The New Brain Sciences

Perils and Prospects

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CAMBRIDGE
UNIVERSITY PRESS

2 The definition of human nature

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Our definition of human nature gives us a conceptual foundation for our ideas about human rights, individual responsibility, and personal freedom. These ideas were originally derived from the liberal humanities, and are ultimately the secular modern descendants of the concept of a 'natural law' based on earlier religious and philosophical traditions. In this context, this is not a trivial exercise. It provides a conceptual foundation for our legal system, as well as our constitutional protections of human rights. Since the time of Charles Darwin there have been many attempts to define human nature in more scientific terms. In effect, this has amounted to an attempt to derive a new kind of natural law, based largely on scientific evidence, and especially on the theory of evolution. Here I am not speaking of Social Darwinism, an earlier intellectual movement that naively tried to extrapolate the laws of natural selection to human society, but of more recent empirical attempts to construct a culturally universal description of the human condition, and to explain it in terms of evolution and genetics.

In such attempts, human nature is usually defined as having been fixed when our species evolved in the Upper Palaeolithic, and this suggests that we have been genetically engineered to survive under the special conditions of late Stone Age civilisation. This raises the disconcerting possibility that human nature might prove to be maladaptive in today's high-tech, fast-moving, urbanised world. On the other hand, the logic leading to this conclusion is not compelling. It is based on two assumptions. The first is that human beings have a fairly rigid set of constraints on their mental and social life, imposed

The New Brain Sciences: Perils and Prospects, ed. D. Rees and S. Rose.
Published by Cambridge University Press.

by an inflexible genetic inheritance. The second is that human mental and social life is determined largely by organismic variables, and that the human mind can be treated like that of any other species.

But there is an alternative view of human nature, based on scientific evidence and evolutionary theory that comes to a different conclusion, and fits existing scientific evidence better. It is based on a different set of assumptions. The first is that human nature has been characterised by its flexibility, not its rigidity. This is due largely to the overdevelopment of conscious processing, and those parts of the brain that support it. The second is that human beings, as a species, have evolved a completely novel way of carrying out cognitive activity: distributed cognitive–cultural networks. The human mind has evolved a symbiosis that links brain development to cognitive networks whose properties can change radically. Critical mental capabilities, such as language and symbol-based thinking (as in mathematics) are made possible only by evolving distributed systems. Culture itself has network properties not found in individual brains. The individual mind is thus a hybrid product, partly organismic in origin, and partly ecological, shaped by a distributed network whose properties are changing. Our scientific definition of human nature must reflect this fact, and free itself, not only of pre-scientific notions about human origins, but also of restrictive and antiquated notions about organismic evolution.

One consequence of this idea is that 'human nature', viewed in the context of evolution, is marked especially by its flexibility, malleability and capacity for change. The fate of the human mind, and thus human nature itself, is interlinked with its changing cultures and technologies. We have evolved into the cognitive chameleons of the universe. We have plastic, highly conscious nervous systems, whose capacities allow us to adapt rapidly to the intricate cognitive challenges of our changing cognitive ecology. As we have moved from oral cultures, to primitive writing systems, to high-speed computers, the human brain itself has remained unchanged in its basic properties, but has been affected deeply in the way it deploys its resources. It develops in a rapidly changing cultural environment that is largely of its own making. The result is a species whose nature is unlike any other on this planet, and whose destination is ultimately unpredictable.

HUMAN ORIGINS

Anatomical and DNA evidence suggests that we emerged as a new species about 160 000 years ago in Africa, and then migrated over most of the Old World, replacing all other existing hominids. The human adventure had its starting point with the Miocene apes of Africa, which existed about 5 million years ago, and were our common ancestors with modern chimpanzees and bonobos. The primate line that led to humanity diverged from the orang-utans about 11 million years ago, from gorillas about 7 million years ago, and from a species similar to modern chimpanzees about 5 million years ago. The next phase of the human story proceeded through a series of intervening human-like or hominid species, which provide a well-documented morphological linkage to our distant ape cousins. The first to diverge in the human direction were the australopithecines, who dominated the hominid niche from 4 million until about 2 million years ago. This species crossed a major hominid threshold, in becoming the first primate species to walk erect. However, their brains did not increase greatly in volume from those of their ape-like predecessors. Although this period saw the emergence of some important human traits, such as pair-bonding, there is no good evidence to suggest that australopithecines made any major progress toward our distinctive cognitive capacities.

The first move in that direction came much later, about 2 million years ago, with the first member of the genus *Homo*, *Homo habilis*. Habilines had brains that were slightly larger than those of their predecessors and had a characteristically human surface morphology. This change was the result of an expansion of tertiary parietal cortex, and remains characteristic of modern humans. Habilines were replaced, only a few hundred thousand years later, by larger hominids that were much more human-like in appearance, and had a much higher encephalisation, or brain–body ratio, which eventually reached about 70% of that of modern humans. These archaic hominids, variously called *Homo erectus*, archaic *Homo*, or pre-sapient *Homo*, had larger brains gained at the expense of a reduced gut size, a metabolic trade-off necessary to service their energy-expensive brains. This means that they could not have scavenged for a living, and probably had to pre-process foods, such as root vegetables and meat, before such foods would have been digestible. This demanded a considerable improvement in cognitive capacity, since pre-processing food requires foresight, and the tools needed for this required the diffusion of complex skills to all members of the hominid group. Very soon after appearing in Africa, *Homo erectus* migrated to Eurasia, and over the next few hundred thousand years began to domesticate fire, eventually mastering the considerable technical demands of its continuous use. *Homo erectus* also developed better stone tools (the so-called Acheulian tool culture, which originated with them, continued in use for well over a million years), and underwent a series of other major changes, including the adoption of progressively more challenging campsites, which were sometimes far removed from the sources of toolmaking materials and water. This implies changes in their strategies for finding and transporting food and water, their division of labour, and their diet and hunting capabilities. I have referred to this long period as the first transition; that is, the first period during which hominids took major steps towards the development of the modern form of the human mind.

The second transition occurred much later, starting about 500 000 years ago, and ended with the appearance of our particular species. This period was marked by a pattern of rapid brain expansion that continued until relatively recently. One of its prominent features was the appearance of the Mousterian culture, which lasted from about 200 000 to about 75 000 years ago, and had such distinct features as the use of simple grave burials, built shelters and systematically constructed hearths. The Mousterian toolkit was more advanced, and included more differentiated types of tools, and better finish. These two transitions culminated in our own speciation, and might be taken as the end of the human story, from a biological standpoint.

But from a cognitive standpoint, it was not the end. I have proposed a third transition, one that was largely culturally driven, and did not involve much, if any, further biological evolution. Nevertheless, the cognitive grounds for postulating this third transition are identical to my reasons for postulating the first two: fundamental changes in the nature of mental representation. This third period of change, which started about 40 000 years ago and is still under way, was characterised by the invention and proliferation of external memory devices. These included symbols, and the use of symbolic artefacts, including scientific instruments, writing and mathematical systems, and a variety of other memory devices, such as computers. Its greatest product was the growth of cognitive networks of increasing sophistication. These networks, which include governments, and institutionalised science and engineering, perform cognitive work in a different way from individual minds. This has produced a cognitive revolution that is easily a match for the two previous ones.

These periods of transition form a chronological backbone for any scenario of cognitive evolution, but do not constitute the primary evidence for a deeper cognitive theory of origins. The most important evidence for the latter comes from cognitive science and neuroscience. One of the most controversial issues revolving around human evolution is the question of whether humans have specialist or generalist minds. There is some evidence to support both positions. On the one hand, we have some unique intellectual skills, such as language and manual dexterity, that seem to call for a specialised brain. Such skills are defined as innate or instinctual by many theorists, because they are found universally in all cultures, and are difficult or impossible to change. They are regarded as an integral part of human nature, built right into the genome, and the result of adaptation to environmental pressures that were specific to the time of our speciation.

On the other hand, the human mind is notable for its flexibility and general-purpose adaptability. Our abstract thinking skills can be applied in a number of domains, such as mathematics or polyphonic music, that did not exist at the time we evolved. Thus, our proficiencies in these areas could not be the result of the direct evolution of specialised abilities in maths and music, since natural selection can only act upon existing alternatives. The evidence we have on the human brain seems to rule out the strong form of the notion that the power of the human mind is the result of many specialised neural adaptations. We have many examples of specialisation in other species, and we know what such adaptations look like. Such cognitive abilities usually reside in identifiable neural structures, or modules. For instance, birdsong resides in certain clearly delineated brain nuclei that are uniquely developed in songbirds. There are dedicated neural modules of this sort in many species, supporting such capacities as echolocation in bats, magnetic navigation in migrating birds, and stereo vision in primates, and they all depend upon specialised sensory organs, with associated brain structures. Humans have the specialist profile common to primates, including excellent stereo vision, but, with the exception of our vocal tract, we have no modules that are unique to us. Some thinkers seize upon spoken language as a unique specialist adaptation, and, to a degree, it is. But the catch is that we do not need our vocal tract to produce language. Sign language, as spoken by the deaf, makes no use of our special vocal apparatus. Moreover, although it is normally localised on the left side of the brain, language does not seem to be restricted to any particular lobe, or subsection, of the association cortex, or even to the left side. Thus, it is difficult to claim that there is a neural module for it.

If we review the deep history of the vertebrate brain, we find that very few new modules have evolved during its 500 million years of evolution, and that each has taken a great deal of time. For example, the motor brain underwent a major modular reorganisation after vertebrates moved onto land, and the standard motor brain architecture of land animals, particularly that of the higher mammals, is quite different from that of aquatic species. However, the aquatic brain is retained, virtually intact, within our nervous system, although it has been surrounded by powerful new modules. The aquatic brain evolved to control the wriggling movements, and alternating rhythms, typical of fishes. But a complex web of other structures has evolved to support the many new demands faced by land vertebrates. The neuropsychological study of the component structure of the human brain has not turned up any truly novel structures, in the form of lobes, nuclei or ganglia that do not have an equivalent homologue in apes, or any new transmitter systems, neurotubular networks, or even dendritic structures that are completely unique to our species. Admittedly, the human brain's enlargement is unprecedented, and there have been some epigenetic changes in synaptic growth patterns and interconnections, but the basic architecture of the primate brain was not changed by this expansion. The most dramatic change in connectivity is in the prefrontal cortex (see Deacon, 1996), where a disproportionate increase has caused the frontal cortex to split into subregions and invade areas that it does not typically infiltrate in other species. Our frontal lobes have more influence, and our species is highly frontalised in its intellectual strategies. Moreover, the association zones of our neocortex, cerebellum and hippocampus are much larger than corresponding structures in chimpanzees. But even this trend is not unique to us. The increased encephalisation of primates has been ongoing for tens of millions of years, and roughly the same structures have continued to increase in our own species. Just as there was a tripling of brain size between primitive monkeys and chimpanzees, there was a tripling between apes and us. This presents us with several questions. If humans inherited a brain architecture that is relatively universal in the higher vertebrates, how is it that our minds are so special? How could we have evolved capacities for language, art and technology without much change at the modular level in the nervous system, given that less drastic cognitive changes in many other species have required new modules?

One answer is to remember that brain evolution cannot explain everything about us. Culture is a huge factor in human life, and the distributed networks of culture have been accumulating knowledge since very long ago. The presence of culture as an immense collective cognitive resource is a novel development in evolution. Culture is constrained by biology, of course, and there is often a delay between evolutionary changes in the brain and major cultural advances. For example, improved tool use and the domestication of fire came many generations after the period (about 2 million years ago) when there was rapid hominid brain evolution. These large time lags between neural and cultural change suggest that the increase in brain size was not initially driven by immediate improvements in toolmaking and fire-tending; they had not yet happened. The human brain evolved most of its physical features for other reasons, related to such things as diet, habitat, social coordination and developmental plasticity. Our major cultural achievements have evidently been the delayed by-products of biological adaptations for something else. The same is true of the second great hominid brain expansion which accompanied the emergence of our modern vocal apparatus. Our brains reached their modern form less than 200 000 years ago, but evidence of rapid cultural change only appeared around 50 000 years ago. Our larger brain and vocal tract must have been the products of other significant fitness gains, perhaps related to survival during the Ice Ages, which did not cause an immediate revolution on the cultural level. Vocal language could have been the major change, and would not have left any immediate evidence of its arrival. The long-term result was increased cognitive plasticity. The implication is that archaic humans evolved a set of flexible intellectual skills that led to gradual and continuous cultural change.

CROSSING THE RUBICON

The key to rapid cultural change is language. Humans are the only minds in nature that have invented the symbols and grammars of language. Some apes can be trained to use human symbols in a limited way, but they have never invented them in the wild. This even applies to enculturated apes who have acquired some symbolic skills, and we conclude from this that the mere possession of symbols cannot in itself bring about radical change. It is the capacity to create symbols that they lack. Crossing the abyss between pre-symbolic and symbol-driven cognition was a uniquely human adventure, and consequently there is a huge gap between human culture and the rest of the animal kingdom. Any comprehensive theory of human cognitive evolution ultimately stands or falls on its hypothesis about how this gap came to be bridged.

Cognitive science is broadly divided between the artificial intelligence, or AI, tradition, which builds symbol-driven models of mind, and the neural net tradition, which develops models of simulated nervous systems that learn without using symbols, by building hologram-like memories of experience. A neural net is basically a tabula rasa network of randomly interconnected memory units, which learns from environmental feedback, by building associations in a relatively unstructured memory network, much the way many animals do. Artificial intelligence models, on the other hand, depend on preordained symbolic tools – in the form of elementary categories and rules – given to them by a programmer, and these are used to construct symbolic descriptions of the world, rather like those that humans build with language. But there is a crucial difference between such artificial expert systems and the human mind. Expert systems have no independent knowledge of the world, and remain locked in at the symbolic level, so that to understand a sentence, they are limited to looking up symbols in a kind of computational dictionary, each definition pointing only to more words or actions, in endless circles of dictionary entries. In such a system, there is no path back to a model of the real world, and symbols can only be understood in terms of other symbols. Since, as Wittgenstein observed, the vast majority of words cannot be adequately defined with other words, this is not a trivial limitation. The development of the AI tradition has run into a brick wall, as Dreyfus predicted twenty years ago, precisely because it cannot cross the boundary-line between pre-symbolic and symbolic representation, and access the holistic, non-symbolic kinds of knowledge that humans use to inform their symbolic constructs.

The key question of human cognitive evolution might be rephrased in terms of this dichotomy: somewhere in human evolution the evolving mammalian nervous system must have acquired the mechanisms needed for symbol-based thought, while retaining its original knowledge base. To extend the metaphor, it is as if the evolving mammalian mind enriched its archaic neural net strategy by inventing various symbol-based devices for representing reality. This is presumably why the human brain does not suffer from the limitations of AI; it has kept the basic primate knowledge systems, while inventing more powerful ones to serve some non-symbolic representational agenda. But, how could the evolving primate nervous systems of early hominids have crossed the pre-symbolic gap? What are the necessary cognitive antecedents of symbolic invention? Cognition in humans is a collective product. The isolated brain does not come up with external symbols. Human brains collectively invent symbols in a creative and dynamic process. This raises another important question: how are symbols invented? I attribute this ability to executive skills that created a nervous system that invented representation out of necessity.

When considering the origins of a radical change in human cognitive skill, we must look at the sequence of cultural changes, including the cultures of apes and hominids. The cognitive culture of apes can be epitomised by the term 'episodic'. Their lives are lived entirely in the present as a series of concrete episodes, and the highest element of memory representation is at the level of event representation. Animals cannot gain voluntary access to their own memory banks, because, like neural nets, they depend on the environment for memory access. They are creatures of conditioning, and think only in terms of reacting to the present or immediately past environment (this includes even their use of trainer-provided symbols, which is very concrete). Humans alone have self-initiated access to memory. This may be called autocueing, or the ability to voluntarily recall specific memory items independently of the environment. Consider an animal moving through a forest; its behaviour is defined by the external environment, and it can be very clever in dealing with that environment. But humans can move through the same forest thinking about something totally unrelated to the immediate environment – for instance the recent election, a movie or an item in the newspaper. In thinking about some topic, the thinker pulls an item out of memory, reflects on it, accesses another memory item, connects this to the previous idea, and so on, in recurrent loops. This reflective skill depends on voluntary autocueing; each memory item is sought out, precisely located and retrieved, preferably without retrieving a batch of other unwanted items, and without relying on the environment to come up with the relevant cues to help find the item. Our ability to transcend the immediate environment could not have developed without autocueing skill. Note that I am not saying we can introspect on the process by which we voluntarily access memory. We do not have to be aware of the retrieval process to have voluntary control over it. Language is 'voluntary' cognition, but we have no awareness of where the words are coming from when we speak. The first symbolic memory representations had to gain explicit access to the implicit knowledge latent in neural nets. The initial adaptive value of the representational inventions of early humans would have been their ability to provide retrieval paths to a knowledge base that was already present, but not voluntarily accessible, in the primate brain. But, given the functional arrangement of the primate brain, where would such paths have been built?

THE FIRST STEP TO LANGUAGE: MIMESIS

The first cognitive transition occurred between 2.2 and 1.5 million years ago, when major changes in the human genome culminated in the appearance of *Homo erectus*, whose achievements indicate some form of improved memory capacity. This species produced (and used) sophisticated stone tools, devised long-distance hunting strategies, including the construction of seasonal base camps, and migrated out of Africa over much of the Eurasian land mass, adapting to a wide variety of environments.

Many evolutionary theorists are fixed on the idea that there was only one great cognitive breakthrough for humans: language, that this breakthrough came early, with *Homo erectus*, and that all higher human mental abilities followed from it. Bickerton (1990) argued that some form of proto-language must have existed at the time of *Homo erectus*, which might explain early hominid cultural achievements with a single adaptation – a sort of grammarless language – that later evolved into modern speech capacity. Pinker (1994) has suggested that grammar itself started its evolution early, and that some parts of a language module must have already been in place in *Homo erectus*.

I find this unconvincing. First, archaeological evidence doesn't place speech so early in evolution; neither of the principal markers for human language – the descended larynx and rapid cultural change – appears in the archaeological record until *Homo sapiens*, who evolved more than a million years later. Second, early hominids had no existing linguistic environment, and even proto-language would have required a capacity for lexical invention. This issue is crucial, because it raises the question of the autocueing of memory: lexical inventions must be self-retrievable, that is, autocueable. True linguistic symbols, even the simplest, could not suddenly pop up in evolution before there was some principle of voluntary memory retrieval in the hominid brain; to be useful, lexical inventions had to be voluntarily retrievable and modifiable, as well as truly representational acts, intentionally modelling some aspect of reality.

Before lexical invention became a realistic possibility, it was necessary to establish voluntary retrieval, or autocueing, in the pre-linguistic brain. The same adaptation would also have provided the cognitive prerequisite for a number of non-verbal representational skills. After all, language is not the only uniquely human cognitive advantage that has to be explained in evolution (Premack, 1986). If all our higher thought-skills were based on our linguistic capacity, how could we account for the virtual autonomy of some non-verbal forms of human intelligence? A good evolutionary theory of pre-linguistic adaptation should try to account for as many of these skills as possible, while providing the cognitive grounds for language.

My key proposal is that the first breakthrough in our cognitive evolution was a radical improvement in voluntary motor control that provided a new means of representing reality. *Homo erectus*'s gift to humanity was mimetic skill, a revolutionary improvement in voluntary motor control, leading to our uniquely human talent for using the whole body as a subtle communication device. This body skill was mimesis, or a talent for action-metaphor. This talent, without language, could have supported a culture that, in terms of its tool-making abilities, was much more powerful refinements of skill, and flexible social organisation, than any known ape culture.

Mimetic skill logically precedes language, and remains independent of truly linguistic modes of representation. It is *the* basic human thought-skill, without which there would not have been the evolutionary opportunity to evolve language. Mimesis is an intermediate layer of knowledge and culture, and the first evolutionary link between the pre-symbolic knowledge systems of animals and the symbolic systems of modern humans. It is based in a memory system that can rehearse and refine movement voluntarily and systematically, in terms of a coherent perceptual model of the body in the surrounding environment, and is based on an abstract model of models that allows any action of the body to be stopped, replayed and edited, under conscious control. This is inherently an autocueing route, since the product of the model is an implementable self-image. Although the precise physiological mechanism of this system is not known, its functional retrieval path employs kinematic imagery. The principle of retrievability was thus first established at the top end of the motor system; and retrievable body-memories were the first true representations.

Mimesis is a supramodal skill. A mimetic scenario can be acted out with eyes, hands, feet, posture, locomotion, facial expression, voice, or any other motor modality, or combination of modalities. This is evident in the uniquely human behaviour pattern known as rhythm, which is the motor translation of an abstract sound pattern, or the conversion of sound into motion. Rhythm is truly supramodal: revellers at a rock concert use every muscle in their bodies to convert an abstract sound pattern into movement. But the more complex human motor skills necessitate more than a capacity for supramodal rehearsal: they also require a capacity for purposive sequencing of large-scale patterns of action over longer periods of time, such as those used in advanced toolmaking. This assumes a larger self-modelling capacity whereby a series of actions can be imagined and then altered or re-sequenced. This kind of extended kinematic imagination is still the basis of human non-verbal imagination, and is essential to the training of those who work with the body, such as actors and gymnasts. Although it is sometimes seen as primarily visual, non-verbal imagination is a body-based skill that captures visual images in its wake. It is not an accident that the ancient mnemonic method favoured by the Greeks and later European cultures did not rely on static visual imagery, but rather on generating an image of self-motion inside an imaginary visual space, where the kinematic image was made the engine of visual recall.

The universality of these uniquely human body skills is still evident in children of all cultures, who routinely practise and refine their motor skills without training or conditioning; images of boys bouncing a ball off the wall over and over again, or girls skipping a rope endlessly, come to mind. An advance in human motor representation of this magnitude would automatically have had ramifications in the area of expressive capacity. Actions and events could be represented and re-enacted independently of the environment; and this resulted in improved toolmaking and tool use, and in constructional and other instrumental skills. But, as in many evolutionary adaptations, mimetic skill would have had unforeseen consequences: now hominids had a means of re-presenting reality to themselves and others, by the use of voluntary action. This means that hominids could do much more than rehearse and refine existing movement patterns; they could also imagine and invent completely new ones, as human gymnasts, dancers, actors and divers still do. And they could re-enact events and scenarios, creating a sort of gestural proto-theatre of everyday life. The body became a tool for expression; it was just a matter of discovering the social utility of this possibility.

The expressive and social aspect of human mimetic skill may be called pure mimesis. For a long time (more than a million years) hominids subsisted on a mimetic culture based on improved voluntary motor skill, extensive use of imitation for pedagogy and a much more sophisticated range of voluntary facial and vocal expressions, along with public action-metaphor, which formed the basis of most custom and ritual. Could such a language-less culture have carried *Homo erectus* to the heights he achieved? There is strong support for the power and autonomy of non-verbal mind in the study of modern humans. One line of evidence is the enduring cultural autonomy of mimesis. Whole areas of modern human culture continue to function magnificently with a minimal use of language. These include the practice and teaching of many crafts and occupations: games, especially children's games; many aspects of custom, social ritual and complex interactive scenarios such as those documented by Eibl-Eibesfeldt (1989) and others (Argyle, 1975); athletic skill; and many group expressive customs – for instance, the systematic use of group laughter as a means of ostracism or punishment, and culture-specific customs for indicating deference, affection, manliness, femininity, tolerating pain, celebrating victory, maintaining group solidarity, and so on. These aspects of culture do not depend on language skill, either in their original invention, or in their transmission from one generation to the next.

Another line of evidence is neurobiological. These areas of skill are typically resilient in certain cases of global aphasia. This is especially clear in temporary aphasias caused by some types of epilepsy, where patients may lose all use of language (including inner speech) for a few hours, but remain conscious and able to function on a non-symbolic level. They can still find their way around in a purposive manner, operate a relatively complex device like a radio or elevator, and manage mimetic social communication (for instance, they know when they are having a seizure and can communicate this to others by gesture). This implies that mimetic skills come from an autonomous level of representation in the brain, unaffected by temporary but complete loss of language.

Further evidence for the independence of pure mimesis comes from the documented lives of illiterate deaf people from the eighteenth and nineteenth centuries, before the diffusion of formal sign languages. Without any training to help them communicate, such individuals had to survive without the lexical, syntactic or morphological features of language. They could not hear, and thus did not have a sound-based lexicon of words; they lacked an oral lexicon; they could not read or write and thus lacked a visually based lexicon; and in the absence of a deaf community with a formal sign language, they had no signing lexicon. None of the lexical components of language was available, and this would have eliminated the possibility of constructing anything we might recognise as true linguistic representations. Yet, they often lived remarkable lives (Lane, 1984), and by recorded accounts were quite sophisticated in their use of pure mimesis, both in constructional skill and in communicative and metaphoric gesture.

Mimetic representation is an autonomous, uniquely human level of mind that still supports the non-linguistic cognitive infrastructure of human society. It allowed humans to break the primate mould and construct retrievable memory representations for the first time. It also led to a slow-moving process of cultural change that culminated in the distinctively human cultures of late *Homo erectus*, and set the stage for a second drastic innovation that would create a much more powerful representational device.

THE SECOND STEP: MYTHIC CULTURE

The second transition, from mimetic to mythic culture, was made possible by language. As a result, the scattered, concrete repertoire of mimetic culture came under the governance of narrative thought and ultimately, integrative myth. Archaeological markers indicate that a long transition period, from 500 000 to 100 000 years before present, preceded the appearance of modern *Homo sapiens*. This is the period when language is most likely to have evolved. Language involves a different type of cognitive operation from the holistic motor strategy underlying pure mimesis. It depends primarily upon a capacity for inventing and retrieving thousands of lexical items – words – along with the rules that govern their use, and constructing narrative commentaries out of these lexical items. Words were the first true symbols, and language in this sense is the signature of our modern human species. Evolutionary pressures favouring such a powerful representational device would have been much greater once a mimetic communicative environment reached a critical degree of complexity. Mimesis is inherently an ambiguous way of representing reality, and words are an effective means of disambiguating mimetic messages. Modern children still acquire speech in this way, with most of their early utterances embedded in mimetic exchanges, such as pointing, tugging, prosodic voice sounds, eye contact, non-linguistic sounds and gestures, and mimetic whole body movement. Even when the young child is talking to itself, it is usually in a mimetic context.

Lexical invention is a constant process of labelling, defining and differentiating aspects of the perceived world (including the products of speech itself). Humans are constantly inventing new lexical items or acquiring them from others, and oral languages are seldom static for long. This reveals a continuing tension between lexical inventions and their significations, as if there was a natural tendency for the system to keep differentiating and defining reality. Like mimesis, language is at core a thought-skill, but rather than using the holistic, quasi-perceptual strategy of mimetic motor skill, it employs true symbols and constructs narrative descriptions of reality.

Spoken language provided humans with a second form of retrievable knowledge and a much more powerful way to format their knowledge. The natural product of language is narrative thought, or storytelling. Storytelling had a forerunner in mimetic event re-enactment, but is very different in the means by which it achieves its goal, and much more flexible in what it can express. Mimetic re-enactment is bound to imagery of the original event being depicted, but the quintessential narrative act – verbally labelling agents, actions and their relationships – lifts the observer outside of space and time, allowing the component parts of the story to be examined, reassembled and shared much more freely.

Spoken language altered human culture not merely in the number and complexity of available words and grammars, but in the shared products of oral cultures. The collective use of narrative thought led inevitably to standardised descriptions: shared, agreed-upon versions of past events. These formed the basis of myth and religion, which were the direct products of evolving linguistic skill. It is telling that mythic invention seems to have preceded any further advances in human toolmaking. Even the most technologically primitive cultures have fully developed oral languages and mythic systems. However, the new oral cultures did not abandon mimetic representation; to the contrary, they encompassed the more concrete, pragmatic culture of mimesis, which continued to function much as it had in the past, in its own traditional cultural arenas. Mimetic skill still provides the cognitive basis for human social institutions like craft, athletics, dance, and the complex non-verbal expressive dimensions captured and cultivated in ritual, acting and theatre; and language provides the narrative framework that ultimately governs those institutions. Myth and narrative thought are the governing level of thought in oral cultures. Whether they know it or not, all humans grow up within a mythic system. Myths form the cultural glue that holds societies together. Myths and stories contain and supersede the prototypes and mimetic stereotypes of social roles, social structure and custom. They rely on allegory and metaphor, and lack precision, but they remain the universal form of human integrative thought, and one of the most potent and meaningful ways of representing reality.

In modern humans, language and mimetic skill work closely together in the expression of ideas, but can also be used independently of one another, to create simultaneously contrasting messages. Such contrasts are common devices in many areas of culture, but especially in cinema, theatre, comedy and opera, which employ mimetic–linguistic counterpoint very effectively The tension produced by driving these two contrasting modes of representation in opposite directions is a very powerful dramatic device. This suggests that these separate representational realms are sufficiently independent in the brain that they can operate concurrently, without interfering with one another.

THE THIRD COGNITIVE–CULTURAL TRANSITION: THEORETIC CULTURE

The third transition involved a switch from mythic to theoretic governance. The two evolutionary steps described above form the innate structural foundations of human thought, our gene-based cognitive inheritance. But cognitive evolution did not stop when we reached our modern form, somewhere between 100 000 and 50 000 years ago. A third major cognitive breakthrough has to be posited to account for the astonishing changes that have taken place more recently. These changes revolve around one central trend that has dominated the history of the past 20 000 years: the externalisation of memory.

Early humans, like their predecessors, depended on their natural or biological memory capacities. Thus, even though language and mimetic expression allowed humans to accumulate a considerable degree of knowledge shared in culture, the physical storage of that knowledge depended on the internal memory capacities of the individual members of a society. Thought was entirely inside the head; whatever was heard or seen had to be remembered and rehearsed orally, or visualised in imagination.

The advantages of external memory storage are obvious, but the invention of external memory devices has taken at least 20 000 years, and the full social realisation of the power of external symbols is very recent. The common keyword for the most recent phase of that transformation is literacy, but this term needs broadening to include much more than its conventional connotation, which in Western culture often means simply the ability to read and write alphabetic symbols. A more adequate description of human symbolic literacy would encompass all the skills needed to use every kind of permanent external symbol, from the pictograms and line drawings of the Upper Palaeolithic, to the astrolabes and alchemical diagrams of the medieval era, to the digital information codes used in modern electronic communications.

There has been no time for a genetic adaptation for external symbol use. We have basically the same brain we had 50 000 years ago. It might be argued that the shift to external memory was purely cultural, and therefore not as fundamental as the two previous ones. However, using the same criteria employed to evaluate earlier cognitive steps, recent changes constitute strong evidence for a third major breakthrough in our cognitive evolution. Both the physical medium and the functional architecture of human memory have changed, and new kinds of representations have become possible.

External symbols have transformed the medium of storage, although they constitute a change in technological, rather than in biological hardware. This is not trivial, since the storage properties of external media are very different from those inside the head. Whereas biological memory records are in an impermanent, fixed medium with a constrained format, external records are usually in enduring, refinable and reformattable media. These properties allow humans to construct completely new types of memory records, and to expand greatly the amount of knowledge stored in memory. External storage has also introduced new ways of retrieving and organising information; in fact, the retrieval workhorses of biological memory – similarity, and temporal and spatial contiguity – are not particularly important in external memory retrieval. The addition of so many external devices has actually changed our memory architecture – that is, the storage and processing options in the system, and their configuration – allowing us to move freely through an external information space that is virtually frozen in time. Because of their stable display properties, external memory devices have allowed us to harness the power of our perceptual systems, especially vision, for reflective thinking; and have literally changed which part of the brain we use to do much of our thinking. This has increased our options for interrelating various kinds of images and information, and for doing mental work in groups. All this has a neuropsychological dimension. There has been an invasion of the brain by culturally imposed programming, mostly in the form of institutionalised education.

A partial list of devices mastered by humans along the way to full symbolic literacy includes (in rough historical order) iconography, maps, emblems, totems, pictorial representations, pictographs, sequence-markers like knotted cords or prayer beads, various types of tokens, currencies, property markers, writing and counting systems, mathematical notations, schematic and geometric diagrams, lists, syllabaries and alphabets, scrolls, books, archival records of various sorts, military plans, organisational charts, environmental signs of various kinds, graphic images, scientific manuals, graphs, analogue instruments, specialised technical languages, computing languages, and a variety of modern multimedia storage devices that employ virtually all of the above. Even our personal memory system has been programmed with photographs, memoranda, TV images and other kinds of stored knowledge.

Once the required codes are in place in the brain, and the semantic memory system has a sufficient base of knowledge to work with, a successful external memory device will reproduce an intended mind-state in the reader or viewer. To the expert reader, the encoding strategies are so deeply established that the medium itself is invisible; ideas pop out of the page, and the message is processed unconsciously. While processing a major symbolic artefact – a novel, for instance – a particular set of abstract representations is set up in the reader's mind; and this temporary mind-state is highly dependent on the external device. Once the artefact is removed, little remains; put down a long novel and the temporary richness of the story rapidly dims, leaving only a general impression of the story and its characters. Pick it up again, and within minutes, the world created by the author reproduces itself in the mind.

The literate mind has thus become externally programmable, which is both an advantage and a danger. The advantage lies in the creative possibilities of symbols; societies can support much greater complexity, science and technology can advance, scholarship is made possible, and artists and writers become cognitive engineers, leading their audiences through tangled symbolically driven nets of ideas to end-states that are not otherwise conceivable. The danger is found in potential threats to individual integrity; free access to external memory tends to pull apart the unity of mind, fragmenting experience, undermining the simpler mythic thought structures humans have grown attached to, and exposing them to a bewildering variety of powerfully packaged messages.

The more complex forms of symbol use require the combination of all kinds of visual representations – pictorial, ideographic and phonetic – into large-scale external artefacts, such as architectural proposals, engineering plans, government commissions, scientific treatises, cinematic scripts or works of art. The high-level skills needed to do this kind of mental work are difficult to acquire, and far from being universal to all humans. These brave new capacities were not acquired without trade-offs. There is only so much brain-matter (or mind-matter). The physiology of brain plasticity suggests that when we increase the demands on one area of the brain it expands its territory more or less in proportion to the imposed load. Accordingly, cerebral capacity is used up and no longer available for something else. There is some evidence that with literacy we sacrificed a degree of visual imagination; and that we are losing our capacity for rote verbal skills, like mental arithmetic and memorisation (see for example Richardson, 1969). The nature of these trade-offs should be explored further, because symbolic literacy is not easily or naturally acquired in development, the way mimesis and speech are. Literacy is unnatural, and requires a wrenching redeployment of cerebral resources.

It is easy to underestimate the degree to which we depend on external symbols. Throughout a typical day, we encounter many of them. From clocks, to cereal boxes, to microwaves, maps, cartoons and road signs, our day is filled with digital, analogue and pictorial representations, as well as complex devices and artefacts, such as equations, poetry and computerised systems. The impact of external symbols on the brain, besides their ability to engineer our mind-states, is increased cerebral baggage in some domains, and a decreased load in others. Exograms (as opposed to engrams or internal brain representations) give us a permanent external memory record, and allow us to distribute cognitive work across many individuals. Moreover, their capacity for iterative refinement is unlimited, their retrieval paths are unconstrained, and perceptual access to them is very good. This gives them an advantage over engrams, which are hard to refine, have very few retrieval paths, and allow only very poor perceptual access.

CONCLUSIONS

A final point about the mediating role of consciousness. In our traditional theories, we have often defined consciousness as a rather narrow band of short-term memory storage, a window only a few seconds wide, within which we pass through the stream of experience that constitutes a lifetime. Long-term memory may contain everything we know, but it is unconscious, and thus useless to us as conscious beings, unless we can retrieve it into awareness. But between these two systems, there is a level of conscious processing that I have labelled 'intermediate-term' governance. This is a much wider, slower-moving form of working memory, which contains all simultaneously ongoing mental activity, including activity that is not as vividly conscious as, say, visual sensation, but is nevertheless a very active and causal element in behaviour. An example of this would be the complex of forces that govern a conversation between several people. Such a conversation has a vividly conscious element that is very short-term in its duration (the sounds of words as they are spoken). But it also has a slower-moving dynamic that can last for hours, and involves the strategic tracking of several lines of interconnected thought and the subtle adjustments made as the conversation itself unfolds in the memory systems of the participants. I have suggested that the existence of this slow-moving conscious process suggests that there is a dimension to brain activity that we still do not understand, and which must become the focus of a new generation of neurophysiological experiments aimed at slow-moving integrative neural processes.

The other focus of these studies must be the brain's interaction with culture itself. This will open up a whole new series of fields and specialties, but among these, the study of the neural effects of literacy training will stand out. When we introduce external symbolic memory storage into the traditional architecture of human memory, there is a radical change in the nature of the cognitive models we can propose: in effect, we reflect the entire internal structure of memory onto the outside world, and the conscious minds becomes a mediator between two parallel memory systems, one inside the brain, and the other (much larger and more flexible) outside. Of course, we retain our traditional biological memory structures, but we also have acquired a vast amount of permanent external symbolic storage, with novel retrieval and storage properties. Moreover, a new feature is introduced into the cognitive model: the external working memory field, which has become a very active area of research. External storage complements traditional biological working memory systems. For instance, if we sit in front of a computer, the screen becomes a temporary external working memory field. Anything we display in it is processed in consciousness, and the viewer is locked into an interactive loop with the display while creating, writing or thinking. This changes the traditional function of the brain's biological working memory system. In principle, this idea applies not only to computer displays, but also to other types of external symbolic display. For example, painters interact in this way with their easels, poets with their sheets of paper, accountants with their spreadsheets, and so on. The external memory device is built right into the cognitive system, and changes the properties of the system. The impact of such technology is even greater if the technology is an active player, as, for instance, in the case of an interactive computer display system with cognitive properties of its own.

This not only changes the way the growing brain adapts to the information environment, but it brings about an even more fundamental change in the existential predicament of individuals, as they accumulate massive networks of knowledge about the world, stored partly externally, partly internally. We might still be able to think of ourselves as 'monads' in the Leibnizian sense; that is, self-contained entities bounded by our skin membranes. But, as peripatetic minds plugged into a network, we are immersed in a gigantic external memory environment within which we can move around. We can connect with an almost infinite number of networks out there. We can share memory for a moment with other people and, at that time, we are networked with them. This creates new possibilities, some of which are not thrilling to contemplate, for group manipulation. But, it also provides more possibilities for freedom, and individuality, than at any other point in history. In simple oral cultures, freedom and individuality as we know them were virtually impossible. But in our complex cultures, there are so many ways of configuring the world that extreme individuality has become a possibility.