

Why Brains Are Not Computers, Why Behaviorism Is Not Satanism, and Why Dolphins Are Not Aquatic Apes

Louise Barrett¹

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Abstract Modern psychology has, to all intents and purposes, become synonymous with cognitive psychology, with an emphasis on the idea that the brain is a form of computer, whose job is to take in sensory input, process information, and produce motor output. This places the brain at a remove from both the body and environment and denies the intimate connection that exists between them. As a result, a great injustice is done to both human and nonhuman animals: On the one hand, we fail to recognize the distinctive nature of nonhuman cognition, and on the other hand, we continue to promote a somewhat misleading view of human psychological capacities. Here, I suggest a more mutualistic, embodied, enactive view might allow us to ask more interesting questions about how animals of all kinds come to know their worlds, in ways that avoid the (inevitable) anthropocentric baggage of the cognitivist viewpoint.

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Anthropomorphizing comes easily to us: it takes little more than a pair of strategically placed eyes to transform an inanimate object into an animate being—if you harbor any doubts about this, you should spend half an hour checking out websites like eyebombing.com (<http://eyebombing.com>; see Fig. 1 for an example). When the beings

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✉ Louise Barrett
louise.barrett@uleth.ca

¹ Department of Psychology, University of Lethbridge, 4401 University Drive, Lethbridge T1K 6T5, Canada

are already animate to begin with, the tendency to attribute human thoughts and feelings is even more difficult to shake. I regularly speak to my dog as though she has a degree from Harvard, for example, which probably owes much to growing up in a Disneyfied and Muppet-saturated culture full of talking animals. I do not think it does either of us any harm. When it comes to studying other species scientifically, however, this tendency to anthropomorphize becomes problematic for all kinds of reasons. Obviously, this is not a new insight, and there is a large literature debating the use of anthropomorphism as a scientific strategy (see Barrett 2011 for a review; also Andrews 2014; Burghardt 2007; Keeley 2004; Timberlake 2007; Wynne 2007).

On the positive side, anthropomorphism is deemed perfectly appropriate because, given the nature of evolutionary processes, we undoubtedly share certain characteristics with related species by descent. As Darwin noted, the differences between species are likely to be largely of degree and not kind. Indeed, it is not even “anthropomorphic” to attempt to identify such characteristics because, in this view, the term is literally nonsense, suggesting as it does that certain traits are inherently human and that we can unequivocally identify those that “belong” to us (Tyler 2003).

On the negative side, it is often argued that an anthropomorphic strategy should be avoided because it tends to limit the range of hypotheses we put to the test; as Blumberg (2007) suggests, an anthropomorphic research strategy is unlikely to generate the hypothesis that eating the urine and feces of one’s young is a good solution to avoid the dangers of foraging outside the nest, even though this is precisely what lactating mice do. Stated more broadly, anthropomorphism has the effect of anchoring other species to a human standard. Although couched in terms of undermining human arrogance (along the lines of “who are we to assume that only humans can love, grieve, and feel regret?”, e.g., De Waal 1997), such a view nevertheless shores up human self-regard because the similarities identified are almost inevitably couched in terms of



Fig. 1 An example of “eye-bombing.” Reproduced with the permission of Kim Nielsen

“human-like” abilities (e.g., Hare and Tomasello 2005; Hunt 2000; Krupenye et al. 2015). The available evidence is thus used to raise other species up to our level, rather than leading us to concede that, if much smaller-brained species show similar abilities to our own, perhaps these “human” skills are not so impressive after all (Barrett 2011).

There is also an interesting “chaining” process by which species become tethered to this human standard. Great apes are tested for skills deemed characteristically human, e.g., tests for mirror self recognition and self awareness (e.g., Povinelli et al. 1997). Other large-brained, charismatic species are then tested similarly to discover if they share these skills with apes (e.g., Reiss and Marino 2001). In this way, dolphins become a species of “aquatic ape” (Barrett and Würsig 2014; Marino 2002) and members of the crow family become “feathered apes” (Emery 2004). We lose the quiddity of each species in this approach, however: the sense of how animals in different ecological niches, with different bodies, and different nervous systems solve the problems they face in unique ways. That is, although such research is argued to undermine the notion of human exceptionalism, it also has the effect of rendering other species unexceptional too, because they apparently think and feel just like we do. They become simply pale versions of us.

Anthropocentrism, then, is the real problem. It is the way we position ourselves front and center in any comparison across species that renders anthropomorphism problematic, whether we view it positively or negatively. This is especially true of current comparative psychology, where we are in a phase where the emphasis is placed on identifying high level “cognitive” abilities in other species. This forms part of a continuing effort to rid the field of “mindless behaviorism” (see Barrett 2012, 2015b for a critique of this position). Given that many of our own behaviors can be explained through operant learning—witness the immense success of various smartphone apps that record and reinforce “good” behavior, like exercising and eating healthily—this effort seems both misguided and inaccurate (again see Barrett 2012, 2015b for a more detailed discussion). Clearly, this is not a point I need to be labor among behavior analysts. Instead, I would like to argue that it is the dominance of cognitive psychology, along with its computer metaphor—the idea that internal brain-bound information-processing mechanisms are the drivers of behavior—that enables and encourages a deeper anthropocentrism that seems to go unremarked and perhaps unrecognized in most of the comparative literature. I then go on to describe an alternative perspective that, even if it cannot dispel anthropocentrism completely, at least forces an awareness that such a bias exists and may, as a consequence, keep it under control.

Dogs are People too. Or are they?

A good place to begin is with recent work by Berns et al. (2012), in which fMRI scans were used to measure brain activity in awake but motionless dogs. Writing in the *New York Times*, Gregory Berns was unequivocal about the implications of this research: “...after training and scanning a dozen dogs, my one inescapable conclusion is this: dogs are people, too...By looking directly at their brains and bypassing the constraints of behaviorism, M.R.I.’s can tell us about dogs’ internal states” (Berns 2013). While this reinforces my point about anthropocentrism beautifully, it is perhaps unfair given that the piece was written for a lay audience and not scientists.

Turning to the actual scientific article on which the Times Op-Ed was based, however, one finds that the same tone persists. Berns et al.'s (2012) newly developed method will, it is argued, pave the way for studies that can answer the question of "how does the dog's mind actually work?" (p.1). For Berns et al. (2012), this means gaining insight into how, among other things, dogs mentalize the minds of humans, represent human facial expressions, and process human language. Indeed, they suggest we now have an "endless" series of questions to answer now that we have bypassed the need to "guess at the workings of the dog's brain" (p.1) and can observe cognitive processes directly.

Again, to be fair, the anthropocentric nature of this "endless series of questions" is justified by the fact that domestic dogs have been bred to be attentive and responsive to human words and gestures. Indeed, their skills in this respect outstrip those of our fellow primates, the chimpanzees (Hare and Tomasello 2005). The more serious problem here is the explicit assumption that a scan of a motionless dog's brain is more informative about the nature of its mind than any aspect of its world-involving physical activity. Indeed, it draws a very clear distinction between mind and behavior, generating the dualism so characteristic of modern cognitive psychology. Berns et al.'s (2012) approach also makes the further (implicit) assumption that behavior does not constitute or contribute in any way to what it means to be a "minded" creature. The brain alone is what matters, because it is the brain alone that takes inputs, processes information, computes outputs, and so generates the mind. This is what licenses us to conclude that "dogs are people too" because, when shown hand signals indicating food, or presented with the smell of familiar humans, activity is produced in a region of the brain (the caudate nucleus) that is similarly active when humans engage in rewarding activities (Berns et al. 2012, 2015; Berns 2013). Assuming that food and familiar humans are things that dogs are likely to enjoy, we can then take the activity of the caudate nucleus to indicate similar kinds of emotional experience in dogs and humans.

The massive irony here is that, in order to get the dogs into the MRI scanner in the first place, Berns et al. (2012) used "positive reinforcement, in combination with behavioral shaping, conditioning and chaining" (p.5) (escaping the constraints of behaviorism indeed...). The further irony is that this represents the only convincing evidence presented in the paper, while the inference from brain activity to shared emotions is shaky at best. It is important to note (once again) that I am not in any way denying the possibility that humans and other animals may share similar traits, including their emotions, rather I am questioning the nature of the evidence we use to draw those conclusions and the basic cognitivist premise on which they are based.

There is also a question of the kinds of humans we are talking about in these comparisons. Berns (2013), for example, informally suggests that adult dogs show capacities equivalent to that of a human child. Although he goes on to propose that this requires us to rethink our treatment of dogs, equating an adult dog to a human child nonetheless implies that dogs' abilities remain inferior; a stance that, again, is symptomatic of the anthropocentrism lying at the heart of much comparative cognition. If other species' abilities are not being characterized as somehow childlike, they are usually presented as evolutionary pre-cursors to our own fully developed capacities (even though we often lack evidence that our own cognitive abilities are, in fact, all that well developed: see Buckner 2013 for an argument developing this notion of "anthropofabulation"; see also Barrett 2015a, b). There is a vein of work in

comparative cognition that constantly feeds into and fuels this anthropocentrism, making heavy appeals to behavior that looks like our own, and leaning on phylogenetic parsimony to justify claims of similarity (or even identity) between psychological events and experiences in other species (reviewed in Barrett 2011, 2015a). In many cases, this probably tells us more about us than about them, and we should perhaps view the human-like skills of other species with some degree of skepticism (but see Andrews and Huss 2014 for precisely the opposite argument).

Brains in the Service of the Body

One major reason for skepticism is the recognition that evolution is also a diversity-generating process and not only one that preserves continuity. It seems highly dubious that other animals should have converged on a way of encountering the world so suspiciously like our own, when their bodies are so different from ours, with their flippers, wings, beaks, and their occupation of such diverse ecological niches. It seems odd that these things should matter so little.

This neglect of a species embodiment stems, as we have seen, from the cognitivist position that we can understand all species' behavior in terms of brain-based computational mechanisms and information-processing. If brains do all the heavy-lifting, and if other big-brained species produce behavior like that of our own big-brained species, then it seems reasonable to assume that the nature of the representational processes and computational algorithms that give rise to this behavior will also be the same. Unlike bodily anatomy, then, and despite wide variation in brain structure (e.g., Kirsch et al. 2008), similar cognitive architectures are assumed to underpin the diverse array of behavior animals produce. This heavy reliance on a computational-representational theory of mind is, however, a further reason why we should be skeptical of this heavily cognitivist position: computational, representational theories of mind are not derived from a naturalistic view of cognition and behavior, even though evolutionary theory is frequently waved about like a cross to a vampire to justify this kind of computational approach (see e.g., Byrne and Bates 2006)

As Brooks (1991) has argued, the cognitive revolution and the original artificial intelligence began as an effort to reproduce human-like intelligence in a machine. When this proved to be too tall an order, workers in AI tackled a series of more tractable problems, such as symbolic algebra, geometrical problems, natural language understanding, and vision (Brooks 1999). Importantly, in each case, the “benchmark” used was tasks that humans could achieve in these particular areas (Brooks 1991). What is even more important to note is that these problem domains were both defined and then refined by the researchers. That is, in order to generate a simple description of task at hand, and so simplify the problem, they abstracted away most of the details of the task to identify the core processes. In other words, most of the intelligence needed to solve a task—i.e., the part of the process involving abstraction—was accomplished by humans well before the artificial systems were let loose on it. Abstracting to the relevant details therefore ensured that notions of intelligence remained anthropocentrically oriented. In addition (and perhaps inadvertently), this approach also promoted the idea that differences in the perceptual worlds of organisms—that is, differences produced by variation in sensory and motor systems—were not relevant to understanding

cognitive processes. This is because the abstracted tasks were considered to be both general and generalizable to all species when, of course, this is not the case: they were the work of humans in possession of particular kinds of perceptual systems, and their simplified task descriptions naturally reflected this fact. This went largely unnoticed because cognitive processes were seen purely as a property of the brain, with sensory and motor abilities functioning simply as “peripherals” concerned only with the input to, and output from, the processes occurring in the brain—processes that augmented, transformed, and manipulated the information that was delivered by the senses. This view thus exposes the real heart of the computer metaphor: the idea that brains construct an internal model of our environment, and that we use these internal representations to act efficiently and effectively. We need such representations, so the argument goes, because the inputs to our senses are too impoverished to allow us to cope with the world around us (Blakemore 1977; Gregory 1980). The flat, upside-down image on our retina, for example, has to be converted into our dynamic three-dimensional view of the world by cognitive processes in our brains. Our contact with reality is therefore argued to be indirect, via the representational model our brain builds and not with the world itself.

The embrace of a computational-representational theory of mind by researchers in cognitive ethology and comparative psychology (for review see, e.g., Barrett 2011; Byrne and Bates 2006) means that the field implicitly accepts, and so reinforces, the idea that representational processes capture some essential quality of the brain that is not tied to any one species, but applies to brains in general. If representational theories of mind are not species-neutral however—if they have human intelligence and intentionality built into them right at their source—then computational cognitivist theories have their evolutionary continuity precisely the wrong way around. We begin with human intelligence as modeled by an inanimate object and not, as Brooks (1991) points out, from the way in which whole animals solve the much older, and more fundamental, problems of sensing and acting in a dynamic, unpredictable environment. (The other thing to note here, then, is the way that these highly specialized skills, like mathematics and language, were taken as models for all human intelligence, even though they cannot explain most of our everyday activities: the way we can cross a busy road without getting run over, run along a rocky beach, make coffee, eat doughnuts, spot a familiar face in a crowd, and dance the tango: Hutto and Myin 2012).

4-E Cognition as an Alternative

What we need, then, is an approach that does not take the computation-representational mind as axiomatic and allows other species to speak with their own voice. As I have argued elsewhere (Barrett 2011, 2015b), the burgeoning literature on 4E-cognition (embodied, embedded, enactive, and extended, e.g., Chemero 2009; Clark 1997; Gallagher 2005; Hutto and Myin 2012; Menary 2010; Pfeifer and Bongard 2007) helps tremendously here. Although they differ from each other in a number of important ways, all 4E approaches share in common the idea that cognitive processes emerge from the unique manner in which an animal’s morphological structure and its sensory and motor capacities enable it to engage successfully with its environment to produce adaptive, flexible behavior.

In this view, a brain forms only one part of a complex dynamically-coupled system: a brain is always brain embedded in a body, embedded in an environment, and it is the complex of all three that constitutes the “cognitive system.” Instead of an animal’s ability to produce flexible, reliable perceptually-guided action being seen as independent of its physical embodiment, with the environment viewed simply as the stage on which behavior is played out, the embodied, embedded, enactive view considers the animal’s body, and how it engages with the environment, to be a crucial resource that can be exploited in ways that actively contribute to the animal’s problem-solving abilities.

For example, using mobile robots, Scheier and Pfeifer (1998) demonstrated that, by moving through the environment using a distinctive circling pattern, the robots could produce similar cyclic regularities in the inputs that the robot’s “brain” received. This enabled them to avoid small cylinders in the environment while staying close to large ones, without the need for any kind of internal categorization process. The robots’ movement actively structured the inputs from the environment in such a way that there was no need for any kind of internal computational process by which cylinders were categorized as either large or small (i.e., it was “enactive”, its bodily engagement with the environment gave it a form of skilled access to its environment). By exploiting the structure of its body, via the interaction with the environment, the robots transformed a difficult “cognitive” task into an easily learned statistical pattern (see also Scheier and Pfeifer 1995). Whatever a “mind” might be, then, a 4E-approach views it as a verb and not a noun. This view of “minding” as embodied action in the world leads naturally to the “extended” view, which redraws the bounds of the cognitive system to include not only the body, but also environmental structures (including human-made cultural artifacts) and shows how these actively contribute to the kinds of flexible, adaptable behavior we associate with intelligent systems (for some examples of this, see below).

Although a lot of work in 4E-cognition is focused on humans, it applies equally well—if not better—to other animal species. This is particularly true of more radical 4E positions that reject the notion of cognition as a form of “mental gymnastics” (i.e., those that involve the construction, manipulation and use of representations; Chemero 2009; Hutto and Myin 2012). Hutto and Myin’s (2012) Radical Enactive Cognition (REC), for example, equates basic cognition with “concrete spatio-temporally extended patterns of dynamic interaction between organisms and their environments” (p. 5). Further, REC holds that “mentality-constituting interactions are grounded in, shaped by, and explained by nothing more, or other, than the history of an organism’s previous interactions. Sentience and sapience emerge through repeated processes of organismic engagement with environmental offerings.” The non-representational dynamical view of Chemero (2009) makes a similar argument, drawing more heavily on the work of the James Gibson (1966, 1979), along with his precursors among the American Pragmatist philosophers, Peirce, Dewey, and James; a grouping he refers to as the “American Naturalists.”

It should be apparent both from this brief description of radical embodied/enactivist views, and the array of thinkers that has inspired them, that BF Skinner should also be included on this list (see Barrett 2012, 2015b for precisely this argument). Morris (2009), for example, emphasizes Skinner’s pragmatist viewpoint and the clear links between Gibson’s ecological psychology and radical behaviorism/behavior analysis. In

Morris's (2009) view, the former can be considered as a "natural history" of psychology that complements the "natural science" of the latter, i.e., behavior analysis, and discusses how the two could be brought together productively. Most obviously, both Skinner and Gibson worked to eradicate the dualism that lies at the heart of psychology, where internal and external processes are treated as fundamentally different in kind. Morris (2009) demonstrates convincingly how Gibson's (1979) theory of direct perception (which involves the detection of invariants in an ongoing flux of energy) can be used to underpin Skinner's science of perceiving in terms of stimulus control (when an organism behaves one way in the presence of a stimulus and another in its absence). Morris (2009) also highlights the similarities in their views of organism–environment relations, where Gibson's "affordances" (the opportunities for action that particular environment resources offer to an animal) can be seen as akin to Skinner's concept of discriminative stimuli. Radical behaviorism thus provides a link between Chemero's (2009) Gibsonian-inspired radical embodiment and Hutto and Myin's (2012) radical enactivist view of cognition (see also Tonneau 2011).

One reason why 4E cognition works better, then, is because it allows us change the "job description" of the brain. Instead of thinking of brains as representational, we can view them as "performative" (Pickering 2010): their job is not to model the world around us, but to guide and control action in an inherently dynamic, unpredictable world. Brooks (1999) makes the argument this way: 4 billion years of evolution were, in the main, spent refining the perception-action mechanisms that guide effective action. It took an enormously long time to build insect-level intelligence, while those things we think of as highly intelligent human capacities—language, logic, and mathematics—evolved very rapidly, in a mere blink of evolution's eye. This being so, the latter must have been pretty easy to implement once the former was in place (Brooks 1999). Brooks (1999) take-home message is that we would therefore do better investigating how whole animals cope with the changeable environments they encounter, rather than focusing our attention on the computing power of brains in isolation. Indeed, Brooks was the pioneer of an alternative behavior-based robotics, which demonstrated that flexible, intelligent behavior does not require a representation-heavy computational model to achieve. His robots were built to "use the world as its own best model", and he did not worry about providing them with any kind of central processing unit or "brain." After all, why go to the expense of representing the world, when the world itself contains all the information needed? As inventor of the Roomba, the vacuum cleaner that uses these principles to clean your house all by itself, the strength of Brooks' approach is clear: as the old saying goes, 10 million Roomba owners can't be wrong.

Although 4E-cognition is heralded as a new and innovative way of thinking—which it is, do not get me wrong—another reason to welcome this alternative view is because it helps bring back to prominence some older but extremely good ideas. I have already discussed the links with Radical Behaviorism and Gibson's Ecological psychology, but another feature of a more embodied-embedded perspective is von Uexküll's concept of the "Umwelt" (Uexküll and Von 2014), a term which can be translated as "the environment as perceived by the organism". The main idea here is that species are sensitive only to those aspects of the environment that hold significance for their survival and reproduction. Adopting this view simply is to take an embodied-embedded perspective on matters, as the notion of an umwelt forces us to pay attention to an animal's sensory and motor capacities, the niche it occupies and the kinds of tasks its lifestyle demands of

it. In this way, an animal's body and environment come into sharper focus, and the brain is put in its place as just one element of a complex, dynamical system.

Another reason for broadening our investigations beyond the brain, especially if one is interested in cognitive evolution, is because brain tissue is enormously expensive, energetically speaking (Parker 1990). If a problem can be solved without the need for expensive neural tissue, it seems likely that evolution, being a thrifty process, will produce a highly cost-effective solution (all else being equal, an animal that solves its problems more efficiently has more energy available for reproduction, and animals that reproduce more have a greater chance of leaving descendants in future generations).

What this means, in practice, is that an evolutionary perspective promotes an embodied perspective, because being made in the right kind of way can reduce the need for brain tissue. So, we find, for example, that the planthopper, *Issus coleoptratus*, has a “gearing mechanism” on its legs: small protuberances that interlace and allow the movements of its legs to be precisely synchronized as it jumps (Burrows and Sutton 2013). The gears achieve this synchrony much more precisely than is possible with neural control alone, and they also work much faster as a consequence, because there is no delay due to neural transmission. For much the same reasons, seahorses have tails that are square prisms, rather than the more standard cylindrical tails; these improve their ability to grasp onto coral reefs and mangrove roots and enable them to do so with more control (Porter et al. 2015). Spiders of the genus *Portia* display a startling variety of flexible, context-dependent hunting behaviors, including mimicry, stalking, and “smoke-screen behavior” (that is, taking advantage of disturbances to advance undetected), all with the brain the size of a poppy seed (Jackson and Pollard 1996). They also show a remarkable ability to take complex detours through their environment as they stalk their prey (Tarsitano and Jackson 1994), a behavior considered almost impossible without the ability to maintain a mental representation of the prey during those periods when it is out of sight.

Experiments on *Portia* spiders indicate, however, that this complex and seemingly representation-dependent behavior can be explained in terms of their perceptual skills: patterns of scanning and fixating are governed by a few simple “rules”—such as maintaining an uninterrupted horizontal line in its visual field—that enable these spiders to act effectively without any inner map or plan (Tarsitano 2006; Tarsitano and Jackson 1994, 1997). This, in turn, is linked to the physical structure of their large “anterior medial” eyes. These eyes are active and vibrate in characteristic patterns. These vibrations are suggested to be instrumental in allowing the spider to pick out horizontal features effectively and enabling them to “ignore” other features in its environment. The complex pattern of movement produced by the eyes may therefore filter out irrelevant detail and pick out the most important features needed to reach prey (Land 1969).

Body structure similarly may be important even for those animals that are well endowed with brain tissue. New Caledonian crows (NCC), for example, are famous for their tool-using skills. They manufacture their own tools and use them to solve natural foraging problems, and they have also been shown to successfully tackle some rather more unnatural tasks in the laboratory environment (e.g., Hunt 1996). Other brainy birds, like keas, jays, rooks, ravens, and carrion crows, also use tools, but NCC are suggested to be more cognitively competent than other species, given the variety and ingenuity with which it uses tools in its natural environment; its greater cognitive competence is argued to show itself in improved performance.

What is interesting, however, is that, when tested against carrion crows (along with another tool-using bird, the Galapagos woodpecker finch) in a non-tool using task, there is no discernible difference in their performance (Teschke et al. 2013). One suggestion, that follows a standard cognitivist narrative, is that NCC competence is highly domain specific, with evolved cognitive mechanisms that drive tool-using behavior. Recent work by Troscianko et al. (2012), however, suggests that this domain specificity may arise as an aspect of the bird's embodiment.

Specifically, both the shape of the crows' bills and the positioning of their eyes make a significant contribution to the superior tool-using and problem solving skills (Troscianko et al. 2012). Compared to the other corvids, NCC possess very high binocular overlap of their eyes and very straight bills. These anatomical features allow them to maintain a stable grip on a tool while simultaneously being able to look along the length of the tool as they use it. This gives NCC a distinct advantage over those species that are less able to guide their actions visually and can explain why they show markedly improved performance compared to other tool-using species argued to possess equivalent cognitive competence (Teschke et al. 2013).

Other neurophysiological work on tool use demonstrates another aspect of embodiment, this time by highlighting the "negotiable" boundaries of the body (Clark 1997). Contrary to standard thinking, we should not think of bodies as fixed and stable, but as more fluid entities that are constantly constructed and reconstructed into different kinds of "task-specific" devices (e.g., Bingham 1988). In this way, animals' bodies incorporate a diverse array of resources available in the environment that can help simplify the task at hand and/or enhance an animal's ability to complete it (Clark 1997, 2004). Maravita and Iriki (2004), for example, trained macaques to pull objects toward them using a rake, and then monitored the activity of so-called "bimodal neurons" in the intraparietal cortex as the monkeys engaged in this task. Bimodal neurons are those that respond to both somatosensory and visual information. In this case, activity of neurons that responded both to stimulation of the hand (the somatosensory receptive field sRF) and visual stimuli near the hand (visual receptive field, or vRF) were recorded. After only 5 min of tool use, the neurons whose sRF corresponded to the hand showed a change in their vRF. Specifically, the vRF elongated to include the length of the tool. Consequently, objects placed within reach of the tool stimulated the visual neurons previously associated only with the objects in reach of the hand (see also Maravita et al. 2003). In effect, then, the rake could be considered as part of the monkey's "reaching system." Crucially, the macaques had to engage in active tool use for this effect to manifest. Holding the rake passively did not induce any change in the receptive fields. In addition to suggesting that the bounds of the body have rather fuzzy edges, work like this emphasizes the impossibility of considering an animal independently from its environment. The bounds of the body are continually in flux as animals exploit the various environmental resources at their disposal.

Paradoxical Tuna, Hydrodynamic Tongues, and the Extended Mind

There are other ways in which animals can extend the powers of their physical bodies. Studies of the anatomy and musculature of the blue fin tuna, for example, reveal that it is physically incapable of swimming as fast as it does. Studies by fluid dynamicists,

however, show that tuna are able to swim faster than their own physical capacities allow because they find naturally occurring currents in the water and then use their tails to create additional vortices, which they then exploit to gain extra propulsion (Triantafyllou and Triantafyllou 1995). My current favorite example of this kind of environmental exploitation is the way that mudskippers (fish that have the ability to feed on land) use water to form a “hydrodynamic tongue” that assists with the capture of food (Michel et al. 2015). The fish emerge onto land with a mouth full of water, and then eject this using a pattern of motion that shows a clear resemblance to the way newts protrude their sticky tongues to catch prey. Clark (2001, 2005) uses findings like these to spell out the implications for his view of intelligent and flexible behavior: “what goes for physiology applies equally well to cognition: we should not expect evolved organisms to store or process information in costly ways when they can use the structure of the environment, and their ability to act in it, to bear some of that cognitive load” (2001, p.143).

We can see this most clearly in the way humans use the physical world. We use post-it notes, memory sticks, notebooks, computer files, whiteboards, books, and journals to support our written work; we lay out all the ingredients we need for cooking so that what we need comes to hand at the moment we need it; we leave our keys right by the door so that we do not forget them on our way out of the house (Barrett 2011). All of these behaviors reflect a habit of simplifying what would otherwise be cognitively demanding tasks—a habit that is all-pervasive and underscores just how much of routine human cognition is enacted in the context of environmental supports (Kirsh 1995). In other words, like the paradoxical tuna, there is a true sense in which the real “problem-solving machine” is not the brain alone, but the brain, the body, and the environmental structures that we use to augment, enhance, and support whatever internal processes operate to help get us through the day.

To conclude then, I just want to point to the ways that 4E approaches provide us with a more interesting means by which we can consider our own behavior in evolutionary perspective. They do so by allowing the differences that make a difference between humans and other species to be brought to the fore, especially those behaviors that seem to defy an evolutionary account, such as the weeks and months people will spend training for punishing endurance races, the effort placed into building a scale model of San Francisco from matchsticks, or the years spent secretly planning and training for a tightrope walk between the twin towers of the World Trade Centre, as Phillippe Petit did in 1974. These examples are, of course, also outside of most humans’ experience, but I choose them deliberately because I want to counter the pervasive tendency, discussed at the beginning of the paper, to emphasize evolutionary continuity at the expense of diversity. An emphasis on the former can lead all too easily to the conclusion that human traits are “nothing but” those found in other species, just tweaked a little here and there. Obviously, I raise no objections to good evidence of continuity, but humans *are* different, and a desire to understand the sources of such difference does not necessarily translate into a desire to argue for a more unique kind of uniqueness in our own species compared to all others.

One way to illustrate this is with a story I found while searching online for examples of bizarre human behavior. It came from an article documenting a phenomenon seen across several coffee shops in the San Francisco area, all of which were selling single slices of cinnamon toast for around \$4.00 each—a price that easily could

buy several loaves-worth of bread where I live. I ended up following an internet trail that led me to a story about a small San Francisco coffee shop, run by a woman called Giulietta Carelli (Gravois 2014). Having suffered from mental illness for much of her life, Carelli's coffee shop was as much a way for her to cope with life, as it was to make a living. Dressed constantly in the same distinctive "uniform" of bandana, tank-top, and jeans, her arms covered with tattoos, Carelli sells nothing but coffee, cinnamon toast, coconuts, and lime juice: items that all hold personal significance for her. Her shop lacks many seating options, a deliberate choice made to encourage strangers to sit together and socialize. All of these measures are ways that help Carelli cope with her condition: as Gravois (2014) notes, "Most of us dedicate the bulk of our attention to a handful of relationship: with a significant other, children, parents, a few close friends. Social scientists call these 'strong ties.' But Carelli cannot rely on such a small set of intimates. Strong ties have a history of failing her, of buckling under the weight of her illness. So she has adapted by forming as many relationships—as many weak ties—as she possibly can." Carelli's quirky coffee shop ensures she encounters a consistent and familiar set of people, and her distinctive appearance ensures she is recognized and remembered in turn; both serve as a means by which she can maintain the ties that keep her stable and anchored to society and the human world.

I was struck by this story, not just because it gave some meaning to the whole notion of ludicrously expensive toast, but also because I was also writing up a paper from my long-term study of baboon behavior. In this analysis, my collaborators and I show that the number of weak social ties a female baboon maintains is associated with higher fertility and greater reproductive success (Murphy et al., submitted). Weak ties, then, are functional for both human and non-human primates. Yet, the manner in which Carelli exploits a wide variety of material and technological resources to form and sustain her weak links (tattoos, clothing, a coffee shop, benches, an industrial espresso machine, a supplier of coconuts, water, electricity, and cinnamon) is a world away from the way in which her distant primate relatives do it: they rely solely on spatial proximity and grooming behavior to tie themselves to others. Such differences surely must be acknowledged, even as we recognize a fundamental similarity in the need to integrate oneself into the social matrix.

My final point, then, is that the alternative models of mind offered by 4E cognition cannot only offer a less anthropocentric view of other species, but they can potentially provide a more satisfactory understanding of our own by offering *us* the right kind of anthropocentric viewpoint. A 4E perspective that recognizes how bodily and environmental resources are constitutive of a "cognitive system" provides a means for us to interrogate the possible reasons why we can achieve feats seemingly beyond those of other species, such as the building of life-enhancing coffee shops. The human "cognitive system" is extended far beyond that of other species because of the complex interaction between the biological brain and body, and the wide variety of artifacts, media, and technology that we create, manipulate and use. As Clark (2004) puts it, we are no longer "constrained by the limits of the on-board apparatus that once fitted us to the good old savannah" (p.242).

The promise of 4E thinking for humans lies in its explicit recognition of the historical, sociocultural nature of human psychology—the fact that we develop in a socially and culturally rich milieu that reflects the contingent nature of developmental and historical events, as well as those that occurred in our more distant evolutionary

past; sentiments with which all radical behaviorists would no doubt agree. It is surely the way that we incorporate all manner of material and technological artifacts to form a distributed, extended cognitive system that contributes to the differences we see between humans and other creatures: the more negotiable the body, the more world-involving the behavioral loops, and the more behavioral flexibility there is, the more “intelligence” we see. The difference between humans and other animals, then, may lie in the extraordinary extent to which we augment, enhance, and support our brain-based learning processes, hauling ourselves up by our bootstraps to achieve feats that no one individual could achieve alone. The things that make us smart in our own peculiar way are thus likely to lie outside our heads, rather than in them. In the words of Mace (1977), it starts to make much more sense to “ask not what’s inside your head, but what your head’s inside of.”

Compliance with Ethical Standards

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

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