

# COMPARATIVE COGNITION & BEHAVIOR REVIEWS

2010

Volume 4, pp 66 -85

## Resituating Cognition

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Cognition, historically localized in one part of the body—the heart in earlier times, the head in latter—involves the action of the organism as a whole: within and dependent upon the details of its physical and social environment. Recent experiments with humans, and classic ones with animals, reveal the essential role played by perceptual and motor acts in shaping the character of thought. Cognition is redefined in terms of Aristotle’s four causes: Occasioned by changes in the environment, its substrate is the nervous system—peripheral as well as central; it evolved to guide action, and may be represented as a special kind of automaton. Cognition is repositioned, from a species of mindwork to an activity pervading the body and the locale, without which it would be difficult to maintain, and would have been impossible to achieve.

Keywords: Behaviorism, Causation, Cognitive Science, Embodied Cognition, Exocentric Cognition, Situated Cognition

Gerald Holton introduced the concept of *themata* in scientific activity to describe how unspoken assumptions color the activity of generations of scientists (Holton, 1975). As examples from physics, he pointed to the value placed on unification (of theoretical explanations), elementary objects (as units of analysis), isotropy (there is no favored direction in the universe along which measurements differ), homogeneity (particles of the same species are absolutely identical, whether they exist in our living room or the opposite end of the universe), and symmetry (whose failure in classical mechanics for the motion of magnets and

conductors motivated Einstein’s special theory of relativity (Einstein, 1905)). Themata differ from Kuhn’s *paradigms* in that they persist during normal and revolutionary epochs, and issue more from the individual than the community. The assumption of continuity is another pervasive thema, which Einstein kept because, he said, “I have been unable to think up anything organic to take its place” (cited in Holton, 1975).

For generations the community of experimental psychologists have held dear another thema—cognition as a brain process—unable, it has seemed, to think up anything organic to take its place. The brain is the most complicated object in the universe, remove the brain and you delete cognition; ergo, thinking happens in the brain. Small brains, such as those possessed by small animals, are capable of only small thoughts (Suddendorf & Corballis, 2007); divided brains are of two minds about the world (Gazzaniga, 2002; Turk et al., 2002); sick minds cause sick behavior (Sims, 2003). The roots of this thema, a central mind over exogenous matter, go back to Descartes:

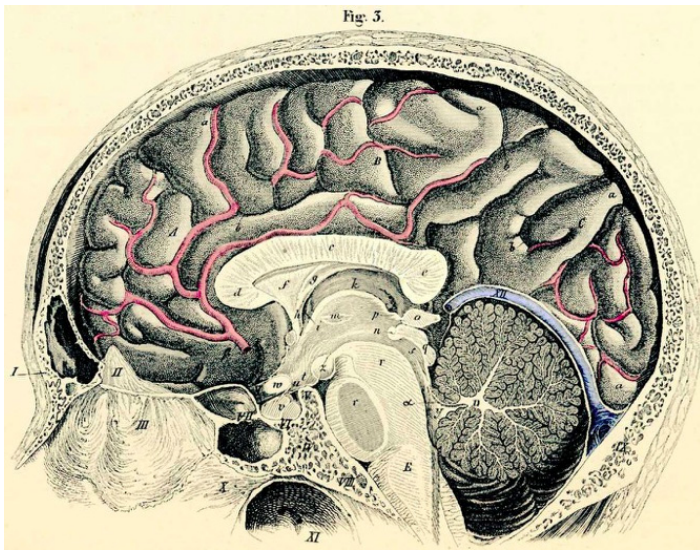
Work on this article was supported in part by the National Science Foundation under Grant No. BCS 0744105 to Arthur Glenberg. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Mailing address for both authors: Department of Psychology, Arizona State University, Mail code 1104, Tempe, AZ, 85287.

It is now manifest to me that bodies themselves are not properly perceived by the senses nor by the faculty of imagination, but by the intellect alone; and since they are not perceived because they are seen and touched, but only because they are understood [or rightly comprehended by thought], I readily discover that there is nothing more easily or clearly apprehended than my own mind. But ... it is difficult to rid one's self so promptly of an opinion to which one has been long accustomed...(Descartes, 1637).

Descartes' brilliance instigated an opinion—a thema—to which we have been long accustomed, and of which it has been difficult to rid ourselves. If it is chemical, Descartes went on, it is part of our body; but if we cannot conceive of it as chemical, it is mental:

Anything we experience as being in us, and which we see can also exist in wholly inanimate bodies, must be attributed only to our body. On the other hand, anything in us which we cannot conceive in any way as capable of belonging to a body must be attributed to our soul. Thus, because we have no conception of the body as thinking in any way at all, we have reason to believe that every kind of thought present in us belongs to the soul. (AT XI:329, CSM I:329) <http://plato.stanford.edu/entries/pineal-gland/-2.1>.

A soul that, most famously, interacts with the body at the pineal gland (Figure 1).

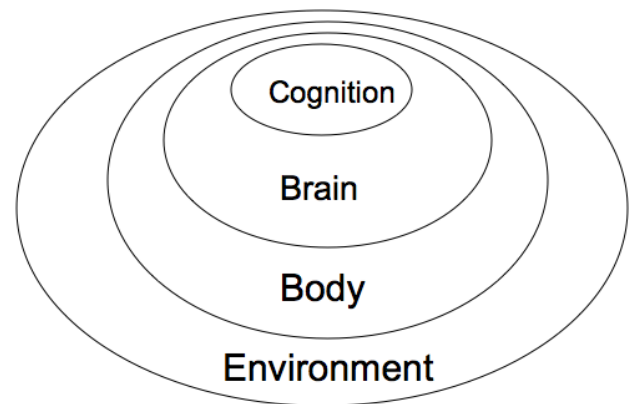


**Figure 1.** *The Pineal Gland (letter o). Sagittal section of brain, view from the left, the surface of the medial half of the right side is seen. (From, "Handbuch der Anatomie des Menschen," by C. E. Bock, Leipzig, 1841. In the public domain.)*

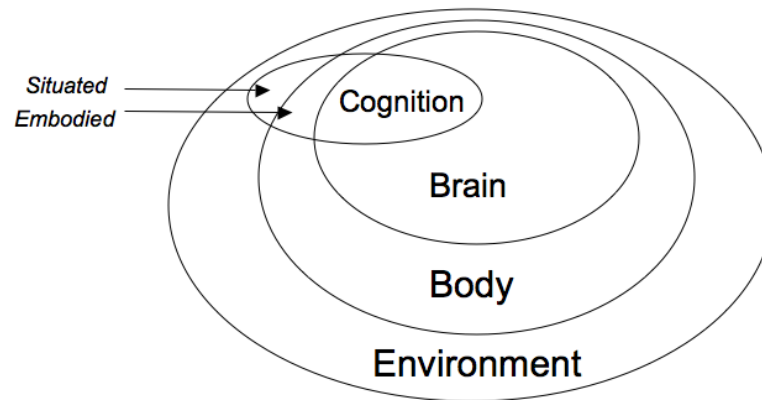
Quaint? "C. S. Sherrington was a great neuroscientist [of the 20th] century, and one could hardly improve on his expression (1934) of the Cartesian view: 'The mental action lies buried in the brain, and in that part most deeply recessed from outside world that is furthest from input and output.'" (Dennett, 1996). Figure 2 draws this *Centrist Cartesian thema*.

The innermost circle, cognition, carries a burden of surplus meaning; to various readers it may connote, "Thinking", "Covert Behavior" and even "Mentation"; to Descartes, "Soul". Thus, one version of this paradigm avers that Minding (conscious cerebration) is the highest level of cognition; cognition is what the brain does; the brain controls the body; the body changes the environment. Changes in the environment are sensed by the body and communicated to the brain, where they are filtered, categorized, compared, evaluated, and stored for future reference; after calculating costs, benefits and alternatives, and reflecting on future implications, summary commands may be issued to the body. After some qualifications of types characteristic of the niceties of their sub-discipline's ideology, few psychologists would take issue with Figure 2. We do take exception to it, however, and offer in its place the eccentric locus for cognition shown in Figure 3. In this article we describe the meaning of that figure, and explore some of its ramifications for the behavior of humans and other animals.

Figure 3 posits that cognition happens in the brain; and in the body; and in the environment. There are names for extra-cranial mentation: That part that finds home in the extra-corporeal world is called situated cognition, short for situated in the world; and the part that occurs between the dermis and the dura mater is called embodied cognition. We shall refer to this newer framework in general as the Exocentric Paradigm. In explicit contradistinction to Descartes, anything in us which we cannot conceive as capable of belonging to a soul must be attributed to our body and its environment.



**Figure 2.** *The Centrist Cartesian thema.*



*Figure 3. The Exocentric paradigm.*

Thus, because we have no conception of the soul as thinking, we have reason to believe that every kind of thought present in us belongs to the body, including its brain, in interaction with its environment. The Exocentric Paradigm holds that cognition is a process that typically involves brain, body, and environment.

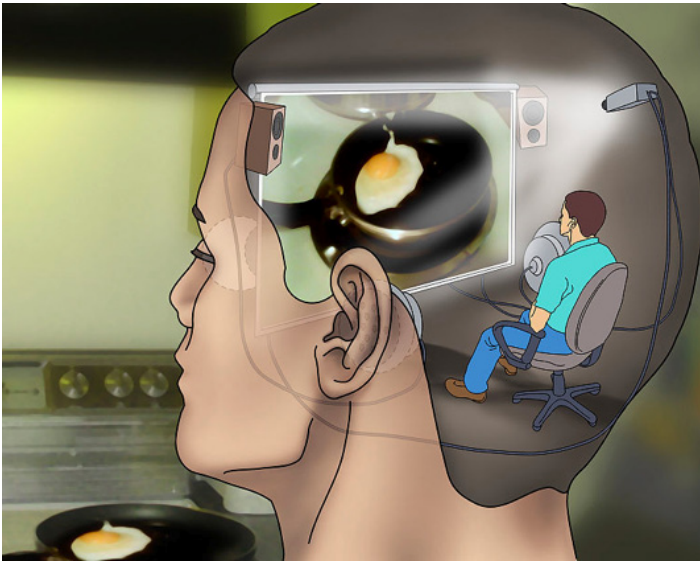
No one would gainsay that information from the world and body serve as input to the mind. We say more: The structure of the context, and of the body, structure the process of thought. The change in structure of the environment, and of the body, changes the flow of thought. Enough of the real work of cognition is outsourced to body and context that they become an essential part of it: Context and corpus are part and parcel of cognition. The complex machinery of the brain is clearly necessary for *Homo sapiens* to think; but it is the locus of thought in the same way that the office of the Board of Directors is the locus of Ford Motor Company. Our argument is punctuated with examples. We suspect that most readers will start by rejecting the Exocentric Paradigm, and then, step by step, come to hear themselves saying (embodied metaphors if there ever were two): “Well if that’s all you mean, sure ...”;... “Of course, but ...”; and by the end, they will be left facing only two options: A retreat to encephalized cognition, or an advance to exocentric cognition. In either case, their reaction will be embodied—we walk or lean forward or back as events are attractive or aversive to us (Barsalou, Simmons, Barbey, & Wilson, 2003; Mehrabian, 1969), just as inevitably as a physical retreat or advance biases our attitude (Cacioppo, Priester, & Berntson, 1993; Koch, Holland, Hengstler, & van Knippenberg, 2009).

This audience is better prepared for the idea of embodied cognition than most, as the field of animal cognition borders it; for a survey of the former, see Shapiro (2007); and reviews of the latter Bekoff, Allen, and Burghardt (2002) and Wasserman and Zentall (2006). However one connotes cognition, it is clear that it must be embodied, as is all behavior. But just how one should connote cognition is a delicate matter—as are all definitions of fundamental terms,

even of such overt processes as behavior. Neisser, one of the godfathers of the cognitive revolution, gave us the omnibus: “The term ‘cognition’ refers to all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. ... Such terms as sensation, perception, imagery, retention, recall, problem solving, and thinking, among many others, refer to hypothetical stages or aspects of cognition.” (1967, p. 4). Cognition seems to be—just about everything. We see two shortcomings of Neisser’s landmark thesis, beyond its breadth: It connotes central processing, and it gives short shrift to action.

An unfortunate legacy of the centralist paradigm, inherited from the Cartesian cut between mind and body, is the homunculus residing in an upstairs bedroom of our mind (Figure 4). For the little man inside, the executive who perceives, decides and initiates action, the senses and muscles are simply peripheral input-output devices (Wilson, 2002). But if all the afferent information were to accomplish was to re-present a simulacrum of the external world to our cerebrum, and all the efferent information were to do was preform and direct the complete motion, then a much reduced set of resources, all within the cranium, would be charged with the same problem that had had the body as a whole available for its accomplishment. In Figure 4 the seated figure represents this benighted vision of Cognition (not shown for lack of space in the margins of that mind is Cognition’s own, smaller, homunculus). Such a cephalization of cognition out-sources the problem of mentation, leaving fewer resources for its accomplishment, and no hint of how it will be achieved. If this seems too much a 20th century parody, the reader is invited to consider how it differs from the 21st century version, in which only the name of the homunculus has been changed to *Executive Functions*.

One of the newer developments in artificial intelligence research is an architecture in which a constellation of “experts” analyze problems and compete for the answer. Jerry Fodor offers a similar, neocartesian picture of intelligence, one in which a corporation of expert modules



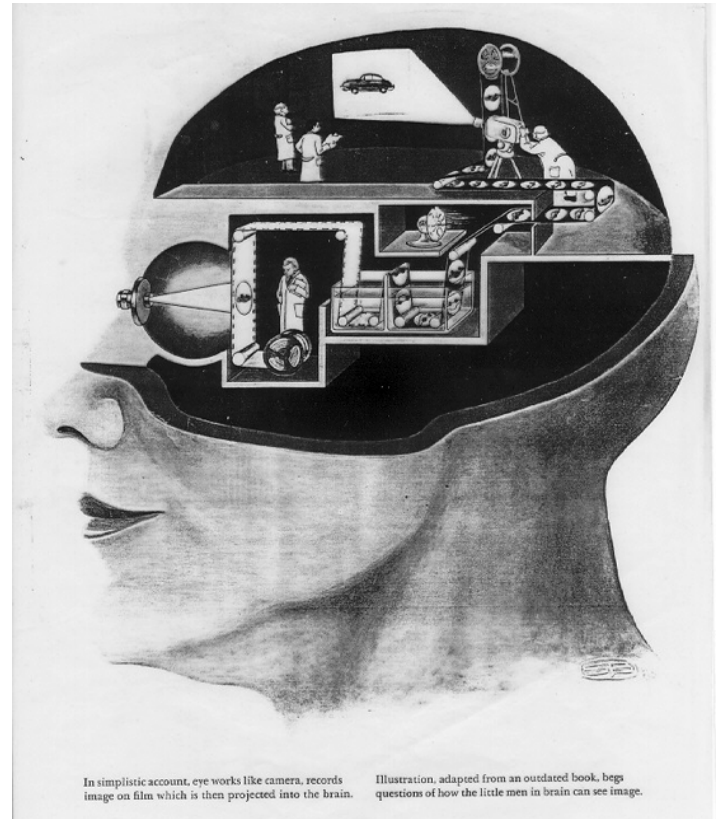
**Figure 4.** *A homunculus gets breakfast. (Image by Jennifer Garcia, [http://commons.wikimedia.org/wiki/File:Cartesian\\_Theater.jpg](http://commons.wikimedia.org/wiki/File:Cartesian_Theater.jpg). Used with permission.)*

discharges their functions, under supervision by a more flexible executive controller (Fodor, 1983). Not one, but multiple agencies (Figure 5).

*Everting the homunculus.* An alternate vision of the homunculus lays out the body on the cortex in proportion to the enervation subserving those body parts (Figure 6). If this figure is viewed, not as an embedding of those functions in the brain, but rather an extension of the cortex into that flesh, it provides a more apt metaphor for exocentric cognition. The cerebrum may coordinate and bind, but it does so in active collaboration with the sensors and effectors it serves. Unlike the centrist paradigm, information flows as a dialogue, not a dictate (Grossberg, 1980; Shepard, 1984).

### ***The Four Causes of Cognition***

To clarify how our concept of cognition differs from the Centrist Paradigm, we invoke an old clarification of what is necessary for comprehension (one which we hope will itself someday become a thema for psychology). Aristotle proposed that comprehension of a phenomenon starts with a description, and proceeds to consideration of the four causes of the phenomenon so described. The definition as a whole involves those four causes. For Aristotle, cause meant not efficient cause, but rather *because*—one of the essential dimensions of explanation (Hocutt, 1974). The description we propose is quite general; this is possible because identification of its attendant causes subsequently reins it in from over-generality. Different processes may satisfy the description, but, distinguished by differences in trigger, or substrate, or function, they are different constructs. Description gets us in the ballpark; characterization of the



**Figure 5.** *A distributed-process homuncular model of cognition. (From, “Consciousness: More like fame than television” by D. Dennett, 1996. Picture out of copyright.)*



**Figure 6.** *The homunculus turned out. (From <http://commons.wikimedia.org/wiki/File:Homunculus.PNG>. Used with permission.)*

causes tells us the essence of the game and its rules and reasons (Killeen & Nash, 2003); together they constitute the definition. First we thumbnail, then unpack, this definition. Our description of cognition is:

*Cognition is behavior that is sensitive to its context.* By “sensitive to” we mean the behavior is contingent upon its environment; the change in the behavior with respect to a change in the environment is somewhere non-zero. In terms of the probability calculus, if behavior  $i$  is cognitive, then for two different environments  $e_j \neq e_k$ ,  $p(b_i|e_j) \neq p(b_i|e_k)$ , whereas for two similar environments  $e_j \approx e_k$ ,  $p(b_i|e_j) \approx p(b_i|e_k)$ .

The efficient cause of cognition is a change in the environment of the organism.

The material cause, the substrate for cognition, is the complete nervous system (not just neocortex), as defined below.

The final cause, or function, of cognition is the guidance of action.

The formal cause of cognition—its form or account or representation—lies in the eye of its framer. Theories of cognition have ranged from British associationist to British quantum mechanical (Penrose, 1994). Our formal model of cognition is that of an automaton with content-addressable memory in the form of finite rewritable stores—in particular a linear bounded automaton (Hopcroft & Ullman, 1979; Hopkins & Moss, 1976). To be clear, this assertion concerns the nature of our preferred model of cognition; it may characterize cognition, but cognition is both more, and more constrained, than such automata, as it must satisfy the other aspects of its definition.

Note that cognition is not any one of these things; cognition is contextually sensitive behavior that has *all* of these properties. We may see the heliotropism of sunflowers as behavior that is sensitive to its environment; the differential sensitivity of the plant to the sun as a functional mechanism to guide action; and we may represent that action as a servo-system, a simple automaton. It is not cognitive, however, because the plant lacks the *material cause* that our definition requires: the machinery involves, not a nervous system, but photosensitive cells that pump potassium ions into nearby cells, changing their turgidity. Other conceptions of cognition specify different causal structures; traditional cognitivism has largely restricted the substrate to the central nervous system, whereas some students of artificial intelligence would allow silicon chips as a substrate for thought. Not right or wrong, but different constructs.

We allow for extended chains of *efficient causality*. Deliberation over a chess move may extend for hours after the opponent’s gambit. As the chain is lengthened, the possibility of other causal factors enters. The model of efficient causality we require is not that of billiard-balls; cognition is more like a soccer play involving a complex interaction of causal factors. Not a hair trigger, but a causal net.

The *material cause* of cognition is the nervous system, not the neocortex. The nervous system includes peripheral afferent neurons that subserve proprioception and efferent

neurons that subserve feedforward tuning of receptors and priming for action. It includes the paleocortex, seat of emotions. This inclusion of the whole nervous system offloads some of the computation required for cognition; but it offloads it not to the little man inside, but rather to the larger man as a whole. This collaboration is a form of distributed computation, letting the wisdom of the body inform the wisdom of the brain. This expansion of the substrate is what makes cognition embodied.

The *final cause* of cognition, the reason that evolution favored it, is its ability to inform action. This guidance increases the likelihood of success in acquiring and defending resources. This function does not guarantee that the guidance will meet our personal standard for rationality; only that it meet selection’s standard for viability. Folly, superstition, aggression and exploitation often capture our “best minds”, and often do so to the advantage of them and their progeny.

The theoretical model, or *formal cause*, we favor is provided by automata theory. Minsky has noted that “every finite-state machine is equivalent to, and can be ‘simulated’ by, some neural net” (1967, p. 55). In an influential paper, Hopfield and Tank (1985) demonstrated how to construct such networks of simulated neurons that could be said to make decisions. But not all automata are equally powerful, or equally intelligent in their decisions. Finite automata can distinguish only what can be represented in their memory. When that memory is augmented with push-down stores, or finite rewritable drives, or infinite tapes, increasingly powerful computations become possible that correspond, respectively, to Chomsky’s (1956) context-free grammars, context-sensitive grammars, and universal Turing machines (Hopkins & Moss, 1976). The computation of very simple animals may correspond to the simplest of these automata, and be described in other words by associationist principles. Upon reaching the level of complexity of many mammals, if not sooner, the late (context sensitive) reduction of memory to disposition made possible by their finite re-writable memories suggests that these automata, corresponding to context-sensitive grammars, becomes the models of choice (Killeen, 2001). No biological (or other!) system has access to the endless memory required by universal Turing machines. An added feature, that memory be content-addressable, is essential for the associations that cognitive creatures make, and it is one that can be emulated by neural nets at this level (Hopfield, 1984).

Whence the *memory* by which we so amply enlarge our potential from simple association machines to more sophisticated computers? Much of it is found in the erasable and reusable synaptic connections of the neocortex. But some of it is stored in the body as a whole, some in the environment. Gesturing, for instance, is a crucial aid in the production of fluent speech (Krauss, 1998), and occurs even

in congenitally blind children (Iverson & Goldin-Meadow, 1998). Not only is gesture useful in retrieving words, it is involved in the conceptual planning of speech (Alibali, Kita, & Young, 2000), and can facilitate or interfere with learning of new concepts. Kelly, Manning, and Rodak (2008) provide an excellent overview of current neuroscientific, experimental, and educational research involving gesture. Non-human animals have also evolved embodied and situated memories, discussed below.

Memory is not only embodied, as the rapidity of adjustment in riding a bike or playing a piano crescendo attests; it is often ensconced in the environment. This may not always be so obvious—perhaps because its obviousness is of little evolutionary value—but it is not only our retinas that have blind-spots. The recent plethora of research on inattentive and change blindness and deafness reveals that much that meets the eye never gets in to see the mind (Most, Scholl, Clifford, & Simons, 2005; Simons & Chabris, 1999). Our assumption of having a relatively complete record of our proximate environment is generally optimistic. But why indeed process all that information when it will largely be there for you the next time you look? Let the environment remember its status. Just as efficient pictorial and video compression does not represent anew bits that haven't changed, our own encoding is sparse. You may know how to find your way through a city when enroute, but describing that to another, absent the seriatim cues, may be impossible. Or more locally, try to describe (or gesture) how to tie a shoelace without the lace itself. The actions that are close to automatic when supported by the environment (the shoelace) can become next to impossible without that support. If we knew as much as we thought, in a context free way, we would have little capacity left to process that over-rich harvest.

Although our nervous system has a finite memorial capacity, its ability to upload information from its body and environment ad libitum tremendously extends its computational capacity. A person is deemed knowledgeable if she can demonstrate and deploy relevant information. If, between query and response she consulted Pub Med, that might only give us more confidence in the quality of her response. A key to the evolution of *homo sapiens* was its ability to use narrative to transmit cultural innovation. That information is now digitized, with episodic condensation in narratives such as this article, to quickly diffuse again into the web. The linear bounded automaton *homo sapiens* supplements its limited internal memory by resituating it in the environment, on clay tablets, paper books, or silicon wafers, searching to locate within it the fields most resonant to its final ends. To have a coherent effect on cognition, the contents of the books and wafers must be grounded, construed in relation to the body, able to be parsed by its systems of perception, action, and emotion (Glenberg, 2007).

## 2. Particulars of the Body

Given our expanded definition of cognition as involving more than the central nervous system, to remind the reader that our paradigm is non-central—exocentric—is redundant. However, until the associations stick, we shall continue referring to embodied and exocentric cognition. There are multiple approaches to human mentation consistent with this paradigm (for reviews see Calvo & Gomila, 2008; de Vega, Glenberg, & Graesser, 2008; Glenberg, 2010; Shapiro, 2010). A common theme is that all cognition involves perceptual systems, action systems, and emotional system, and all of these depend on particulars of the body. To flesh this out, consider Gibson's (Gibson, 1979; Noë 2005) approach to visual perception. Gibson most early and clearly voiced our functional cause of behavior: Perceptual systems exist to guide action. From this starting point, he developed the idea that effective perceptual systems should pick out possibilities for action that he called *affordances*. Affordances are jointly determined by bodily capabilities and the environment: A kitchen chair affords sitting for an adult, but not an infant; and a burrow affords protection for a mole but not a person. Thus the claim is that how the chair is perceived is different for the adult and for the infant just as how the burrow is perceived is different for the person and the mole. The components of mind are determined by the components of the body interacting with the environment. The potential of this simple argument can be appreciated by tracking the role of affordances through cognitive development and into that most cherished of adult cognitive processes: language.

Campos and associates (2000) review evidence that simply learning to crawl changes socio-emotional development, perception, and search strategies. Consider the case of self-produced locomotion (SPL) and fear of heights as detected by the visual cliff. Infants who are not skilled in SPL can be tempted by their mothers to cross a glass surface over an empty space (the visual cliff). But once children become skilled crawlers, they are more likely to demonstrate fear and refuse to cross. Why might that be?

When an infant begins to crawl, by necessity she will keep her eyes on a goal to guide direction of movement. By keeping eyes on the goal, the infant induces a correlation between optic flow, vestibular information, and somatosensory information. In contrast, when the infant is carried, she is free to look around, so that there is no consistent correlation amongst these variables. The strong correlations define for the mobile infant (and adults) the relations that constitute a stable world, an effect demonstrated earlier in cats (Held & Hein, 1963). For example, there are different expected (correlated) sensory consequences when immobile (no optic flow) and when walking. When those expectations are not confirmed, our world goes awry. For an adult, this happens

when sitting in a car and seeing with peripheral vision another car begin to move. Often we interpret that as self-movement and hit the brakes. When an infant is placed near a visual cliff, the expectations are disconfirmed in that the visual information obtained from the drop-off is no longer tightly linked to vestibular and somatosensory information produced when crawling. That is, the stability of the infant's world is called into question, and that produces fearful freezing—hitting the brakes. In brief, physical development changes the way the infant can interact with his world, and thus there are changes in the information structures provided by the body interacting with the world, and that fundamentally alters psychological processes.

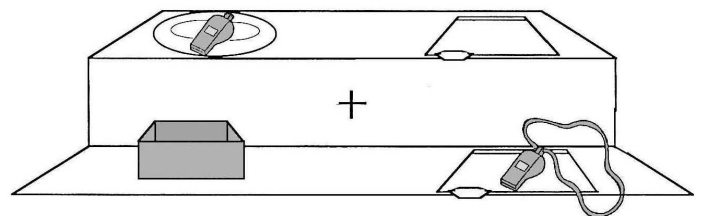
Somerville, Woodward, & Needham (2005) make a similar case for how changes in manual skill affect attention. They begin by asking what infants attend when watching adults act. Do the infants attend to the movements (e.g., trajectories of limb movements) or to the goals that the adult is accomplishing? To answer this question, three-month old infants were exposed to a hand repeatedly approaching one of two targets, a doll or a ball. After the infant stopped looking at this display (an index of habituation), the infant was shown two other displays. In one, the hand moved to the same goal object, but through a different trajectory. If the infant looks at this changed-trajectory display (i.e., dishabituates), that implies that the infant previously attended to the trajectory, which had become boring, and so a change in trajectory is now interesting. In the other display, the hand moved to a different goal object, but through the same trajectory as used previously. If the infant dishabituates to this changed-goal display, it implies that the infant previously attended to the goal, which had become boring, and so a change in goal is now interesting.

A critical manipulation in the Somerville and associates' (2005) experiment was the infant's experience before the habituation task. Half of the infants wore mittens with one side of a Velcro strip attached. The other side of the strip was attached to a toy. Thus, by swiping at the toy, the infant was able to precociously bring the object under its control for examination and play. Stated differently, these infants were given, for the first time, the ability to correlate self-arm movements and the accomplishment of manual goals. When these infants were placed in the habituation task, they preferred to look at the changed goal display over the changed-trajectory display. Infants without the experience of bringing objects under their control showed no preference between the displays. In brief, changing bodily abilities altered attentional processes and changed the infant's interpretation of the world from one dominated by movements to one dominated by goal-directed action.

Infants undergo extraordinary changes in physical and psychological development. Perhaps once those changes are in place, is cognition better characterized by the Centralist

paradigm (Figure 2) rather than by the Exocentric paradigm (Figure 3)? No. For adults, also, fundamental perceptual, linguistic, emotional, and social processes change when there are changes in the relation between bodily capabilities and the environment, that is, when there are changes in affordances. As one example of changing these relations, Witt, Proffitt, and Epstein (2005) projected dots of light onto a surface. When the dots were close enough to reach, the adult participants were to touch them, and when the dots were farther away, the adults pointed to the dots. Half of the adults used their fingers to touch and point, and the others used a conductor's baton. Thus, participants using the baton could reach dots that were farther away. After reaching, participants judged the distance of the dots by adjusting markers in the horizontal plane perpendicular to the previous direction of reaching. After reaching with the baton, judged distances were compressed, as if reachability was used to scale distance perception. That is, changing bodily capabilities changed affordances and thus how the world was perceived.

Chambers, Tanenhaus, and Magnuson (2004) demonstrated an effect of changing affordances on syntactic analysis. Their research used the "visual world" paradigm in which people hear instructions to move objects, and then they execute the instructions. As an example of the task, a participant might have before her a whistle on a plate, a different whistle on a folder, as well as an empty folder and an empty box (Figure 7). One instruction might be, "Put the whistle on the folder into the box." Another might be, "Put the whistle on the folder." Note that when uttered, the phrase "on the folder" is syntactically and semantically ambiguous. In the first example, "on the folder" is a reduced relative clause (the "that" is missing) that modifies whistle: The relative clause indicates which whistle is being referred to (the whistle that is on the folder). In fact, relative clauses are



**Figure 7.** "Put the whistle on the folder..." is ambiguous because "on the folder" might indicate which whistle to move or a location to which a whistle should be moved—until disambiguated by subsequent context. (From "Actions and affordances in syntactic ambiguity resolution," by C. G. Chambers, M. K. Tanenhaus, and J. S. Magnuson, 2004, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30, p. 691. Copyright 2004 by the American Psychological Association. Reprinted with permission.)

often used when there are two possible referents (the whistle on the plate and the whistle on the folder) that need to be distinguished. In the second example, “on the folder” is a prepositional phrase that provides the location to which the whistle should be moved.

In the experiment, eye movements were used to track the syntactic interpretation of “on the folder” as the sentence was uttered. When there were two whistles in the scene, upon hearing “on the folder” the eyes tended to move to the whistle on the folder. That is, the eyes indicated that the phrase was interpreted as a relative clause when disambiguation was necessary. When there was only one whistle in the scene, upon hearing “on the folder” the eyes tended to move to the empty folder, the likely location of the movement. That is, the eyes indicated that the phrase was interpreted as a prepositional phrase when disambiguation was not necessary. Thus, the environmental scene affected the syntactic analysis...but that is not all.

One whistle had a lanyard attached, and that set the stage for the important manipulation. Half of the participants moved objects, such as the whistle, using their hands. For those participants, on hearing “on the folder” the eyes moved to the whistle on the folder, indicating that “on the folder” was interpreted as a relative clause disambiguating which whistle to move. The other half of the participants moved objects using a hand-held hook. While holding the hook, only the whistle with the lanyard afforded moving. That is, for these participants, visually there were two whistles, but functionally there was only one. When these participants heard “on the folder,” their eyes moved to the empty folder, indicating that “on the folder” was interpreted as a prepositional phrase giving a location for the one whistle that could be moved.

At first glance, this result may appear to be just a trick: The words are ambiguous and looking at the situation disambiguates them. But that glance is too fleeting on two accounts. First, it is not the situation that disambiguates, but the situation in relation to bodily capabilities. Holding the hook changes the situation which in turn changes the syntactic analysis and the semantic interpretation. Second, a cornerstone of the Centrist analysis of syntax is that it is a separate module that is unaffected by peripheral considerations such as the state of the body. In contrast, these results clearly demonstrate that the operation of syntax is penetrated by the body, the environment, and their interaction, that is, affordances for action.

The story goes on and on: Changing the body or its relation to the environment changes cognition and behavior. Rather than telling the whole story, perhaps the description of one additional project in the domain of social cognition will do. Williams and Bargh (2008) tackled the problem of applying the concepts of embodied cognition to the understanding of social relations, in particular, the notion of social warmth.

Could social warmth be related to literal bodily warmth? The association of social closeness and literal warmth might be encouraged by early experiences with a care-giver, such as a mother holding her infant while feeding (Harlow, 1958; Harlow & Harlow, 1974). To test the hypothesis that social warmth is understood (at least in part) as physical warmth, Williams and Bargh had their participants hold a hot pack or a cold pack. After obtaining the participants’ ratings of the pack’s effectiveness, each participant was asked to choose a thank you gift either for the participant or for a friend of the participant. After holding the hot pack, participants were twice as likely to choose a gift for a friend.

In summary, whenever one looks for it, one finds that the relation between the body and the environment plays an enormous role in cognition. Those findings appear to be irrefutable evidence for the exocentric hypothesis.

### *Is exocentric paradigm just a gussied up version of the Centralist paradigm (Figure 2)?*

An active debate in the cognitive science literature (see, Shapiro, in press) concerns the extent to which any of this research presents real difficulties for Centralists. “After all,” says the skeptic, “this research only demonstrates that Centralists have not given due consideration to how the body can shape input to the brain. But, there is nothing to convince me a) that the brain is not the sole organ of cognition, and b) that standard cognitive science is unable to accommodate the results.” In fact, if standard cognitive science can accommodate the results, it is for reasons that should make the skeptic uncomfortable. There is no definition of centralist cognition or a cognitive process comparable to the one we offer. Does Neisser’s, shown in the opening paragraphs, constitute a contrasting or synonymous definition? Hard to say; but it certainly does not emphasize the research reported above, which we find revolutionary. Consequently, it is hard to point to any evidence that clearly demonstrates the truth or falsity of the centrist world-view, if it is allowed to qualify the role of the body ad libitum. Virtually any process or computation can become part of a standard cognitive theory (again, see Neisser’s definition). Unfortunately for the skeptic, this fact demonstrates that the standard approach is not so much powerful, as unfalsifiable.

For the Centralist, there is a circle around the brain, and that circle is identified as the domain of cognition, *by fiat*. But if we think about *cognition as a process*, particularly a process with feedback, then the arbitrary nature of the circle becomes clearer. Perceptions are shaped by actions as much as actions by perception. Muenzinger’s (1938; Tolman, 1948) rats looked back and forth and forth and back at the two ends of a Y-maze before deciding which was most likely to contain food. Sampling their environment, or sampling their readiness to commit to one action? Shapiro (2010) provides

a useful analogy. Consider the process of providing power to a car using a turbocharger. The engine produces a hot exhaust that spins the turbocharger. This spin drives a compressor so that compressed air can be injected into the cylinders. The compressed air creates a more powerful explosion in the cylinders which produces a hotter exhaust to spin the turbocharger faster. Normally we think of the engine as powering the car, and the exhaust as a byproduct. When the turbocharger is engaged, however, the exhaust becomes part of a system to create a more powerful drive train.

Similarly, consider the process of identifying objects. With vision, an important part of the process is movement of the eyes, head, and body to create the stimulation needed for vision to work. Or consider identifying objects by touch. If an object is simply placed in your hand, the identity of the object is obscure. Even if the object is rotated in three dimensions for you, there is little shape information that can be extracted. But allowing the fingers to move over the object provides an immediate sense of three dimensionality and shape. Thus, the particulars of the body and how it interacts with the environment play a crucial role in generating the information that powers cognition. In cases such as these, excluding the body from the process of cognition is as arbitrary as excluding the exhaust from the process of powering the car.

### *Are the instances of exocentric cognition just fringe phenomena?*

Just how many cases are there where the body must be included in the process of cognition? Perhaps exocentric cognition is an anomaly, better left alone. There is a very large cognitive psychology literature, and relative to that, the number of publications from the perspective of exocentric cognition is (relatively) small, with only 18000 hits for embodied or situated cognition in Google Scholar, about 1% of those for cognition. Could it be that exocentric cognition, while real, constitutes but just a tiny portion of cognition? No; that unbalance of publications is poor measure of the balance of contributions of body to mind. Furthermore, the exponential growth of the exocentric publications will soon tip the balance of the literature. In the last 10 years, the market share for exocentric cognition rose to 10%, and in the last five, to 40%. It has become part of the popular science literature (Ananthaswamy, 2010). This growth justifies Hostetter and Alibali's characterization of the field as a "sea change" in cognitive science (2008). But tides ebb and flow; exocentric cognition may soon become a new dogma, following the standard trajectory of all heterodoxy: from "patently wrong" to "blurring important distinctions" to "we knew it all along"; and eventually blocking by prior entry other more productive visions of cognition.

One aspect of that growth, the growth across traditional

boundaries, is most hopeful. There is research from the exocentric position in areas traditionally associated with cognition, such as perception (e.g., Estes, Verges, & Barsalou, 2008), memory, decision making, and language (Barsalou, 2008, provides a current review). But there are also active research programs looking at exocentric contributions to emotion (Niedenthal, 2007), and that in turn to perception (Bocanegra & Zeelenberg, 2009); social processes (Bargh & Gollwitzer, 1994; Semin & Smith, 2008), and disorders (Dapretto et al., 2006; Iacoboni & Dapretto, 2006; Lindeman & Abramson, 2008). The exocentric perspective is also becoming a source of research in the application of psychology to education (Glenberg, 2008) and to the law (Spellman & Schnall, 2010).

### *3. Exocentric Comparative Cognition*

The field of comparative cognition, embodied in this journal, has always had to struggle against old guard behaviorists who felt the qualifier *cognitive* a synonym of either the null set when applied to non-human animals, or of a set of complex repertoires already studied under different names. The *nothing-but defense: Cognitive* adds a patina that could easily cloak simpler processes with the vestiture of ratiocination. Clever Hans too clever by a mite. It constituted, in their eyes, an appeal to "mental way-stations", increasing the degrees of freedom in theory without a commensurate increase in the degrees of freedom in the data (Killeen, 2004). Now that the study of embodied cognition in humans is resituating cognitive science on a more behavioral path, it is time to reforge the bonds between behavioral analysis of human and non-human complex repertoires, making the study of cognition truly comparative. Marshall (2009, p. 113) observes that embodiment points the way to an "integration of brain, body, mind, and culture [that provides] an important line of defense against ...the reduction of psychology by neuroscience". Echoing Darwin, Barsalou (2005) argued for the continuity of the conceptual system across species; but Barsalou's evidence was primarily from similarities in brain loci when macaques and humans performed similar tasks. There is abundant behavioral evidence available, however, some of which is pointed to in the remainder of this article, under the rubrics of Skinner's 3-term contingency.

### *Stimulus*

None of the senses are content providers for entertainment; they all have work to do in defense, nutrition, and reproduction. When they become irrelevant to those tasks, as sight has in cave fish, they get retired; or they get repurposed, as electrocutaneous sensitivity became hypertrophied in the torpedo-fish, and as the sclera of humans' eyes whitened further to signal the direction of our gaze. Sensory apparatus

may be projected outside the body: The worker casts of ants and bees constitute an extended sensorium, just as they do an extended musculature (Holldobler & Wilson, 2008). Bertram (1978) reviewed the benefits and liabilities of living in groups. The probability of detecting a predator increases with size of flocks for various species of birds, as does the probability of detecting food; the flock has many eyes. Birds seem to know that, as their individual vigilance covaries appropriately (Roberts, 1996). Chimpanzees can infer the presence of food from the behavior of conspecifics, and various species of birds benefit from the localization of food by any one of their group. Sensing the sensations of others multiplies our own senses.

Discriminative stimuli are parts of the environment that predict reinforcement or punishment. When the stimuli are insufficient to the need, they are often embellished. Sherry (1987) noted that among the various ways that birds remember the locations of food caches, some species mark their location with local material. Red foxes and wolves mark the location of caches they have emptied with urine. In these ways animals make memoranda, offloading the key information into the environment, handy to when and where needed, rather than loading a scarce internal resource; they situate memory. Wilson (2002) calls these *epistemic actions*. A classic instance is the marking of routes by ants' deposition of pheromones. Marsh tits, like some other birds such as pigeons, can store information from each eye independently. Seed catches learned with one eye (the other covered) cannot later be found with the other eye—a case of embodiment more extreme than the effects of posture on memory (Dijkstra, Kaschak, & Zwaan, 2007) and perception (Ito, Tiede, & Ostry, 2009) found in humans.

For humans, when questions probe events that are high (ceilings, balloons and sky) responses are faster when the response location is high rather than low (Borghi, Glenberg, & Kaschak, 2004); and conversely. Expectancies of reinforcer location (high or low) and quality can also serve as cues for conditional discriminations in pigeons (D. A. Williams, Butler, & Overmier, 1990), with a differential outcome effect that, absent only the verbal control, mirrors that seen with humans. There exists a large literature on stimulus response compatibility—the Simon effect being a leading example. When responses are in the same direction as discriminative stimuli they are faster, even though there is no relevant information carried by the location of the stimulus (see, e.g., Markman & Brendl, 2005). When a CS is localizable, it attracts the organism, and responses are made to it even though they are unnecessary for the UCS—the infamous sign-tracking effect (see, e.g., Hearst & Jenkins, 1974; Wasserman, Franklin, & Hearst, 1974). Symbolic sign-tracking is found in the topography of responses. Zwaan and Taylor (Taylor & Zwaan, 2008; Zwaan & Taylor, 2006) had participants turn a knob either clockwise or

counterclockwise to advance through a text. Some of the sentences described an action that is typically clockwise (e.g., increase the volume on a radio) or counterclockwise (decrease the volume). The actual movement and storied movement interfered with one another. When a CS moves toward a locus of reinforcement, pigeons track it more vigorously than when it moves away from the food source (Cabrera, Sanabria, Shelley, & Killeen, 2009). Thus not only is stimulus learning contingent on context and susceptible to manipulation, so also is the stimulus-response-reinforcer relation.

### *Response*

If perception expands to utilize the perceptions of conspecifics, so too does action. Muscle, like perception, can be leveraged. Small birds mobbing a hawk or eagle or poodle, are soon joined by others, to drive off the intruder. Such enlistment is one of a number of ways in which individuals amplify the effectiveness of their response to predators (Heinrich, 1978); or in leks, amplify their attractiveness to mates. Cooperative breeding (Emlen, 1991) enhances the survivability of neonates, whether those are birds, monkeys or primates. Just as it takes a village for humans to survive (Gurven, Allen-Arave, Hill, & Hurtado, 2000; Hill & Hurtado, 2009), it takes conspecifics to hone an individual's survival skills. The best responses made the best way to the correct objects are often best learned by imitation—most of us know from personal experience that “show me how to do it” is typically a more effective request than “show me the manual”. Pigeons (Klein & Zentall, 2003), no less than people (Bargh & Dijksterhuis, 2001), make use of affordances in their environment, including the actions of themselves and others. The sequence of responses of pigeons and rats predict their temporal judgments better than does the duration of the stimulus presented (Fetterman, Killeen, & Hall, 1998); they time by watching themselves. Observation of self and others is trial-and-error learning that minimizes the errors-per-trial. Zentall (2003, 2006) reviews the variety of types of social learning, including mimicry, contagion, social facilitation, incentive motivation, transfer of fear; and gestural, deferred, sequence, and generalized imitation.

We often learn (or create) who and what we are by how and when we behave. This varies from the mundane observations such as “Wow, I ate all that?!? I must have been a lot hungrier than I thought” (Skinner, 1945), to character engineering (Wills, 1984). The learning of identity is tightly associated with action in the world, and its reaction to us (Echterhoff, Higgins, & Levine, 2009; Held & Hein, 1958). Gestural imitation plays an especially strong role in enhancing group cohesion. Keeping together in time (McNeill, 1995), whether marching, dancing or choral singing, strengthens

identification with the group, and makes individuals more altruistic to members of it (Wiltermuth & Heath, 2009). Rats and other animals prefer to cooperate to earn food, even at the cost of some efficiency (Schuster, 2002; Schuster & Perelberg, 2004). Some of that cost may be laid off against the subsequent greater efficiency and willingness to work together in circumstances where such practiced cooperation is essential for success (e.g., Stander, 1992).

Part of the importance of temporal coordination may be due to the subversion/exploitation of learned sensory integration. When a visible rubber hand is stroked at the same time our own unseen hand is stroked, we come to view the artifact as part of our own body—the “rubber hand illusion” (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). It may be that social animals have co-opted this learning-of-self as an exaptation (Gould & Vrba, 1982) that cements the social bond. After all, in the majority of other eusocial species cooperation is undergirded by haplodiploidy, making it of more benefit to your own genes to cooperate than to go it alone. Coordination, whether cheering in sports arenas or genuflecting in churches, may play a pervasive role in our social economy, making up for the forces of egocentrism fueled by our diploidic sex system. If this is the case, then we not only benefit from watching others, and behaving as others, in some real sense we become part of others and their world; and they become part of us and ours (Echterhoff et al., 2009).

### **Reinforcer**

The behaviorists’ prototypical reinforcer is the dropped Noyes pellet, closely followed by the raised Gerbrands hopper. Premack reoriented the field to reinforcement as action—eating the pellet or grain. The concept then naturally generalized to non-consummatory action, whether that is running in a wheel, playing handball or making love. Allison and Timberlake (Allison, 1993; Timberlake & Allison, 1974) further generalized the idea of reinforcement as action to reinforcement as action that had been depressed below its natural rate. The classic notion of reinforcers as stimuli has been replaced with reinforcers as enablers of reinforcing behavior—whether that behavior is satisfying hunger by eating a fine meal, or creating hunger by taking an invigorating hike. Even Pavlovian conditioning may depend more on the CS-UCR relation than it does on the CS-UCS relation (Donahoe & Vegas, 2004). Once our sights are raised from the hopper, it is easy to see how potent and ubiquitous coordinated action is as a reinforcer. The coordination may be with a video-game, a dance partner, or a book club. In all cases, reinforcement is not something that happens to us or to our responses: it is intrinsically an interaction with the world.

Not only may action be reinforcing, action that satisfies

others may reinforce our behavior. Empathy and altruism are fundamental aspects of what it means to be human: Not only is our behavior reinforced when others benefit (e.g., Fehr & Fischbacher, 2003), we sacrifice our own resources to punish those who have cheated members of our group (Boyd, Gintis, Bowles, & Richerson, 2003; Fehr & Gächter, 2002). Just as stimuli and responses are amplified through our environment and group, the core behaviorist concept of reinforcement is amplified and socialized. This is perhaps one of the most powerful roles played by religion (Nevin, 1997). “Inasmuch as you did it to one of the least of these My brethren, you did it to Me.”

### **Retention**

Among many others, Skinner (1981) has likened the action of reinforcement to the action of evolution by natural selection. For selection-by-consequences to work, however, there must be a differential representation of the winners of each round. In nature this is provided by the flourishing of types; in behavior, by the results of learning, which we call memories, associations, and habits. The role of memory is key in distinguishing types of learning theory, such as the associative from computational, as noted above. Context-sensitivity is ubiquitous in the conditioning of all higher organisms (Bouton, 1993; Myers & Gluck, 1994; Nieuwenhuis et al., 2005; Wagner, 2003; Wickelgren, 1969). Memory is not just differentially cued by the environment; it is often situated in the environment, even in the case of invertebrates (e.g., Holldobler & Wilson, 2008; Johnson, Rissing, & Killeen, 1994). For humans, the default off-loading of information to the environment is unmasked most graphically in cases of inattention blindness. Memory is not just for reminiscing; its purpose in guiding action deeply conditions its formation and access (Glenberg, 1997).

## **4. Resituating Cognition**

*Why people think that animals can't* paraphrases Minsky (1982), who systematically reviewed—and undermined—reasons why people think that computers cannot. Those reasons translate as: Animals can do only as they're told; they cannot be creative; they cannot choose their own problems; they cannot really understand things; they cannot know what something means; they cannot know what numbers mean; they cannot know about the real world; they cannot be aware of themselves; they cannot have a self; they cannot have common sense; or make mistakes; or be conscious. Can animals do these things? Most; assuredly. How would you show whether that is or is not the case? How about human animals? How would you show whether a particular human can do these things? Could our students pass a Turing test? Could we? To the extent that we can do, or

think we can do, some of these things, it is because we spend many years grounding our vaunted cognition by practicing relevant behaviors, which carry with them the indelible signatures of those physical and contextual embodiments (Glenberg, 2010). As we come to enact this understanding, not only our conceptualization of thinking, but our teaching of it, will improve (Cook, Mitchell, & Goldin-Meadow, 2008; Glenberg, 2008). It is not *cogito ergo sum*, but rather *ago ergo cogito*; I act, therefore I think. “The architecture capable of generating cognition must relate to the motoricity upon which such cognition was developed” (Llinas, 2001, p. 265); and we can build upon that architecture only as we understand it for what it is.

Allusions to animal cognition do not imply that animal cognition is conscious. Nor does it rule out that state of affairs. Many people feel it more parsimonious to deny animals such a faculty, asserting a discontinuity of evolutionary function due to the difference in genetic endowment of humans, at least 1% divergent from chimpanzees and rather more from other animals. To our minds, one of the best treatments of the human cognition is offered by Barsalou’s perceptual symbolic system of situated simulations (e.g., Barsalou, 2003, 2009) which makes heavy use of understanding-as-enactment. At the same time, other philosophers argue that consciousness itself finds its locus in the environment (Tonneau, 2004; Velmans, 2009). The resituation of cognition does not require that it carry consciousness with it; but it does open the door to new understandings of that difficult and ephemeral activity.

*Metacognition: What do I know?* There has been an increasing interest in asking animals about their confidence in responses they have given in various tests. A recent issue of *Comparative Cognition and Behavior Reviews* contains excellent perspectives on that research. One noted that “Most or all cases of nonhuman metacognition may be adequately accounted for by public mechanisms.” (Hampton, 2009, p. 19). Examples are an animals’ taking a long time to choose one response or another, and using that as a cue to infer that it’s ability to make the distinction is weak. In that case, it may opt out of the test for a certain smaller reinforcer, rather than taking a chance of making an error on the test response. Because humans are often unaware of the causes of their behavior (Nisbett & Wilson, 1977; Terrace & Metcalfe, 2005), such mechanisms may not be apparent, and relative confidence then attributed to a fifth sense, a sense of knowing.

Humans also use available public cues when making meta-cognitive judgments. If I asked you if you knew which was Skinner’s first book: *Behavior of Organisms*, or *Principles of Behavior*, you might opt for a \$5 payoff for “Not sure”, rather than risking a \$10 loss if your answer is incorrect. The long latency attending an inability to respond informatively could be your discriminative stimulus. In the human literature this

is known as the *availability heuristic*. Unfortunately, many of the authors (see the summary of Crystal & Foote, 2009) seem to rule out instances of such embodied knowledge as good cases of metacognition (which they called “private” or “second-order” representations). But some authors (e.g., Jozefowicz, Staddon, & Cerutti, 2009) noted that definition by allusion (to human ratiocination), and by exclusion (of public cues), is a poor way to construct scientific concepts; better to undertake systematic research to understand just what cues *are* used to control such clever behavior. Perhaps the best way to do that is to construct models that do not require such second-order representations, show how they fail to predict animal behavior, and correct the failure only by activating a meta-cognitive module. Our sense, and that of Jozefowicz and associates, is that similar cues will be used by both humans and non-humans, and that they will typically be embodied.

Fluency—ease and speed—of making a response is one such embodied cue. Johnston, Dark, and Jacoby (1985, p. 3) found that “recognition judgments for nonwords were more dependent on speed of identification than they were on actual old–new status. It is proposed that perceptual fluency is the basis of the feeling of familiarity”. A recent stream of fascinating research shows the ubiquitous role of fluency in a multiplicity of behaviors (Alter & Oppenheimer, 2008; Alter, Oppenheimer, Epley, & Eyre, 2007; Novemsky, Dhar, Schwarz, & Simonson, 2007; Reber, Schwarz, & Winkielman, 2004). Read my lips; but importantly, also note their latency to move.

### ***Consilience with Other Frameworks***

*Dawkins’s Extended Phenotype*. “The last four chapters of [*The Extended Phenotype*] constitute the best candidate for the title ‘innovative’ that I have to offer” (Dawkins, 1999, p. viii). Like the best innovative ideas, Dawkins’s thesis is easy to state, yet carries profound implications. His “‘central theorem’ of the extended phenotype: *An animal’s behaviour tends to maximize the survival of genes ‘for’ that behaviour, whether or not those genes happen to be in the body of the particular animal performing it*” p. 233). This extends the traditional notion of phenotype, from the body and its instinctive behaviors that the genotype governs, out to those parts of the environment that are necessary for the organism to function. These are the parts of the environment that the genotype can either “take for granted”—as bees do the flowering plants, and as the flowers do the bee—or that it tailors to need. The tailors’ cloth may be cut from unimproved substrate, such as the termites’ towering clay mounds. It may be specially-constructed from hi-tech materiel, such as the spiders’ intricate orb webs of steely strands. It may be a masterful sauce to make a dull meal more palatable and digestible, such as the injectate of the ichneumonid wasp,

that will first paralyze then soften the innards of its prey. These are inanimate prostheses.

Dawkins's vision gains force and relevance when the behavior modifies the behavior of other organisms. Some behavior modification is heavy-handed. Predators stop prey in their tracks. Parasites control the rate of growth of hosts, causing them to super-size, or to stay in juvenile form; they may castrate them to protect them and themselves from the risks of sex, or move them into dangerous terrain to expose them to the next vector in their life stages. Gentler is the male canary who induces a female to mate with him, manipulating her hormones into reproductive condition by singing to her. Orchids seduce bees, predators circle prey in spiraling arms races, and social animals are punished or reinforced by the reinforcement or punishment of their compatriots—they feel the world as others feel it. Social creatures multiply their efficacy by motivating their group; through the bonding of coaction, through the hypnotism of rallies and media (Killeen & Nash, 2003), through appeal to identity of worldview. They predict and control others by imagining how they will react to their behavior—they run simulations. They exploit the physical and intellectual products of others. They elicit and then interpret impression-relevant information from others (Smith & Collins, 2009). To particularize Dawkins' central theorem, we hypothesize: *An animal's cognitive behaviour tends to maximize the survival of memes 'for' that behaviour, whether or not the cognition happens exclusively in the body of that particular animal.*

*Artificial Intelligence.* Rodney Brooks (1991) has built increasingly capable mobile robots by turning his back on central processing modules, building a successful series of "Intelligent Creatures" with little or no reliance on central processing. "The fundamental decomposition of the intelligent system is not into independent information processing units which must interface with each other via representations. Instead, the intelligent system is decomposed into independent and parallel activity producers which all interface directly to the world through perception and action, rather than interface to each other particularly much. The notions of central and peripheral systems evaporate—everything is both central and peripheral." (p. 139). Pragmatics was his whetstone in these endeavors, as it was in Skinner's. Ultimately, however, Brooks's subsumption architecture reached its limits; some internal memory storage, such as that available from three layered architectures, is essential to smooth the vicissitudes of input, and to allow changes of attention and implementation without a complete system rebuild (Gat, 1998). Minimal finite state automata won't do.

*Skinner's Radical Behaviorism.* Skinner was ahead of his time in many of his opinions, including embodiment: "Cognitive psychologists like to say that "the mind is what the brain does," but surely the rest of the body plays a part.

The mind is what the body does. It is what the person does. In other words, it is behavior..." (Skinner, 1987, p. 784). Exocentric cognition is a fresh approach to a behavioral science of cognition, initiated by cognitive psychologists, yet a fair game for all psychologists, behaviorists and comparative cognitive psychologists in particular. We believe it moves Skinner's and other behaviorists' agendas ahead, by respecting what we do as a central aspect of what we are; by placing the context, without which behavior is nugatory, at the center of their science; by recognizing that cognition is not central; it is pervasive.

*The fourfold-root of comprehension.* Aristotle's four causes are not just good things to know about a phenomenon; together they define the phenomenon. Descriptions, or denotations, are mere abstracts of that larger meaning. Reductive, functional, and causal definitions are not alternatives to one-another; they are complementary parts of a complete definition (Killeen, 2001). The present article has argued that expanding one of the four causes of cognition, from the central nervous system to the nervous system as a whole, opens a new realm of comprehension for students of comparative cognition. Although we have referred throughout to exocentric, situated and embodied cognition, these are mere contradistinctions to centrist cognition. Our description and its fourfold definition was of cognition *simpliciter*, with no interest in a plurality of types. As we learn more, this definition will evolve. Little attention was given to the efficient, final or formal causes in this paper, which also need continued consideration as our discipline evolves.

It is possible to fit many of the examples listed above into the centrist paradigm. Posture, for example, provides stimulus input and thus can serve as a retrieval cue. "Outcome expectancy" may be adduced to explain the differential outcomes effect perhaps as well as the Pavlovian conditioning of fractional antedating goal responses, which is more consistent with the exocentric position. The Simon effect may be mediated by a predisposition to approach a CS; although that is not so much an alternative to embodied cognition as an example of it. The issue, and the reason for our writing this paper, is not to prove the centrist position wrong; as, given the ambiguity or breadth of that position it is indefeasible. It is to lay out the rich productivity of the exocentric paradigm; a productivity that has not been recently seen in the centrist position. And, in the end, the motivation has been ideological: We see the exocentric position as much more compatible with a renewal and empowerment of both cognitive and behavioral science.

A remaining problem with our analysis is that it is static. Aristotle suggested a fifth cause of behavior, reciprocal causation. He gave the example of how a man may exercise to become healthy, and as he becomes healthy, he is able to exercise more. Feedback of behavior on input gates and

regulates it; on substrate, modifies it to support learning; on form, changes its mode (Higgins & Pittman, 2008), enabling or disabling contrasting behavior systems (Kenrick, Neuberg, Griskevicius, Becker, & Schaller; Timberlake, 2000, 2001). Self-referential, and therefore dynamic, processing is central to our humanity (Northoff et al., 2006). Incorporating such dynamic processes into cognitive psychology, along with the behavioral analysis necessitated by embodiment, will restore psychology, mended of the Cartesian divorce of mind from matter, to the center of our science.

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