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Convergent? Minds? Some questions about mental evolution

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In investigating convergent minds, we need to be sure that the things we are looking at are both minds and convergent. In determining whether a shared character state represents a convergence between two organisms, we must know the wider distribution and primitive state of that character so that we can map that character and its state transitions onto a phylogenetic tree. When we do this, some apparently primitive shared traits may prove to represent convergent losses of cognitive capacities. To avoid having to talk about the minds of plants and paramecia, we need to go beyond assessments of behaviourally defined cognition to ask questions about mind in the primary sense of the word, defined by the presence of mental events and consciousness. These phenomena depend upon the possession of brains of adequate size and centralized ontogeny and organization. They are probably limited to vertebrates. Recent discoveries suggest that consciousness is adaptively valuable as a late error-detection mechanism in the initiation of action, and point to experimental techniques for assessing its presence or absence in non-human mammals.

1. Introduction

The title of this symposium is 'Convergent Minds'. I wish to raise some questions about both words in that title.

For two things to qualify as convergent minds, they have to be (i) convergences and (ii) minds. The first qualification is easier to evaluate than the second. The word 'convergence' has a special technical meaning in evolutionary biology. For those who are used to thinking in phylogenetic terms, what follows may be obvious. But it may nevertheless be worth pointing out, because experience shows that even people who are very sophisticated biologists in other respects sometimes make mistakes in evolutionary thinking.

Determining whether a particular resemblance between two species represents a convergence or not requires that we know how they fit into a larger phylogenetic picture—the tree of evolutionary relationships—and what the trait in question looked like in their last common ancestor. In general, a trait that was present in that ancestor cannot be a convergence between two of its descendants. This entails that (for instance) no mental properties that humans share with chimpanzees, our closet living relatives, can be identified as convergences, because we have no way of knowing whether they were present in the last common ancestor of the two.

All this has a bearing on the way we need to think about these issues. The so-called mirror test for self-awareness developed in 1970 by G. G. Gallup Jr [1] provides an example of why and how phylogeny matters. In this test, the experimental subjects are anaesthetized and have a visible mark placed on their faces. Control animals receive a mark that is invisible but feels and smells the same. After recovering from anaesthesia, each subject is presented with a mirror. If, upon seeing their reflection, the experimental subjects touch or otherwise clearly respond to the mark on their faces but the control subjects do not, the species passes the test.

This test has been interpreted as an index of awareness of self, of one's own body as a thing. The meaning of the test is debated, for a number of reasons.

In all species thus far tested (including humans), at least some individuals fail the mirror test, suggesting that it gives false negatives. Some animals (e.g. gibbons, tamarins) fail to touch obviously visible marks applied to their limbs [2,3], thereby rendering the whole test irrelevant; and some experimenters have failed to include this important check in their protocols. Animals that rely heavily on senses other than sight may simply ignore a mirror because they perceive that the reflection is an illusion.

But whatever the mirror test implies about mentation, few non-human animals can pass it. To date, it has been passed unequivocally only by hominoid primates and magpies (*Pica*), and arguably by bottlenosed dolphins (*Tursiops*) and one Asian elephant (*Elephas*) [4–9]. Other animals that have been tested, including giant pandas, sea lions and jackdaws [10–12], have failed the test. Among primates, some chimpanzees and orangutans can pass it, but New and Old World monkeys (and very young human children, or patients with advanced Alzheimer's disease) cannot [2,3,13–19]. The case of gorillas is equivocal. Most gorillas that have been tested have failed. A few have shown clear signs of self-recognition on mark tests, but only after training or extensive familiarity with mirrors [20–25].

When we map mirror-test performance onto a phylogenetic tree, it becomes clear that one parsimonious interpretation of the facts is that gorillas have lost, or are in the process of losing, a capacity for self-recognition that humans and the other great apes have retained from a common ancestor back in the Miocene (white squares, figure 1). This too is a kind of convergence of minds—in this case, convergence with a more remote ancestor that lacked the faculty of self-recognition. Jumping to this conclusion, some authors have tried to account for this puzzling loss of an ancestral capacity preserved in humans. Povinelli & Cant [26] explain the concept of self (or whatever it is that the Gallup test measures) as a locomotor adaptation, related to the need for self-awareness in a large-bodied tree-climber and lost in the terrestrial gorilla. Gallup, who also thinks that gorillas have lost self-awareness secondarily, suggests that self-awareness is advantageous to males competing for access to females (supposedly not a problem for gorilla males, who guard females in single-male groups) [27].

Both these explanations can be questioned; but both are rendered unnecessary if we assume that enhanced awareness of self developed independently in the orangutan lineage and the *Pan–Homo* clade (black squares, figure 1) but not in gorillas. Both interpretations are equally parsimonious, involving two character-state transitions. But they imply different evolutionary changes and different possible explanations. In the present state of our knowledge, there are no grounds for choosing between these two interpretations.

Another illustration of the importance of phylogenetic mapping involves the curious fact that it is impossible to train most animals to move to the beat of a drum [28]. Evidently, most animals hear the *sounds* but do not apprehend the *rhythm* in a way that allows them to couple their body movements to it. Recently, however, it has been shown that at least two and possibly more species of parrots can 'dance'—that is, entrain their body movements to a musical beat and adjust their timing to changes in the tempo of the music [29–31]. Both parrot species are accomplished vocal mimics. It has accordingly been suggested that vocal imitation and rhythmic entrainment are different aspects of a single faculty, which has evolved convergently in humans

Figure 1. Phylogeny of mirror-test performance in hominoids. Taxa that pass the Gallup test by touching marks on their faces when they look in a mirror are indicated by stars. Gibbons (grey text) do not pass the test, but what this means is unclear, because they also show no interest in directly visible marks on their arms. Published analyses of Gallup-test performance [25,26] posit an initial gain (G) of self-awareness in the ancestral great ape and a secondary loss (L) in the gorilla lineage (white boxes). But it is equally parsimonious to assume that test-passing ability evolved convergently in the *Pongo* lineage and the common ancestry of the *Pan–Homo* clade (black squares). (Phylogram after [13].)

and at least these two parrot species [29,30,32]. Understanding the causes and correlates of the imitative faculty would contribute greatly to our understanding of human evolution. But on the basis of the facts presented, we cannot tell whether the supposed faculty exists. A capacity for vocal mimicry may be intrinsically coupled with rhythmic entrainment, precede it as a potential cause, follow it as a potential effect, or represent a merely coincidental co-occurrence. To tell which, we need to seek cases in which the two sorts of imitation are decoupled. Such cases exist. Some phocid seals are apparently capable of vocal mimicry but not of entraining movements to a musical beat [32], whereas the reverse is true of some otariid seals [33]. Similar disjunctions of these two faculties appear among birds, where vocal mimicry has evolved convergently in several orders and families not known to be capable of coupling body movements to music [29]. We would like to know how these two human-like faculties have evolved or been lost in various birds and mammals, and whether one is a necessary precondition or an epiphenomenon of the other. To learn these things, we have to test additional species to permit phylogenetic mapping of the distributions of the two traits.

Placing questions about convergence of mind in a phylogenetic context also helps to dispel the myth of the 'psychological scale' that has dogged comparative psychology. There is a serious temptation in talking about the evolution of mind to fall into a pre-Darwinian way of thinking about mental capacities as arrayed along a linear sequence, a manifestation of the old *Scala Naturae*. Unless otherwise specified, we tend to think of 'convergent minds' as convergent with our own in a linear fashion, via progression up the scale. This way of thinking is imbedded in Morgan's Canon, formulated by C. L. Morgan in the following often-quoted words:

In no case may we interpret an action as the outcome of the exercise of a higher psychological faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale [34, p. 53].

Morgan's Canon is often justified as a special case of Occam's Razor, the principle that our accounts of the world should

make do with as few concepts and assumptions as possible. But this is a mistake. The Razor does not imply the Canon. Because we are already compelled by experience to acknowledge our own mental events, we add nothing to our ontological catalogue by attributing similar mental phenomena to animals. Indeed, it would seem on the face of it that it would be simpler to do just that, applying similar explanations to similar phenomena whenever the facts permit. Morgan himself recognized the force of this objection. 'Is there not some contradiction in refusing to do so?' he asked. 'For, first, it is contended that we must use the human mind as a key by which to read the brute mind, and then it is contended that this key must be applied with a difference. If we apply the key at all, should we not apply it without reservation?' [34, p. 55]

His answer, that we should not, was grounded in a picture of evolution as a temporal reading-out of the Great Chain of Being. Like many people at the time, Morgan saw evolution as a narrative of the ascent of life from mere protoplasm up through 'grades of organisms, with divergently increasing complexity of organic structure and correlated... mental or psychical complexity', to the lofty pinnacle of the human condition, in which '...the organic complexity, the complexity of correlated activities, and the associated mental or psychical complexity, has reached the maximum as yet attained' [34, p. 55].

By substituting 'evolutionary scale' for 'psychological scale' and 'human-like' for 'higher' in Morgan's Canon, we can see what Morgan really meant: namely, that we should never explain other animals' behaviour as the outcome of *human-like* mental phenomena if we can devise any alternative explanation—not because it would be unparsimonious to do so (it would not), but because anthropomorphism confuses the picture of the great linear progression up the ladder of mental evolution. But there is no 'psychological scale' and no linear progression. Once we rid ourselves of that antique scalar preconception and start thinking about mental convergence in genuinely phylogenetic terms, Morgan's Canon no longer seems either parsimonious or plausible [35].

'Convergence' is not a single variable. Brains and behaviours, and presumably minds, can evolve in many directions. Different environmental situations select for different changes in brain size, behavioural flexibility and cognitive complexity. This can entail convergences that have little or nothing to do with modern human cognitive capacities. The case of gorillas and the mirror test shows that we can learn at least as much from studying losses as from studying the sort of accumulation of resemblances to ourselves that we tend to concentrate on in this connection. The goat-like extinct Pleistocene sheep *Myotragus*, which lived on the Balearic Islands off the Mediterranean coast of Spain [36], represents a related case. Unlike wild goats and sheep, *Myotragus* had short, stubby legs, small and frontally directed eyes, and an unusually small brain [37–39]. In cross-section, its bones exhibit periodic growth rings, suggesting that it had a cold-blooded, reptile-like physiology [40]. A similar reduction in brain size has occurred in some other island mammals [41–44]. These similarities have been plausibly interpreted as convergent adaptations for coping with limited food resources, especially in environments where reduced pressures from predators allow animals to get away with making economies in brain tissue [41]. Possible examples of the same phenomenon are seen in the Late Miocene ape *Oreopithecus* and the

Pleistocene insular-dwarf human *Homo floresiensis*, both of which lived on islands and had much smaller brains than would be expected for animals of their clades and body sizes [41,45]. All these cases can be interpreted as another sort of convergence of minds—in this case, the evolution of reduced intelligence as a dietary adaptation. Similar reduction in brain size is characteristic of almost all domesticated mammals, probably as a convergent response to reduction in predator pressures [46–49]. The reduction in brain volume seen in modern human populations over the past 20 000 years has been analysed as part of a similar process of 'self-domestication' [50,51], but is probably better explained as a corollary of reduction in body size [52].

Of the 30-odd phyla of multicellular animals currently recognized, only three—arthropods, chordates and molluscs—have evolved what the cognitive scientist Michael Trestman has referred to [53] as 'complex, active bodies' featuring articulated and differentiated appendages, high mobility guided by distance-sensing organs, and a capability for active manipulation of objects. It seems reasonable to think that this cluster of properties is a necessary substrate for mental evolution; and the three phyla that evince them are precisely the groups in which evidence of such properties as behavioural plasticity have led the contributors to this symposium to try to discern mental convergences. It is not self-evident, however, that convergent *behaviours* necessarily furnish evidence for convergent *minds*.

Consider, as an example, the jumping spiders (Salticidae) of the genus *Portia*. These animals feed chiefly on web-spinning spiders, which they often approach by wide-swinging, circuitous detours that break visual contact with the prey, being careful to remain out of sight and to avoid approaching the prey directly. Having made their way to a concealed spot at the edge of a web, they wait for a light breeze that ruffles the web, then make contact with it and begin plucking at it to produce vibrations that mimic the struggles of snared insects. They try one pattern after another, sometimes keeping it up for days, concentrating on patterns that induce movement of the web-builder toward them. Eventually it approaches too close, and they jump on it and kill it—using different combat tactics, depending on the prey.

All this is very sophisticated and plastic behaviour, incorporating what appears to be long-term intentionality, learning, and insight [54–59]. An opossum would not be capable of it; it would take something like a rather clever cat. Some other spider-eating arthropods have evolved similar flexible and plastic hunting behaviours and similar cognitive capacities [60,61]. These remarkable abilities represent evolutionary convergences with *Portia*, and arguably with cats. And yet I would be very reluctant to talk about these as examples of convergent minds, because I would be reluctant to talk about the mind of a jumping spider or assassin bug. These are small arthropods with brains containing a few hundred thousand neurons. We do not know what the material basis of mental events is, but it is clear that there is one and that it depends on the brain. (We know this because conscious mentation can be abolished by toxins or traumas that differentially affect the brain.) Whatever that material basis is, I doubt that a mass of neurons the size of a pinhead is sufficient to produce it. I suspect that while there is something that it is like to be a cat, being a jumping spider is an experience like being a thermostat or a computer—that is, it is not an experience at all. If so, I am

inclined to say that the convergence in behaviour between jumping spiders and cats does not constitute evidence of convergent minds.

This brings me to the second word in the topic of this symposium—namely, ‘minds’. Deep philosophical pitfalls and morasses open at our feet as soon as that word enters into our discourse. I would like to avoid falling into these, but I feel compelled to further explore the question of whether behaviour without mental events can count as evidence for convergence of minds.

Like the drunkard who lost his keys in the park but searched for them under the street lamp because the light was better there, scientists tend to equate ‘mind’ with ‘cognition’ because there are ways of detecting and measuring the latter. ‘Mind’, understood in terms of this equation, is simply a name for those processes in the brain that generate and control such complex and plastic behaviours as problem-solving, counting, attentive learning and spatial mapping. These behaviours are taken as constituting ‘cognition’, and convergent acquisitions of such capacities are taken as constituting convergence of minds. The difficulty here is that some of these capacities can be demonstrated in creatures lacking brains or even nervous systems, including plants, single-celled eukaryotes and isolated cells extracted from the human body [62–68]. Talking about ‘cognition’ in all these organisms or parts of organisms entails a radical change in the meaning of the word. There is nothing wrong with any of this, as long as we recognize that we are no longer talking about the same topics and issues that we started off with. We may find many interesting things under this street lamp, but we should not hope that they will include the missing keys.

I follow the philosopher John Searle [69] in thinking that the fundamental issue here is the presence or absence of intentionality in the philosophical sense; that intentionality is impossible without consciousness; and that it is misleading to talk about mental phenomena in unconscious organisms. Some quantum-consciousness theorists suggest that ‘the fabric of consciousness may be present within all eukaryotic cells’, and that it has something to do with microtubules [70]. To me, this idea seems to contradict our common experience of the fluctuation of consciousness, which disappears every night during sleep. Its disappearance is correlated with organ-level changes in the activity of our brains as a whole, not with changes at an ultrastructural level. It seems reasonable to think that our subjective awareness of the world is an emergent property of whole-brain activity, and that most organisms lack it.

If we accept all this, then consciousness, mental events, minds and the philosophers’ ‘intentionality’—the property of being *about* something—must require brains, of a certain minimal size and a certain sort of organization. This inference warrants the exclusion of brainless organisms from our search for convergent minds. As many brainless organisms evince ‘cognition’ in the behavioural sense, I suggest that that sense of the word is not good enough for our purposes. It may well be that plants can send and receive signals, alter their responses to stimuli in adaptive ways, and even respond differently to stimuli that number below or above a certain threshold value [63]. Nevertheless, they are not thinking, learning or counting when they do these things, any more than an abacus or a box of rocks are calculating if I pick them up and shake them. I suggest that intentionality is required for something to count as calculation or as

cognition, and that brains of a certain size and organization are required for intentionality. A plant is not *about* anything. It is the way it is, not because its parts or its whole want something, or are intended for something, or are aimed at doing something, but because that configuration has the property of self-copying more reliably and effectively than other, slightly different configurations.

Why should we care about the presence or absence of mental events in organisms, as long as they are operationally or behaviourally cognitive? Many eminent thinkers have argued that mental events have no function—that they are caused by physical events in the brain but are not capable of causing physical events. T. H. Huxley, one of the early advocates of this thesis, summed it up like this:

It seems to me that in men, as in brutes, there is no proof that any state of consciousness is the cause of change in the motion of the matter of the organism. If these positions are well based, it follows that our mental conditions are simply the symbols in consciousness of the changes which take place automatically in the organism... We are conscious automata [71].

This thesis is known as epiphenomenalism. If it is correct—if mental events are functionless, end-of-the-line side effects that cannot cause physical events—then mental events and subjective experience have no adaptive value, and we are justified in ignoring them in comparative psychology.

There are empirical as well as philosophical reasons for accepting some version of epiphenomenalism. We all know from experience that we are not even aware of many of our ‘voluntary’ movements. Many investigators [72–75] have shown that our brains and skeletal muscles usually begin to initiate movements before we are aware of having ‘decided’ to move. But this is not always the case. I may consciously decide to do something next Tuesday. And recent experiments have shown that even for spontaneous movements that have already started to manifest themselves as unwilled cortical ‘readiness potentials’, there is a short window of time (around 800 μ s) during which a conscious decision can abort the movement [74,75], though a point of no return is reached after which a conscious decision to abort has no effect. These facts comport with the late Jeffrey Gray’s thesis [76] that consciousness functions as a ‘late error-detection mechanism’—a domain of perception and evaluation, into which multi-modal sensory inputs, objectives, plans and impending motor outputs are channelled by unconscious parts of the brain and integrated into constructs that reveal mismatches and discrepancies, which the executive parts of the brain then use in terminating or correcting future action.

Interpreting consciousness as a late error-detection mechanism ascribes an adaptive value to it. This gives us theoretical reasons for thinking that it may have evolved convergently, because convergences driven by natural selection are more likely to occur than convergences produced by chance. But because we do not know what sorts of brain events are necessary and sufficient to produce consciousness, we cannot (yet) produce any conclusive positive evidence for it in other animals. It may be that non-human animals are what philosophers refer to as ‘philosophical zombies’. There is a substantial literature arguing the question of whether zombies—that is, creatures who behave exactly like humans but whose actions are unaccompanied by mental events—are possible or even conceivable [77–79]. But as far as I know, there is no logical or philosophical difficulty in thinking that non-human animals are philosophical zombies,

and that none of their behaviours are accompanied by mental events [35].

Though we cannot yet conclusively demonstrate conscious awareness in non-human animals, we can be confident in ruling it out in some of them. We have decisive reasons for believing that brains must be involved. The production of mental events must be constrained by both the organization and size of those brains. The fundamental differences between our brains and those of arthropods and molluscs have to count to some degree against their having 'minds' in the ordinary sense of the word. These animals have 'brains' only in the analogical sense in which a fly has 'legs' or 'wings'. As noted elsewhere in this symposium, some molluscs (squid and octopuses) have the largest 'brains' of any invertebrates, with brain-body mass ratios intermediate between those of reptiles and mammals [80]. They evince a lot of behavioural plasticity and capacity for learning. But the centralized parts of their nervous systems have an entirely different developmental and evolutionary history from those of vertebrates. Although the vertebrate brain is an ontogenetically and phylogenetically unitary elaboration of the front end of the primitive chordate dorsal nerve cord, the 'brains' of cephalopods evolved from a circumoral ring of originally separate ganglia, which have secondarily coalesced where growth has brought them into contact. Roughly 75% of the neurons in the 'brain' of an octopus are located in the two widely separated optic lobes at the base of each eye, which are associated with processing of visual input from the retina. A large proportion of its remaining neural tissue is concentrated in big peripheral ganglia at the bases of its tentacles, which provide each 'arm' with a sort of secondary brain that can function entirely independently from the central ganglia [81]. It seems correspondingly less likely that these diffuse neural arrangements can harbour or generate some sort of unifying central consciousness.

All vertebrate brains share an ontogenetic unity and a common Bauplan, but they differ considerably in absolute and relative size. It is not clear to what extent consciousness, or even behavioural capacities, are dependent upon these metrics. Biologists usually equate absolute size with mass, but in every other respect a 500-gram hawk with a 1-m wingspan is a much bigger animal than a 500-g musk turtle measuring 10 cm in length. The two weigh the same because natural selection has engineered the bird for aerial lightness and the smaller turtle for pond-diving density. Even the brains of flying birds have evolved to minimize weight, enabling them to do a great deal with very little. This factor makes it hard to compare encephalization in birds and mammals. Some birds have evolved startling mental convergences with the most human-like mammals, extending in the cases of parrots and corvids to an ability to make innovative tools and use simplified versions of human languages. They do these things using brains the size of walnuts. Evidently, a millilitre of bird brain is worth more than the average millilitre of mammal brain.

Most of the past scientific literature on encephalization has operated on a different assumption: that the crucial variable in explaining differences and similarities in cognitive capacities is relative brain size, measured in terms of deviation from some interspecific regression of brain mass against body mass. This method of comparison was adopted to provide a standard by which human brains could be seen as in some sense uniquely large despite the annoying fact that

some non-human mammals have brains or brain-body weight ratios that are larger than ours [82,83]. But in recent years, evidence has accumulated that this assumption is simply wrong. Among non-human primates, behavioural measures of cognitive capacities have been found to correlate well with absolute brain size, absolute neocortical volume and body mass—but not with encephalization quotients or deviations (residuals) from brain-body regression lines [84]. Holekamp reports similar findings from another mammalian order, Carnivora, elsewhere in this symposium. If these findings hold up and apply to other groups, it would appear that vertebrate 'intelligence' depends roughly on the absolute number of neurons in an animal's brain over and above the basic minimum needed for maintenance of body functions [83,85]. If this is so, then large animals should on the whole be more intelligent than small ones. We therefore need to ask why crows and parrots, with their absolutely small brains, are as intelligent as they are, and why elephants and cetaceans with their extremely large brains are not more intelligent than humans.

The answers to these questions seem to reside in two factors: the size and packing of cerebral neurons, and their distribution across different parts of the brain. The neurons of bird brains are very small and tightly packed, so that a millilitre of avian brain contains on the average from two to four times as many neurons as a millilitre of mammalian brain; and whereas the vast majority of the neurons in the brains of mammals lie in the cerebellum, most of the brain neurons in owls, songbirds, and parrots lie in the pallial equivalent of the mammalian cerebral cortex [86]. A 1-kg parrot therefore has about 12% more 'cortical' neurons in its brain than a rhesus monkey weighing seven times as much. This difference may account for the parrot's superior cognitive capacities. There is a similar difference in the packing of cortical neurons between primates and some other mammals, with primates having up to seven times as many neurons per millilitre of cortex as a rodent of comparable body size [83,87].

Conversely, an elephant's cerebral cortex, which has about twice the volume of a human's, contains only about one-third the number of neurons; and over 97% of its cerebral neurons lie in its conspicuously enlarged cerebellum [88]. These differences may explain why the behavioural and cognitive capacities of elephants do not equal or exceed our own. At present, however, the functional significance of these differences is not clear. Neuroimaging studies have shown that the human cerebellum is active not only in coordinating movements, but also in a variety of cognitive tasks [89]. An elephant's huge cerebellum may be contributing as much to cognition as to the control of its complicated trunk musculature. It should be noted that humans and great apes have also undergone a marked enlargement of the cerebellum in comparison with other primates and primitive mammals [90,91]. This neuroanatomical convergence between elephants and apes may reflect special convergences in cognitive capacities.

As the case of the diffuse cephalopod 'brain' reminds us, patterns of interneuronal connections are also relevant in assessing cognitive and mental convergence. The myelinated cortical fibres in primate brains are thicker than those of cetaceans and elephants, and should have a correspondingly higher conduction velocity [85]. This difference in conduction velocity may contribute to the observed disparity in cognitive abilities among these extremely large-brained animals.

Cetaceans also have a surprisingly small corpus callosum [92]. The reduction of this big commissure connecting the two cerebral hemispheres must make it more difficult for the two hemispheres to 'talk' to each other. This disjunction is coupled in cetaceans with a unique sleeping pattern, in which one hemisphere remains awake and active (with one eye open) while the other displays deep slow-wave sleep and a lowered metabolism [93,94]. If consciousness and mental events occur in cetaceans, they must be able to manifest themselves in the right and left halves of the brain by turns. All this suggests that a dolphin may be in effect a natural split-brain experiment, in which two cognitively separated individuals in effect coexist in the same body. Whether subjective consciousness and a sense of self exist in either hemisphere, neither, or both is at present a matter for conjecture. In a recent review article based on his 45 years of experience with split-brain patients [95], Michael Gazzaniga suggests that in humans, a sense of self is constructed by a left-hemisphere interpreter on the basis of input from distributed networks on both sides of the brain. If so, then there may not be anything that it is like to be a dolphin—or it may be two separate experiences. Unihemispheric sleep (with one eye open) also occurs in seals, manatees and most birds. But unlike cetaceans, these animals sometimes exhibit bihemispheric and REM sleep of the familiar mammalian sort [93,96]. It seems correspondingly somewhat more likely that there is something that it is like to be a parrot or a sea lion.

If consciousness is not something intrinsic to all organisms, then presumably it has evolved in us, and perhaps in other animals, to perform one or more functions that were not adequately served by prior, unconscious neural mechanisms. To me, as an untutored outsider to these fields, it seems that the simplest way to begin an experimental search for other minds is to identify such functions, determine in which species they are served, and investigate their neurological

concomitants in humans and other animals. In human beings, conscious mentation functions as part of a late error-detection mechanism, involved in judging, and if necessary cancelling, voluntary acts initiated at an unconscious level. In the experimental work cited above on conscious decision-making by humans [72–75,97], an unconscious cortical 'readiness potential' was found to precede spontaneous (unconditioned) action by several hundred milliseconds, with subjects experiencing a conscious intention to move roughly midway between the two events—and being able, if rewarded, to make a decision to abort up to 200 μ s before the movement. Similar pre-movement readiness potentials, differing in timing and degree of complexity, have been found in rats, cats and macaques [98–100], and presumably exist in many other mammals. By adapting the experimental procedures used on humans, it should be possible to determine whether any of these animals have a late error-detection mechanism capable of aborting a voluntary movement launched at the unconscious level. Positive findings from such experiments would demonstrate the existence of two levels of decision-making, corresponding to the separation between the conscious and unconscious mind in humans. Such findings might provide genuine empirical evidence for a domain of conscious mentation and volition in non-human animals, thereby laying the foundation for a phylogenetically based investigation of the convergence of 'minds'—in the original sense of the word—within the Class Mammalia.

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