suggests that disagreement among scientists is not undesirable—quite on the contrary, it is essential for scientific progress.

To obtain a positive $\Delta\overline{z}$ value, one needs a large number of scientists N when cognitive biases α are substantial, or when the tendency to make different inferences β is small. In other words, even if α is disproportionately large, i.e., if human cognitive biases were even further off the mark than they actually are, it is still possible to have scientific progress if scientists make many different inferences and if the scientific community is sufficiently large. The critical value for N, i.e., the minimal number of interacting scientists within a community that is necessary to maintain a given level of scientific knowledge is shown for different values of α/β in the supplementary movie S1, which can be consulted online[39]. Larger values of α make scientific progress more difficult. As can be seen, larger values of α/β require larger critical values for N. Also, the model predicts that, since the natural logarithm of N plays a role in the value of $\Delta\overline{z}$, disproportionate increases of N are required to maintain the same levels of scientific growth once N gets substantially large. Quantitative studies that link the size of the scientific community and scientific discovery in diverse disciplines are in line with this prediction, including genetics (Glass, 1979) and physics (Wagner-Döbler & Berg, 1999). In this latter study, one can see, for example, a concurrence between a steep increase in the number of authors working on electricity and magnetism in the mid 19th century with important discoveries in that field, such as Maxwell's unification of electricity, magnetism and light into a single theory of the electromagnetic field in the 1860s (Wagner-Döbler & Berg, 1999, 256).

It should be noted that this model is highly idealized to enhance its conceptual clarity. One of the factors that it does not take into account is luck, i.e., single individuals working in relatively small research communities (e.g., Newton or van Helmont) can produce large improvements by happening to make the right guess. Translated into this model, this would correspond to an initial high z_h value within a small N. The model is not designed to predict the future history of science, but rather to explain factors that mediate scientific progress, including in actual historical case studies. In the future, it could be combined with other approaches, such as work that conceptualizes science as an epistemic landscape (e.g., Weisberg & Muldoon, 2009).

12.6 An illustration: 18th- and 19th-century transmutation theories

There is no prescribed methodology to assign concrete values to α/β in the growth of scientific knowledge, although it is often possible to get estimations of N. In order to get a qualitative feeling for the predictions of the model, we will apply it to the development of theories on the transmutation[40] of species in biology in the period from 1760 to 1860. Since Antiquity, most naturalistic theories on the origin of species tended to be overwhelmingly (though not exclusively) essentialist. As argued in section 11.4, this may be due to the fact that human reasoning about species is biased toward essentialism. Next to this, psychological evidence (e.g., Kelemen, 2004) indicates that humans also possess a natural propensity for teleological reasoning. Across cultures (H. C. Barrett, 2004), humans have the intuition that animals and plants possess adaptations that are self-beneficial and well-adapted to their environment, such as claws for defense or thorns for protection against being eaten. As we saw in section 9.2.2, children and adults with little schooling also have an overwhelming preference for teleological rather than mechanistic or evolutionary explanations. Teleological explanations are at odds with a correct understanding of the evolution of species, because in such accounts the function of a trait provides a necessary and sufficient explanation for its existence (e.g., a giraffe has a long neck in order to reach high foliage) which does not leave room for mechanistic, evolutionary accounts. Additionally, biological evolutionary changes cannot be directly observed, but must be indirectly inferred. In the case of transmutation theories, there is thus a substantial cognitive bias α. To offset the effects of α, natural historians and natural philosophers (terms that denote what are now called biologists) needed a large β and a sizable population of interacting biologists N. The extent to which biological theories on speciation are truth-approximating will be taken as an indicator of their z-value.

Although transmutation theories go back at least to Antiquity, with authors like Empedocles, Anaxagoras, Democritos and Lucretius, it was only from the middle of the 18th century onward that such theories were systematically considered and explored. Contrary to common opinion, Lamarck's and Darwin's were only two among many such ideas (Mayr, 1982; Bowler, 2003). As we have seen in section 9.4.2, in Germany at the end of the 18th century, members of the so-called Göttingen school, such as Blumenbach, Kielmeyer and Reil, stipulated forces that acted on biological entities, in analogy to physical forces acting on physical entities. French naturalists were the first to propose detailed theories of how species can transmute (change) into other species. An early example is de Maillet's *Telliamed, Ou entretiens d'un philosophe indien avec un missionnaire françois* (1748), which proposed that life-forms had spontaneously emerged on Earth, and that their adaptation to diverse circumstances gave rise to distinct species. In his *Histoire naturelle générale et particulière* (1766) Buffon argued that closely related species, such as horses and donkeys might have a shared common ancestor; evolutionary changes occurred mainly through degeneration. Lamarck delineated a tree-like structure of the origin of species; he thought that transmutation of species occurred through the transmission of acquired characteristics, an idea developed in detail in his *Philosophie zoologique* (1809). These ideas enjoyed wide currency across Europe, being translated within a few years of publication in several European languages, and were further developed by authors in Italy, Belgium, and the United Kingdom (Corsi, 2005). Examples include the Belgian geologist d'Omalius d'Halloy's *Note sur la succession des êtres vivants* (1846) and Chambers' progressive notion of transmutation (originally anonymously published) in *Vestiges of* *the natural history of creation* (1844). Thus, from the mid 18th century onward, there is a burgeoning β value for transmutation theories.

None of these theories would be endorsed by biologists today. Even though they have elements that are correct, they have a lot of assumptions that are now considered to be mistaken. For example, the notion of an inbuilt capacity for striving toward perfection, as marshaled by Lamarck and Chambers, is now uniformly rejected, as are other forms of teleological reasoning in biology (see section 9.2.2). From the perspective of biased cultural transmission, the initial correctness of theories is not important, rather, it is the diversity of the inferences and the size of the scientific community that increase the probability that some of these theories will become more truth-approximating than earlier ones. When more truth-approximating models are adopted by other members of the community, the quality of transmutational theories ratchets upward. This is in accordance with quantitative data on the size of the scientific community at the time. Shelishch (1982) has made estimates of the community size of active biologists (natural historians and natural philosophers) from 1760 to 1860. His numbers are an underestimation of the true size of the scientific community that was involved, as he only included prolific authors, and did not incorporate authors from related disciplines, like the geologist Charles Lyell, who were important for the development of transmutation theories. First, there is a slow linear growth in the community of biologists from 1760 to 1790, followed by a steeper growth in almost all biological fields from 1790 to 1860: in 1760, the number of active biologists was about 60, by 1820, it had increased to 160, and in 1860, it had reached 240.

The effects of N on the ability of a scientific community to maintain complex theories is shown in Fig. 12.2. Here, the Y-axis represents $\Delta\bar{z}$; the X-axis shows the number of interacting biologists N. The logarithmic curves indicate the scientific progress or decline with different values of α/β. The dashed line represents a simpler level of biological theorizing, $\alpha/\beta \approx 4.5$; the full line shows a more advanced level, $\alpha/\beta \approx 6$. The intersections of these curves with the X-axis indicate the critical value of N to maintain particular levels of biological theorizing. As can be seen, a group of 240 interacting naturalists can maintain a more advanced level of scientific knowledge than one of 60.

The model predicts that, given a larger N and a large β, scientific knowledge is likely to be more truth-approximating over time. Is this the

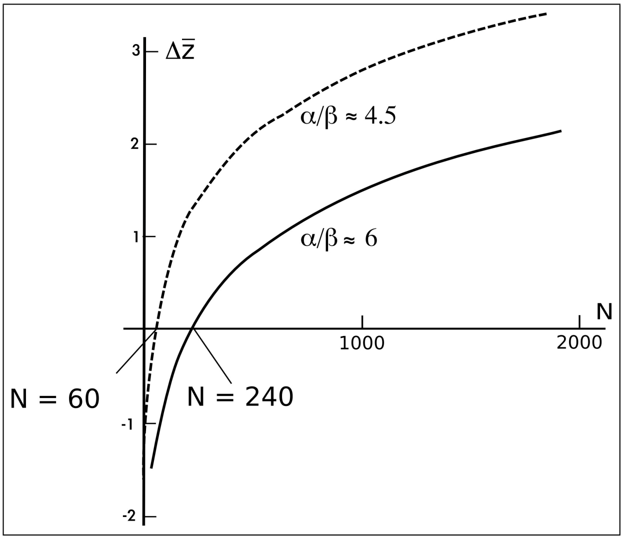

Figure 12.2: Relationship between values of N and complexity of biological theory that can be maintained. A community size of 240 active biologists can maintain more complex theories ($\alpha/\beta \approx 6$), compared to a population of 60 biologists ($\alpha/\beta \approx 4.5$).

case for theories on the transmutation of species? The $\overline{z}$ value of concepts of the transmutation of species increased during the late 18th to the mid 19th century, as more and more naturalists accepted transmutation and common descent, and started to elaborate on these theories. Even scholars originally opposed to the idea came to make active contributions to them. Richard Owen, for example, initially denied transmutation, but in his *On the nature of limbs* (1849) he argued that humans evolved from fish. In the course of the 19th century, these theories also became more accurate than their predecessors. For example, at the turn of the 19th century, the issue of extinction was still hotly debated. Some authors, like Lamarck (1809), thought that species do not go extinct but merely evolve into different species. By the 1830s, due to the work of paleontologists like, for instance, Georges Cuvier and Louis Agassiz, the factuality of extinction was no more in question (Herbert, 2005). Similarly, the persistence of some types of animals over several geological periods, such as the brachiopod *Lingula*, casted doubt on saltationist and catastrophist models of species origination that were common in the 18th century (Mayr, 1982).

Historical studies (e.g., Herbert, 2005) indicate that Darwin relied extensively on earlier transmutationist theories when conceiving his theory of natural selection. These sources included his own grandfather Erasmus Darwin, Lamarck (likely through the Lamarckian anatomist Robert Grant, who taught him at Edinburgh), Chambers (whose *Vestiges* was immensely popular at the time), and Karl Ernst von Baer's embryology, while he also extensively studied critiques of earlier transmutationist models. The increasing recognition of the influence of earlier transmutationist theories in Darwin's work supports the importance of scientific community size in scientific practice and discovery. More speculatively, Peter Bowler (2008) has argued that even if Darwin had never written *On the origin of species*, we would likely still have ended up with something like evolutionary theory today. Indeed, transmutation was widely accepted by the mid 19th century, and several authors, also building on contemporary literature, came up with elements of natural selection independently from Darwin. The physician William Wells proposed a mechanism akin to natural selection operating across human populations to account for variation in skin color and disease resistance in his posthumously published *An account of a female of the white race of mankind, part of whose skin resembles that of a negro; with some observations on the causes of the differences in colour and form between the white and negro races of men* (1818). Patrick Matthew (1831), a timber-merchant who saw the role of random variation in evolutionary change, published this idea almost as an afterthought in Note B (364–365) and in the final appendix (383–385) of his *On naval timber and arboriculture.* In a series of papers, the zoologist and animal trader Edward Blyth (e.g., *An attempt to classify the "varieties" of animals, with observations on the marked seasonal and other changes which naturally take place in various British species, and which do not constitute varieties*, 1835) discerned variation as a causal mechanism to explain why domesticates could revert to their wild types. And, as is well known, Wallace developed his own transmutation theory based on natural selection in two related papers (*On the law which has regulated the introduction of new species*, 1855, and *On the tendency of varieties to depart indefinitely from the original type*, 1858).

The case of the transmutation of species indicates that a large interacting scientific community, combined with an ability to draw many different kinds of inferences, can lead to more truth-approximating theories, even when constrained by cognitive biases, and starting with an initial low accuracy. The analytic model does not guarantee that our current scientific models would be correct. It also allows for the possibility that scientific knowledge declines, for example in the case of a strict orthodoxy that would prevent the generation of many different inferences, or if there were a severe decline in the community size of interacting scientists.

CONCLUDING REMARKS

The aim of this dissertation has been to create a naturalistic picture in order to obtain a better understanding of creative capacities that are specific to our species, focusing on artistic ability, religious reflection, and scientific study. By integrating data from diverse domains within a philosophical anthropological framework, I have presented a cognitive and evolutionary approach to the question of why humans engage in such activities.

Art, religion and science have traditionally been regarded as hallmarks of our species, as behaviors that set humans apart from other animals. Traditionally, their study lay exclusively within the domain of special sciences, such as aesthetics, sociology or history. However, the past 30 years have seen an increasing recognition of the importance of cognitive science in the philosophical and scientific understanding of these phenomena. This has resulted in a cognitive turn in fields of philosophy that have been concerned with these subject matters. This is not a concerted effort, but rather an independent evolution in diverse branches of philosophy in dialogue with the cognitive and evolutionary sciences.

How can we explain this growing philosophical interest for lower-level approaches? Perhaps it is a consequence of the increasing prominence of naturalism in philosophy. Since the second half of the 20th century, philosophers (e.g., Quine, 1969a) have begun to acknowledge that epistemology and other branches of philosophy should take into account that human reasoning processes are fully part of the natural, causal order. Thus, to understand the emergence and transmission of particular cultural phenomena, we need to understand the evolved cognitive underpinnings that constrain or facilitate this emergence or transmission of information (Sperber, 1985). Cognitive science, combined with an evolutionary understanding of the human mind, could provide a unified ontological framework for philosophical anthropology and the related field of philosophy of mind. At present, these philosophical disciplines lack a clear ontological framework. Philosophical anthropology is simply the study of human specificity or uniqueness, but it is difficult to gauge human uniqueness without a unifying explanatory framework in which the diversity of observations that fit in its study (such as art, religion or scientific practice) could be placed. Sperber (1996) remarked that (classical, non-cognitive) anthropology does not have an ontology either. Clearly, anthropology has concepts like KINSHIP or MARRIAGE, but these technical terms are defined mainly in terms of similarities or differences with other cultures. For example, institutions are termed marriages insofar as they have some resemblance to the modern western institution of marriage. Cultural deviations from this western concept (e.g., plural marriages, child marriages) require an extension of the concept, and such continued extensions of concepts have led to an illusion of infinite cultural variability. However, because anthropology lacks unifying ontological assumptions, there is no measure by which cultural diversity can be assessed. Undoubtedly, a spider would think that the variation in spider webs is very large, and would conclude on the basis of this that there are no universal norms or constraints that govern the diversity in arachnid constructions. By introducing cognitive and evolutionary perspectives, I have sought to provide a more solid footing for philosophical anthropological discussions of uniquely human behavior. In particular, I have argued that art, religion and science which are usually seen as achievements that are quite remote from ordinary modes of reasoning are subserved by evolved cognitive processes that serve functions in everyday cognitive tasks, that arise early and spontaneously in cognitive development, that are shared cross-culturally, and that have evolved in response to selective pressures in our ancestral past. These mundane cognitive processes provide a measuring rod with which we can assess a diversity of cultural phenomena; they form a unified explanatory framework to approach human culture. I have argued that we can explain *uncommon thoughts* (exceptional human achievements such as art, religion and science) in terms of interactions between *common minds*, ordinary human minds who share their knowledge through cultural transmission.

The introductory chapter 1 provided a brief review of extant philosophical, archeological and psychological theories on human uniqueness. As we saw there, a fundamental debate on the continuity between human and nonhuman cognition has been going on since Aristotle categorized us as rational animals. This debate has often been conducted in terms of stark opposition. Some (e.g., Darwin, 1871) have argued that human cognition is entirely continuous with that of other animals, only differing in degree and not in kind, whereas other authors have attempted to find a single defining feature that sets human cognition apart, such as cognitive fluidity (Mithen, 1996), or the use of symbols (Tattersall, 1998). However, as we saw in chapter 2, evidence from experimental and developmental psychology, paleoanthropology and archeology hints at a more complex picture. The human mental toolbox has properties that are continuous with reasoning in other animals, such as the ability to formulate intentional mental states or stimulus-independent thought, but has also properties that are discontinuous with it, such as counterfactual reasoning, or the ability to posit unobservables (like internal mental states or physical forces). Chapter 3 explored how it may be more productive to regard aspects of uniquely human cognition, such as language, in a modular, mosaic fashion, that keeps in mind that the human brain is composed of both phylogenetically old and novel, derived modules, rather than seeing human uniqueness in diametrical opposition to nonhuman animal cognition. Chapter 4 presented an evolutionary scenario to gauge how some aspects of human culture, such as our ability to engage in triadic interactions, can be plausibly explained as the outcome of ecological and social factors during hominid evolution.

In parts II, III and IV we saw how exceptional human cultural achievements are continuous with everyday, mundane actions and modes of thinking. According to the picture outlined here, there is a fundamental continuity between the scribbling of a two-year-old and the works of accomplished visual artists like Henri Matisse: both are governed by an intuitive design stance, are guided by the propensities of their perceptual systems (aesthetic sensitivity) and encode symbolic meaning in what they do (chapter 7). The propensities of a stable human cognitive architecture also constrain and guide the cultural evolution of art, such as in the selection for face-like stimuli in portraits, masks and busts all over the world, or in the increasing importance of bold lines and bright colors in abstract art (chapter 5). In the domain of religion, we have seen that sophisticated theological and philosophical arguments, such as the argument from design or the cosmological argument, are subserved by intuitions that spontaneously emerge in the preschool years. Appeal to a Designer is due to an early-developed intuition of design and teleology in nature (chapter 9); the inference to a First Cause stems from our ability to infer causes for contingent events and from our propensity to prefer agents as causes (chapter 10). We have also seen how intuitive ontologies, which govern our expectations about the physical, biological and psychological world, play a role in the development of scientific theories (chapter 11). This is not only the case for historical theories (e.g., medieval impetus theory in physics), but also for recent theories (e.g., paleoanthropology and its struggle with intuitions about human uniqueness).

As we have seen throughout this thesis, these cognitive capacities do not operate in a vacuum—rather, humans rely extensively on social networks to transmit information, and on their material environment to delegate and share cognitive tasks. Thus, in chapter 6, we saw that particular artistic traditions can be explained as a product of cultural group selection, where art objects are used as ethnic markers to signal cooperative intentions. Chapter 8 demonstrated that humans since the Late Pleistocene have extensively relied on material culture to store and transmit information that is hard to keep in memory. Chapter 12 explored how scientists can rely on biased cultural transmission to improve the accuracy of the models they develop: within an interacting scientific community, a diversity of inferences can lead to improvements in scientific knowledge.

Does this cognitive and evolutionary approach mean that the special sciences have become redundant in the study of uniquely human behavior? As is already clear from my extensive use of archeological, historical and cross-cultural data, these data are essential if we are to have a clear picture of stable aspects of human cognition. Archeology, for example, is crucial for testing hypotheses on human cognitive evolution, since it is the only science that studies the material marks of human behavior in the remote past. If cognitive and evolutionary theories provide a measuring rod to approach the diversity of human culture, manifestations of this diversity provide testcases against which cognitive and evolutionary hypotheses can be properly evaluated. Thagard (1989, 655) has emphatically stated that cognitive science should not come to replace the special sciences in our understanding of scientific practice. Indeed, as we have seen in section 5.5, a reasonable reductionism does not obviate the need for other approaches to cultural phenomena. It is not because we can understand some aspects of artistic ability and appreciation in terms of cognitive science that history or sociology of art become redundant. Rather, the emphasis on cognitive processes in this dissertation should be seen as complementary to other approaches. Ideally, in the future, these cognitive and evolutionary perspectives should be more fully integrated with results from the special sciences in order to get a better understanding of aspects of art, religion and science. Indeed, it could be argued that present-day cognitive scientists working in the fields surveyed here have a rather limited knowledge of special sciences like sociology, history, and anthropology. For instance, Hyman (2010) has criticized the neuroscientific work by Zeki (1999), Ramachandran and Hirstein (1999) and others on the grounds that they do not properly distinguish between our appreciation of the works of art and what they represent:

> The point I want to underline is that Ramachandran's theory of art (we can call it the *Baywatch* Theory of Art) doesn't distinguish between a work of art and the kind of object that it represents. For example, if (sic) it doesn't distinguish between a sculpture that represents a woman with big breasts and a woman with big breasts. And it follows that the theory cannot be telling us what "the key to understanding what art really is" (Hyman, 2010, 255).

Hyman may be conflating two things here: the usefulness of the theory and its scope. Indeed, it is true that what he terms "the *Baywatch* Theory of Art" does not distinguish between our aesthetic appreciation of an object and what it depicts (see also section 5.2), but this does not mean that said theory does not critically contribute to our understanding of aesthetic appreciation. Classical theories of art have not fully appreciated the cognitive limitations and possibilities that constrain and enable our appreciation and production of artworks. As we have seen in section 5.4, a better understanding of cognitive biases can help us to explain particular developments in the history of art. Cognitive neuroscientists find these cognitive underpinnings very interesting, because successful art provides a window onto invariant properties of human perception. The subject matter of art (such as faces, landscapes, children) also provides a novel insight into our evolved interests and tastes.

Theories and observations from the special sciences can help to further advance the cognitive study of art, religion and science. They can provide material to test ideas that have only been examined in the *in vitro* environment of laboratory studies, mostly with undergraduates from rich, industrialized nations or with infants and young children from the middle class of these same countries, using highly constrained and artificial experimental procedures. Indeed, as Henrich et al. (2005) have pointed out, the use of these *in vitro* studies does not capture the full diversity of human cognition and behavior. Moreover, an exclusive reliance on western subjects has the same distorting effect (Henrich et al., 2010). To give but one example, Bloom (2007) has argued that humans are intuitive psychological dualists mainly on the basis of experiments with five-month-olds that showed that infants initially do not extend their intuitive physics to human beings. However, as Hodge (2008) has shown on the basis of a survey of afterlife beliefs in diverse cultures, this picture may be too simple (see the introduction to part III). Indeed, in a large-scale corpus analysis of ancient Chinese texts, Slingerland and Chudek (in press) have demonstrated that Chinese make a distinction between material and immaterial parts of a person, but again, this is not simply the strong psychological dualism that Paul Bloom proposes: Chinese sources talk about the mind (*xin*, literally, the heart), the life force (*chi*) and the material body. Thus, while cross-cultural evidence supports Bloom's (2007) assertion that humans make an intuitive distinction between body and immaterial personhood, this rarely takes the shape of a straightforward Cartesian dualism. Hence the need to incorporate cross-cultural, archeological and historical examples in cognitive and evolutionary pictures of human behavior.

Throughout this thesis, there was a consistent focus on human behavior and the cognitive propensities that underlie it—not on the aesthetic qualities of the art objects, the validity of the theological arguments, or the veracity of the scientific theories. Indirectly, though, implications about these subject matters can be drawn, for example, the model outlined in chapter 12 provides a naturalistic mechanism for why theories tend to get better (and presumably more truth-approximating) over time. As we have seen, the cognitive and evolutionary approach to art, religion and science outlined here does not require positing overarching silver bullet theories that pinpoint a single cause of why we engage in these cultural activities. Rather, instead of searching for a grand theory that can explain all of human uniqueness, it seems more fruitful to formulate specific hypotheses about particular manifestations of human culture using an evolutionary and cognitive framework enriched with data from the special sciences—consilience of inductions is an important part of this research program.

Notes

[1] BP stands for 'Before Present'; it is a standard way in archeology to specify dates in the past. To avoid the problem of an ever-shifting present, by convention the term 'Present' refers to 1950, roughly the beginning of radiocarbon dating.

[2] An in-depth discussion of cultural evolution falls outside the scope of this dissertation. For a more detailed exposition, I refer to De Cruz and De Smedt (2004).

[3] In this respect, Mithen diverges quite sharply from the position he defended in 1996.

[4] The use of ethnological and anthropological parallels to examine archeological case-studies.

[5] As is common practice in philosophy and cognitive anthropology, small caps are used to denote concepts.

[6] Because this thesis is concerned with naturalistic views of concepts, I will here not discuss the vast philosophical literature that sees concepts as abstract objects (i.e., the Fregean tradition).

[7] inherited from a common ancestor.

[8] specialized, derived.

[9] The original study I cited to back this up was on cottontop tamarins (Hauser, Newport, & Aslin, 2001). In 2009, when I wrote the paper on which this chapter is based, Marc Hauser's scientific misconduct had not come to light yet. Given the retraction of a related paper in *Cognition* (Hauser, Weiss, & Marcus, 2002), which allegedly showed that cottontop tamarins are not only able to learn statistical regularities, but also more complex grammatical rules, I decided to replace this reference by another one. There is little evidence that nonhuman primates are able to learn complex grammatical rules.

[10] In a refitting process, archeologists try reconstruct the original stone by putting the flakes they find on an archeological site around the core that has been abandoned on the same site.

[11] Retrieved on November 15, 2008, from `http://www.foxnews.com/story/0,2933,312446,00.html`.

[12] 'Nonwestern art' is the term routinely used for artistic traditions from outside of the West, specifically art made by the indigenous populations of Africa, Asia, Oceania, and the Americas.

[13] To give my own example—and one that actually happened to me: during a conference last year, I saw a philosopher I had met on an earlier occasion. This gave rise to the justified belief 'x is also attending the conference'. However, it later turned out that the person I saw was not x, but his twin brother. Both were attending the conference—actually, they were presenting a joint paper, which was a rare occasion for them, since they normally worked in quite different fields (physics and philosophy, respectively). Thus, my earlier-formed belief was true and justified, yet one could argue that that belief was not knowledge.

[14] The term 'aesthetic experience' refers to sensory and qualitative appreciation that involve a subjective sense of pleasure—it is not restricted to art, but can also be elicited by other stimuli, like a beautiful landscape.

[15] The golden ratio is the relationship between two quantities, for example, the length and width of a rectangle, where the ratio of the sum of the quantities to the larger quan-

tity is equal to the ratio of the larger quantity to the smaller one; it is approximately 1.618.

[16] *Contrapposto* is a term for a dynamical position of a human figure, where its weight is shifted onto one foot (a well-known example is Michelangelo's *David*).

[17] 'Academic art' denotes paintings and sculptures in a style that was taught at European academies of the arts, mainly during the 18th and 19th centuries.

[18] In this chapter, we will make use of one particular derivation of the Price equation. In chapter 12, we will use a different derivation of the Price equation.

[19] There was a second refugium (a region where isolated populations of once more widespread species persist) in the Italic peninsula and the southern Balkan and the eastern European plains which we disregard here, since these people did not give rise to the Magdalenian cultural complex. The Epigravettian, the culture in these latter refugia, was distinct from the Magdalenian and its predecessor the Solutrean. It also persisted until the Holocene, but its spread after the Last Glacial Maximum was less successful and less uniform than that of the Magdalenian.

[20] BBC, 22 January 2002, `http://news.bbc.co.uk/2/hi/science/nature/1753326.stm`.

[21] Dating Australian rock art is notably difficult. Many of the pigments are impossible to date directly. Some paintings from the Kimberley region (northwestern Australia) no longer have original pigment, making direct dating impossible. In these sites, the paint has been replaced by a biofilm of living, pigmented micro-organisms whose natural replenishment may account for the longevity of these paintings (Pettigrew et al., 2010). The oldest absolute dating of Australian rock art is a luminescence dating of 17,500 BP (Kimberley region), which actually dates an ancient mud wasp nest that was positioned over the painting (R. Roberts et al., 1997). However, a compelling case can be made for an earlier date for figurative art in Australia, based on indirect evidence. As we shall see in section 8.4, many of these paintings show accurate, naturalistic depictions of extinct animals such as marsupial carnivores (Fig. 8.1) and giant kangaroos, species that died out between 46,000 and 40,000 BP (R. G. Roberts et al., 2001). This means that either the paintings are ancient, or that they are part of an ancient visual tradition that goes back to at least 40,000 BP, since it would otherwise be very hard to explain how the painters could have made these pictures so accurately. (There is some evidence that the demise of the Australian megafauna happened much later in New South Wales. For example, Field, Fullagar, and Lord (2001) claimed that it persisted up to about 30,000 BP, but New South Wales and the Kimberley region lie thousands of kilometers apart, so it is not very likely that the Kimberley artists were familiar with the ecology of New South Wales.)

[22] These hand stencils have not been dated directly; rather, what has been dated is a thin layer of calcite overlaying these paintings. This was done using Th/U, which is a dating method with a wide error margin, hence this wide window.

[23] E.g., `http://news.bbc.co.uk/2/hi/8544332.stm`.

[24] Commonly but erroneously referred to as the Dreamtime. The Dreamtime is the period when the world was created by ancestral beings; the Dreaming is a story that explains the creation of the world within a particular cultural group setting.

[25] In a Lakatosian sense, CSR is a successful research program with at its core the assumption that religion is a product of natural, ordinary cognitive processes, but aside from this it is more a 'movement' among cognitive scientists, anthropologists and

philosophers than a unified research effort.

[26] In canon 1, see `http://www.fordham.edu/halsall/basis/lateran4.html`.

[27] Unfortunately, it seems impossible to find out who first coined this term as there are contradictory accounts of it in circulation.

[28] A few thousand Greek Neopagans notwithstanding.

[29] see, for example, `http://www.hudson-ny.org/1384/europe-decoy-jews`.

[30] I spent several years (intermittently) trying to find the original mention of this powerful image. In the end, I stumbled upon a 1981 edition of *Nature* where an anonymous author had written a piece on *Hoyle on evolution*, which to my knowledge is the first mention of this metaphor.

[31] In the discussion of the causal principle, this chapter will leave aside inductive versions of the cosmological argument, such as Swinburne's (2004), which is based on considerations of simplicity.

[32] The hāḍith are attested narratives of the sayings, actions and tacit approvals and accounts of the Islamic prophet Muhammad. In the Islamic world, these play an important role in jurisprudence and theology (Abdel Haleem, 2008).

[33] Hume believed that our causal intuitions are purely based on the perceived covariation of events. As will be argued in more detail further on, contemporary cognitive science indicates that people are also able to infer causal relationships for unique events if they can identify a plausible mechanism that connects them.

[34] The most recent genetic studies based on comparisons of complete hominid genomes hint at a more complicated picture. Apparently, *Homo sapiens* arose relatively late in Africa, around 200,000 BP according to genetic material (Tang, Siegmund, Shen, Oefner, & Feldman, 2002), and around 195,000 BP according to archeological evidence (McDougall, Brown, & Fleagle, 2005). Once our species left Africa in diverse waves between 125,000 and 40,000 BP (e.g., Armitage et al., 2011), it experienced limited gene-flow due to some amount of interbreeding with remnant ancient hominid populations, in particular *Homo neanderthalensis* (Green et al., 2010) and an as yet unnamed Siberian hominid species based on the finds of a tooth and a finger bone at Denisova Cave (Reich et al., 2010).

[35] BBC, 16 June 2005, `http://news.bbc.co.uk/2/hi/science/nature/4082078.stm`.

[36] E.g., BBC, 20 October 2010, `http://www.bbc.co.uk/news/health-11572894`.

[37] This broad position is not to be confused with evolutionary psychology in the narrow sense as developed by the 'Santa Barbara school', in particular by John Tooby and Leda Cosmides, see sections 2.2.3 and 5.3 for brief discussions of this research program.

[38] This is a type of extreme probability distribution that models long (finite) sequences of random variables.

[39] as supplementary material with the online first version of the paper on the Springer website `http://www.springerlink.com/content/t2443r31h7057093/`.

[40] Transmutation is a historical term for what is now denoted by biological evolution which avoids the anachronism of 'pre-Darwinian evolutionary theory'. The term 'evolution' was not routinely used to denote the natural development of life on Earth until Herbert Spencer popularized this sense of the term in the second half of the 19th century. Darwin, for example, in his *Origin of species* (1859), only once used the derivative 'evolved' (it is actually the last word of the book).

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