A Moderate Approach to Embodied Cognitive Science *

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1. Elements of a Well-Motivated Approach to Embodied Cognition

There are many research programs in cognitive science that urge a re-orientation under the banner of "embodied cognition." Most of these programs promote a rather radical alternative to "standard" or "classical" cognitivism (for a recent review, see Shapiro 2011). Despite the common label, the programs are very heterogeneous, and I shall make no attempt here to survey them or offer any taxonomy. The present paper also uses the label of "embodied cognition," but it advances a rather moderate conception of embodiment-oriented cognitive science. While highlighting the pervasiveness in cognition of bodily factors, it does not invoke this as a ground for revolutionizing the methodology of cognitive science.

There are two core elements in my approach. The first element appeals to the idea of bodily representational codes (or formats), i.e., hypothesized mental codes that are primarily, or fundamentally, utilized in forming interoceptive or directive representations of one's own bodily states and activities (Goldman and Vignemont 2009). The second element of the approach adduces wide-ranging evidence that the brain reuses or redeploys cognitive processes that have different original uses. If this redeployment idea is applied to bodily formats of representation, they jointly encourage the prospect that body-coded cognition is an extremely pervasive sector of cognition. This seems like a significant hypothesis (though hardly a "totalizing" one, I should stress), and it constitutes the core of the approach to embodied cognition presented here. The approach is compatible with many empirical findings characteristically cited by other embodiment enthusiasts, but isn't committed to any radical methodological, metaphysical, or architectural theses that some such enthusiasts embrace. In other words, my conception of embodied cognition is fully in sync with existing empirical research and raises no questions, for example, about such staples of traditional cognitive science as mental representation or computational processing.

Actually, what is advanced here is best seen as two distinct proposals. The first is a philosophical, or conceptual, proposal, namely, an interpretation of the notion of embodied cognition, a proposed definition of the phrase. The second proposal is an empirically based claim that human cognition in fact realizes or exemplifies this definition to a surprising degree -- surprising relative to orthodox or canonical presentations of cognitive science. I support the second thesis with a reasonably wide range of empirical evidence. It is always possible, of course, for readers to take exception to the cited evidence or its probative worth, and there isn't space here to defend that evidence in much detail. But even if only a limited swath of the evidence cited here holds water, embodiment would seem to be realized to a significant degree, a degree quite unanticipated by cognitive science of two or three decades ago and still very far from general acceptance. Future evidence will tell us exactly how extensive embodied cognition is; it would be silly to offer a precisely quantified claim here. This paper is not a manifesto to the effect that all of cognition is embodied. But there is enough existing evidence of its prevalence, I argue, that cognitive science should invest (or continue to invest) a lot of energy and resources into its exploration and documentation.

2. Embodiment and Bodily Representational Codes

What does it mean for cognitive events to be embodied? Or -- since there is no prevailing consensus about the meaning of "embodied" -- what is a fruitful way to understand this term for purposes of cognitive science? I begin by floating and critiquing several candidate definitions before arriving at a more satisfactory one (cf. Goldman and Vignemont 2009).

> (1) Cognition C (of subject S) is a specimen of embodied cognition if and only if C occurs in S's body.

According to this definition, simply occurring in some subject's body suffices for a cognitive event to qualify as embodied. Is this a happy result? Assuming physicalism, every cognition presumably occurs in its subject's body (where "body" includes the brain). This holds even if a mind/body is construed according to the "extended cognition" interpretation (Clark and Chalmers 1998; Clark 2008). That interpretation simply expands the size or extent of the body for cognitions to be "in." So, all cognitions would trivially qualify as embodied under definition (1). This is an unhappy result; it should not be such a trivial matter for universal embodiment to obtain.

> (2) Cognition C is a specimen of embodied cognition if and only if C is caused (or causally influenced) by one or more parts of S's body (other than the brain).

Like (1), definition (2) is an overly lenient definition of embodiment. Assuming that all perceptual experiences are caused by sensory-level inputs involving body parts, (2) implies that every perceptual experience qualifies as an embodied cognition. This follows no matter what detailed account is given of perception. This also seems like an unhappy result, because being (partly) caused by sensory-level inputs is a totally unexceptional property of perceptual events, which no orthodox cognitive scientist would question. Why should it give rise to a special designation associated with embodiment, independent of any new or revelatory story about perception (e.g., the enactive story of perception a la O'Regan and Noe 2001)?

> (3) Cognition C is a specimen of embodied cognition if and only if C's representational content concerns S's body; that is, S's body (or some part thereof) is the intentional object of C.

The chief problem with (3) centers on the necessity side. Definition (3) implies that embodied cognitions are restricted to cognitions that have people as their intentional objects. This is unduly restrictive and unmotivated. Definition (3) also disallows the possibility that embodied cognitions take people other than the subject as intentional objects. Like both (1) and (2), then, condition (3) fails to provide a satisfactory rationale for singling out a special class of cognitions as embodied ones. Nor does it hint at any clear conception of what "embodied cognitive science" might be. I would like to do better, and I think that condition (4) can help.

> (4) Cognition C is a specimen of embodied cognition if and only if C uses some member of a special class of codes or formats for representing and/or processing its content, viz., a body-related code or format (B-code or B-format).

The postulation of multiple codes or formats for mental representation is quite popular in cognitive science. There is no generally accepted treatment of what it is to be such a mental code, and little if anything has been written about the criteria of sameness or difference for such codes. Nonetheless, it's a very appealing idea, to which many cognitive scientists subscribe. Assuming that mental codes are language-like, each code presumably has a distinctive vocabulary, syntax, and set of computational procedures (or some of the foregoing). Each perceptual modality presumably has its own distinctive code. Some modalities -- certainly vision -- have multiple levels of processing, each with its own code or format. The two visual streams, the ventral and the dorsal, presumably have distinct codes (Milner and Goodale 1995; Goodale and Milner 2004). When the brain tries to "convert" information from a visual to a linguistic format, or vice versa, this can be difficult -- which attests to the presence of significant differences between such formats (Jackendoff 1992).

I turn now from representational formats in general to body-oriented formats (Goldman and Vignemont, 2009). Many codes in the mind/brain represent states of the subject's own body, indeed, represent them from an internal perspective. Proprioception and kinaesthesis give the brain information -- couched, presumably, in distinctive formats -- about states of one's own muscles, joints, and limb positions. These interoceptive senses are the basis for B-formats of representation. One's own body, or selected parts thereof, is what they primarily, or fundamentally, represent. One's own body can also be represented via the external senses, which are not specialized for use in connection with one's own body. One can see, for example, that one's right arm is extended. But a token visual representation of one's arm being extended does not qualify -- in the stipulated sense being introduced here -- as a representation in a bodily code, because vision does not use such a code. (More precisely, it is not assumed from the start that vision uses such a code, although section 4 presents a case for revisiting this question.)

Many bodily codes are tacitly recognized in cognitive science (especially cognitive neuroscience), for example, codes associated with activations in somatosensory cortex and motor cortex. Stimulation of areas on the surface of the body produces experiential representations, the neural substrates of which comprise a topographically mapped region of somatosensory cortex. This mapping provides a point-for-point representation of the body's surface: a map for the hand, the face, the trunk, the legs, the genitals, and so on (Gazzaniga, Ivry, and Mangun, 2002, p. 647). Similarly, activation of areas in the motor cortex is topographically organized so as to represent a wide range of bodily effectors and to enable movement commands to be sent to those effectors.

All of the foregoing is "old hat" in cognitive neuroscience; it is introductory-level material. Newer work on internal body representation is illustrated by A. D. Craig's (2002) work on body representation that features a hypothesized sense of the physiological condition of the entire body called "interoception." Craig's account focuses on the lamina I spinothalamocortical system. This system conveys signals from small-diameter primary afferents that represent the physiological status of all bodily tissues. Lamina I neurons project to the posterior part of the ventromedial nucleus, or VMpo. Craig calls VMpo "interoceptive cortex," and argues that it contains representations of distinct, highly resolved sensations, including different types of pain, tickle, temperature, itch, muscular and visceral sensations, sensual touch, and other feelings from (and about) the body.

I propose to classify all mental representations using codes or formats of the sorts just cited as embodied representations. Tokens of such representations qualify as embodied not because their current use, necessarily, is to represent particular body parts or bodily states, but because they belong to an (internal) representational system the primary, or fundamental, function of which is to represent one's own bodily parts and states. In other words, token representations qualify as embodied if and only if they utilize (or belong to) B-formats.

Now suppose it turns out that B-formats are also redeployed or co-opted for representing things other than one's own bodily parts or states. These additional representations would also qualify as embodied cognitions. Moreover, if there were extensive application of B-formats to different cognitive tasks, this would be a departure from "business as usual" in cognitive science as traditionally pursued. The more extensive the borrowed or derivative applications there are, the greater the departure from traditional cognitive science. This prospect -- of extensive derivative applications -- is what I shall highlight as the basis for a (somewhat) novel conception of embodied cognition, albeit one with substantial extensional overlap with a number of pre-existing programs of embodied cognition. In sections 3 and 4 evidence is presented in support of the contention that wide-ranging derivative use of B-formats is in fact the case in human cognition.

Despite the potentially expansive implications of this approach, it would not necessarily classify as embodied every cognitive event that would be so classified by alternative approaches to embodiment. For example, many proponents of embodied cognition count every perceptual event whatever as embodied. Perceptual cognitions are automatically grouped together with motoric cognitions and assigned the status of embodied cognitions. Barsalou (1999, 2008), for example, seems to class all "sensorimotor events" as embodied. The present proposal, by contrast, would not automatically (as a matter of definition) treat visual representations as embodied. Why?

Because the representational contents of the visual system are (generally) states of affairs external to the body. This is the position of almost all representationalist philosophers of mind, e.g., Tye (1995). These same philosophers, on the other hand, would regard pain cognitions as representational states the contents of which are bodily conditions. So feelings of pain qualify as embodied cognitions. This representationalist approach is clear in the following passage from Tye:

> [P] ains represent … disturbances [in the body]… [A] twinge of pain represents a mild, brief disturbance. A throbbing pain represents a rapidly pulsing disturbance. Aches represent disorders that occur inside the body rather than on the surface. These disorders are represented as having volume, as gradually beginning and ending, as increasing in severity and then slowing fading away…. A stabbing pain is one that represents sudden damage over a particular well-defined bodily region…. A racking pain is one that represents that the damage involves the stretching of internal body parts (e.g., muscles). (Tye 1995: 113)

If such representations are elements of one or more bodily formats, as I assume, then if they are used for secondary, or derived, purposes, then according to condition (4), they would still be classified as embodied cognitions, just like B-formatted cognitions when used in their primary, fundamental role.

3. The Massive Redeployment Hypothesis

"Massive redeployment hypothesis" is the name Michael Anderson (2007a, 2008, 2010) gives to a postulated principle of the mind. Another label he uses for this principle is "neural reuse." Whichever phrase is used, the underlying idea is that reuse of neural circuitry for a variety of cognitive purposes is a central organizing principle of the brain. In other words, it is common for neural circuits originally established for one purpose to be exapted (exploited, recycled, redeployed) during evolution or normal development and put to different uses, without necessarily losing their original functions. An initial type of datum from neuroscience that motivates this idea is that many neural structures are activated by different tasks across multiple cognitive domains. Broca's area, for example, is not only involved in language processing, but also in action-related and imagery-related tasks such as movement preparation, action sequencing, action recognition, and imagery (Anderson 2010: 245). Accordingly, rather than posit a functional architecture for the brain in which regions are dedicated to large-scale cognitive domains like vision, audition, and language, respectively, neural reuse theories posit that low-level neural circuits are used and reused for various purposes in different cognitive tasks and domains.

Anderson identifies four theories of this kind in the literature: (1) Gallese and Lakoff's "neural exploitation" hypothesis (Gallese 2008; Gallese and Lakoff 2005); (2) Hurley's "shared circuits model" (Hurley 2005, 2008); (3) Dehaene's "neuronal recycling" theory (Dehaene 2005, 2009; Dehaene and Cohen 2007); and (4) his own "massive redeployment" theory (Anderson 2007a, 2007b, 2010). The core idea of the massive redeployment theory is that evolutionary considerations favor the brain's reusing existing components for new tasks as opposed to developing new circuits de novo. This implies that we should expect a typical brain region to support numerous cognitive functions that are used in diverse task domains. Also, more recent functions should generally use a greater number of widely scattered brain areas than evolutionarily older functions, because the later a function comes on board, the more likely it is that there will already be useful neural circuits that can be incorporated in the service of the new function (2010: 246). In several publications Anderson reports an assortment of evidence that supports these and related predictions (Anderson 2007a, 2007c, and 2008a). Here I shall review just a smattering of the evidence he adduces.

The massive redeployment hypothesis, argues Anderson, implies the falsity of anatomical modularity, the notion that each functional module in the brain is implemented in a dedicated and fairly circumscribed piece of neural hardware (Bergeron 2007). Instead, brain regions will not be dedicated to single high-level tasks ("uses"). Different cognitive functions will be supported by putting many of the same neural circuits together in different arrangements (Anderson 2010: 248). This approach to cognitive architecture is attractively different from various classical alternatives. It is attractive, argues Anderson, because neural reuse is in fact a significant and widespread feature of the brain, inadequately accounted for by other classical architectures (such as massive modularity theory, J. R. Anderson's (2007) "Act-R" theory, and classical parallel distributed processing theory).

What empirical evidence is cited for this claim about the superiority of the neural reuse approach, and in what tasks or domains is the theory best exemplified? Anderson (M. L.) gives six primary examples, of which I shall report three. The first example is the use of circuits associated with motor control functions in higher-level tasks of language comprehension. For example, Pulvermuller (2005) found that listening to the words "lick," "pick," and "kick" activates successively more dorsal regions of primary motor cortex (M1). This is consistent with the idea that understanding these verbs relies on motor activation. Indeed, the action concepts may be stored in a motoric code, and understanding the verbs might involve partial simulations of the related actions.

Another example comes from Glenberg and Kaschak's (2002) research. Participants were asked to judge whether a sentence does or doesn't make sense by pressing a button that required movement either toward or away from the body. The sentences of interest described actions that would also require such movement, and the main finding was an interaction between conditions such that it took longer to respond to a sentence that makes sense when the action described runs counter to the required response motion. So, the simple comprehension of a sentence apparently activated action-related representations. More striking yet was that even sentences describing abstract transfers, such as "he sold his house to you," which involves no directional motor action, elicited an interaction effect.[1]

A second category of examples is the reuse of motor control circuits for memory. An example of the motor system's involvement in memory is reported by Casasanto and Dijkstra (2010) who found bidirectional influence between motor control and autobiographical memory. Participants were asked to retell memories with either positive or negative valence while moving marbles either upward or downward from one container to another. They retrieved more memories and moved marbles more quickly when the direction of movement was congruent with the valence of the memory (upward for positive memories, downward for negative memories).

A third category of examples is the reuse of circuits that mediate spatial cognition for a variety of higher-order cognitive tasks. One such mediation is the use of spatial cognition for numerical cognition. There is substantial evidence, for example, that response effects observed during number processing feature the reuse of a particular circuit in the left inferior parietal sulcus that plays a role in shifting spatial attention (Hubbard et al, 2005). The idea is that there is a "number line" -- a spatial cognitive construct -- on which numerical magnitudes are arrayed from left to right in order of increasing size. Another study, reported by Andres et al. (2007), found that hand motor circuits were activated during adults' number processing in a dot counting task. These activations play a functional role in both domains, as was confirmed by Roux et al. (2003), who found that direct cortical stimulation of a site in the left angular gyrus produced both acalculia and finger agnosia (a disruption of finger awareness).

Anderson recognizes that other theoretical approaches in the embodied cognition family also make appeals to the ideas of reuse or redeployment. He gives considerable attention, for example, to the <u>conceptual metaphor</u> approach originating with Lakoff and Johnson (1980, 1999) and to the <u>concept empiricist</u> approach of Barsalou (1999, 2008; Barsalou et al. 2003) and Prinz (2002). The conceptual metaphor approach holds that cognition is dominated by metaphor-based thinking whereby structures and logical protocols used in certain domains guide or structure thinking in another domain. Thus, Lakoff and Johnson argue that metaphorical mapping is used to borrow concepts from the domain of war to understand events occurring in the domain of love. Concept empiricism focuses on the content of cognitive representations -- symbols, concepts, and other vehicles of thought. The issue here is the degree to which such vehicles (our mental carriers of meaning) are ultimately tied to sensory experience. Concept empiricists endorse a highly modal approach according to which "the vehicles of thought are re-activated perceptual representations" (Weiskopf 2007: 156). They are "perceptual symbols," i.e., "record[s] of the neural activation that arises during perception" (Barsalou 1999: 578, 583). This contrasts with a rationalist or amodal approach in which the vehicles of cognition are nonperceptual, or abstract, structures (Fodor 1975; Fodor and Pylyshyn 1988).

My own original interest in theories of reuse or redeployment arose from work on "theory of mind." According to the simulation approach to mindreading, characteristic attempts to read another person's mind are executed by running a simulation of the target in one's own mind and seeing what mental state emerges (Gordon 1986; Goldman, 1986, 1989, 2006; Gallese and Goldman 1998; Heal 1986; Currie and Ravenscroft 2002). For example, the mindreading task of figuring out what decision another person will make is executed by piggy-backing on the capacity to make decisions of one's own. Rival accounts of mindreading make no comparable appeal to the redeployment of one's own mental activity in predicting (or retrodicting) others' mental states. If neural reuse or massive redeployment is an organizing principle of the brain, however, this would render mental redeployment in mindreading tasks an unsurprising method for the human brain to seize upon.

An interesting side-question arises here. Simulationists about mindreading have long said that people use their capacity for pretense or imagination to generate stretches of mental activity intended to (mentally) imitate a target. But what is this capacity for imagination? How should it be viewed from the perspective of the massive redeployment hypothesis? The massive redeployment hypothesis says that the brain adapts certain preexisting "uses" of a neural circuit to new types of uses. In each case, a particular circuit C is deployed for use U and then gives way -- some of the time -- to a new use, U', of C. But much of this adaptation, Anderson implies, takes place at a biological level rather than a cognitive level, whereas the imagination presumably does what it does at the cognitive level. It seems to be a general-purpose redeployment device that allows people to select routines from a seemingly unlimited variety of mental activities and allow the selected routines be used for a wide swath of novel applications. Given the capacity for visual and auditory experience, the imagination allows one to generate <u>faux</u> visual experiences or <u>faux</u> auditory experiences (i.e., visual or auditory images) and then employ them in a wide variety of tasks. The tasks include planning a novel sequence of behavior, recalling a past experience, and understanding what someone else is experiencing. How did this remarkably flexible cognitive tool -- a "universal" tool for reuse or redeployment -- manage to evolve? I throw this question out as an interesting side-issue, but assessment of the massive redeployment hypothesis does not hinge on it. It certainly does not threaten that hypothesis.

The most striking and pervasive redeployment phenomenon discovered in the last two decades is the family of mirroring phenomena, which include not only motor mirroring but also the mirroring of emotions and sensations. Mirror neurons have been discovered in monkeys (Rizzolatti et al. 1996; Rizzolatti and Sinigaglia 2010), humans (Keysers et al. 2010), and most recently in birds (Prather et al. 2008; Keller and Hahnloser 2009). The fundamental phenomenon, first found in the ventral premotor cortex of macaque monkeys (area F5), is that a specific class of neurons discharge both during the execution of a given behavior and during its observation. More recently it has been shown that neurons in the posterior parietal area LIP involved in oculomotor control fire both when the monkey looks in a given direction and when it observes another monkey looking in the same direction (Shepherd et al. 2009). Several studies in humans demonstrated that observing someone else performing a given motor act recruits the same parieto-premotor areas involving in executing that act (Rizzolatti and Sinigaglia 2010). Brain imaging experiments in humans have shown that witnessing someone else expressing a given emotion or sensation (e.g., disgust, pain, and touch) recruits some of the same viscero-motor and sensori-motor brain areas as are activated when one experiences the same emotion or sensation (Wicker et al. 2003; Keysers et al 2010).

How do these findings mesh with our B-format framework? Very well indeed. Early in their work the Parma group identified what they call a "motor vocabulary" in the monkey premotor area, where individual cells or populations of cells code for particular hand actions such as holding, grasping, breaking, etc. (Rizzolatti and Sinigaglia 2006). This obviously qualifies as a B-format, since selected hand actions -- a species of bodily activity -- are being represented as "to be executed." Of course, these premotor activations (or premotor-parietal activations) would not be redeployments of B-formatted cognitions unless they are recruited to perform different cognitive tasks than commanding their own effectors to move. However, there is strong evidence that mirroring activity in the observation mode does indeed recruit different tasks, although it is (somewhat) controversial exactly which tasks are recruited via observation-driven mirroring. Most of the candidates for these additional tasks are interpersonal or social in nature, but the specifics of the tasks are still being debated.

Early publications of the Parma group already interpreted mirroring activity (at the observational end) as involving more than the mere re-occurrence of an action instruction directed at one's own effectors. Mirroring at the observational end is interpreted as including something like the following representation: "The individual over there is doing this" where 'this' indexes the motor command associated with the neural activation in question, e.g., "grasp object X with such-and-such a grip." Since the "ordinary" (non-observational) activation of the relevant cells includes no reference to another individual, if these cells are activated as part of a representation of what another person is doing, or planning to do, the latter activity would be a different cognitive task than the fundamental one. Thus, even an observer's fairly minimal interpretation of what a target actor is doing constitutes a redeployment of the motoric format in a novel, cognitively interpersonal, task. Stronger interpretations are possible, of course. The observer might engage in the task of understanding the target's action (specifically, understanding it "in" the motor vocabulary of his own action). This need not include an attribution of a goal-state to the target. On the other hand, if mirroring is part and parcel of an act of mindreading by the observer (as Gallese and Goldman 1998 conjectured), then the observer utilizes his motoric vocabulary to perform a very different task, a theory-of-mind task, which is not a fundamental use of the motoric B-format. As we see, however, even "deflationary" interpretations of an observer's cognitions can still warrant the conclusion that he engages in redeployment of the motoric code (which, of course, is a bodily code).[2]

The idea that mirroring prompts mindreading is controversial. There are studies by proponents of mirror-based mindreading that purport to support this hypothesis (Fogassi et al., 2005; Iacoboni et al., 2005), but these may be open to different interpretations.[3] Once again, however, even if those experiments don't decisively demonstrate mirror-based mindreading, they still provide excellent evidence for some kinds of reuse of the motoric format to perform cognitive acts beyond the fundamental use of the motoric format. For example, a further cognition might be an expectation that the actor will perform a specified action, i.e., piece of behavior. A prediction-of-action cognition is not an ascription of a mental state (e.g., an intention), but it is very different from commanding one's own effectors to act, so it qualifies as a secondary, derivative application of the motor code in question.

In any event, the case for mirror-based realizations of the redeployment principle does not hinge on motoric mirroring alone. Indeed, in my view evidence for the mindreading species of reuse is more clear-cut for sensation and emotion mindreading than for mindreading of motor intentions.[4] Challenges to the suggestion that embodied redeployment is exemplified in these cases, however, might be predicated on doubts that the relevant formats are <u>bodily</u> formats. However, it seems straightforward that pain representations and touch cognitions are fundamentally, or primarily, representations in bodily formats. This may be less clear for disgust or fear, at least initially; but a strong case for this is made by Jabbi et al. (2007).

Thus, there is substantial evidence in support of the pervasive occurrence of embodied cognition. Not only does embodied cognition occur in fundamental uses of B-formats -- as all cognitive scientists will presumably acknowledge -- but there is massive redeployment of B-formats for other cognitive tasks. Section 4 will present yet different types of B-format redeployment -- not based on mirroring or any other social interactions. Thus, our initial bodily-format interpretation of embodied cognition not only has intuitive appeal in itself but it paves the way for a strong empirical case for the widespread incidence of embodied cognition. It is noteworthy that Gallese, a long-time proponent of the importance of embodiment (see Gallese 2005, 2007), has recently signed on to the B-format interpretation of embodiment (Gallese and Sinigaglia 2011).[5]

However, I have yet to offer a specific formulation of an embodied cognition thesis. The core thesis, containing many admittedly vague terms, is stated below. Greater exactness should hardly be expected in this kind of generalization, especially at the present stage of inquiry.

(Core Thesis): <u>Embodied cognition is a significant and pervasive sector of human cognition both because</u>
<u>(1) B-formats in their primary uses are an important part of cognition, and</u>
<u>(2) B-formats are massively redeployed or reused for many other cognitive tasks, including tasks of social cognition.</u>

A corollary of this factual thesis is research "advice" to cognitive science: it should devote considerable attention to the two forms of embodied cognition (primary and derived). Obviously, this is not a terribly revolutionary proclamation. Substantial sectors of cognitive science are already doing this. The important take-home message, therefore, is not the advice per se but the theoretical unification of the empirical findings that makes systematic sense of these assorted findings. Moreover, this unification highlights features of human cognition that were nowhere on the horizon twenty years ago and are ignored, doubted, or denied by many cognitive scientists. A wider acceptance of the entire "ball of wax" would mark a major shift in cognitive science as a whole.

Some of the aforementioned skeptics level their criticisms at allegedly excessive claims about the influence of mirroring. Notice, however, that mirroring is just one strand in a much broader landscape of embodied cognition. Similarly, some criticisms (e.g., Jacob and Jeannerod 2005) are aimed at arguably excessive claims about the significance of motoric phenomena. The critics may see these claims as incipient attempts to provide a global "reductive" explanation of all cognitive phenomena to the motoric domain. But motoric phenomena are just a slice of the body-related phenomena that get exploited for supplementary cognitive uses. Section 4 will examine a family of redeployed bodily representations that are, at most, only minimally motoric. So the breadth of the present conception of embodiment -- and the breadth of its empirical support -- should be carefully weighed before accusing it of being some narrow form of reductionism. Finally, no <u>universal</u> claims are made here. Nobody is saying that <u>all</u> cognition is embodied.

4. Perception and Embodied Cognition

Although perception has figured in a number of programs for embodied cognitive science, no previous program, to my knowledge, has appealed to redeployment or reuse to frame the case for embodied cognition in perception. In this section I add weight to the unifying value of the B-format conception of embodiment by showing how recent evidence from vision science fits snugly under this umbrella. The research program summarized in this section is that of Dennis Proffitt and colleagues. Their research shows that representations of one's own body are tacitly at work in executing tasks that are ostensibly far removed from the perceiver's own bodily state, viz., estimating properties of the distal environment.

A good introduction to Proffitt's thinking about perception can profitably begin with his reflections on how the brain functions vis-à-vis the body as viewed from the perspective of behavioral ecology. A principal function of the brain, says Proffitt (2008), is to control the body so as to achieve desired states in both the body's external environment and its internal environment. Studies in behavioral ecology (e.g., Krebs & Davies 1993) show that the behavior of organisms is primarily governed by energetic and reproductive imperatives:

> [O]rganisms have been shaped by evolution to follow behavioral strategies that optimize obtaining energy (food), conserving energy, delivering energy to their young, and avoiding becoming energy for predators. To meet these ends, species have evolved behavioral strategies for achieving desired outcomes in the external physical environment while concurrently maintaining desired states in the internal environment of the body. (Proffitt 2008: 179-180)

Maintaining desired states, it might be added, requires a regular monitoring of, or representation of, what bodily states currently obtain.

Proffitt is a vision scientist, of course. How do these reflections bear on vision? Like any vision scientist, Proffitt assumes that optical factors (e.g., light impinging on the retinas) play a crucial role in determining visual experience. What is distinctive to his approach, however, is that non-optical factors -- specifically bodily factors -- also play a role in determining visual experience. (So far, of course, this says nothing about B-formats or their reuse in visual perception. This will come later.) Here are some of his principal findings concerning the relation of bodily influences on vision.[6]

(A) Visual representations of object size are scaled by reference to one's own bodily parts. In experiments reported by Linkenauger, Ramenzoni, and Proffitt (2010) objects were either magnified or "minified" by the wearing of goggles. Following magnification, when a subject's hand was placed next to the magnified object, the object appeared to shrink to near-normal size. Similarly, following minification, when a subject's hand was placed next to the previously minified object, it appeared to grow to near-normal size. The compelling inference is that objects appeared to shrink or grow when placed next to one's hand because they were rescaled to the magnified or minified hand. (This would be an especially natural thing to do for graspable objects.) It is noteworthy that rescaling did not occur when familiar objects were placed next to the target object. Nor did rescaling occur when someone else's hand was placed next to the object. Only the proximity of one's own hand had the indicated effect.

(B) Visual judgments of environmental layout (e.g., distance or steepness) are influenced by physiological or energetic states of the body. Proffitt's early research showed a pattern of error in judgments of hill inclines viewed straight on. Angles were systematically overestimated. Five-degree hills were judged to be 20-degrees steep and 10-degree hills were judged to be 30-degrees steep. Experimental studies pertaining to bodily states were done by Bhalla and Proffitt (1999). They presented four studies that showed that hills appeared steeper when people were fatigued, encumbered, of low physical fitness, elderly, and in declining health. In these studies, three dependent measures were taken: a verbal report, a visual matching task, and a manual adjustment of a tilting palm board. Across these four studies, the measures of explicit awareness, i.e., verbal report and visual matching, were affected by the factors listed above, whereas the implicit visual guidance of action measure, i.e., palm board adjustment, was not. When subjects wore heavy backpacks while making slant judgments, “explicit” judgments showed increased overestimations. Bhalla and Proffitt studied students with varying fitness levels (including varsity athletes) while riding a stationary bicycle that measured oxygen uptake and recovery time. When subjects made slant judgments of hills, the greater their fitness, the shallower were their judgments of hill inclines.

(C) When intended or anticipated actions are more difficult in terms of required effort, distance judgments are affected. Witt and Proffitt (2008) found that when a subject expected to walk to a target as contrasted with expecting to throw a beanbag to it, the apparent distance to the target differed. In other words, subjects made distance judgments from an "actional" perspective. Their distance judgments reflected their being a "thrower" or a "walker," or expecting to be one or the other. If a person was to be a thrower, the estimate was influenced by the effort required to throw, and analogously if he/she was to be a walker.

What internal mechanism or mechanisms are responsible for these influences? Witt and Proffitt (2008) posit a process of internal motor simulation to explain the influences. Although they don't spell out the steps of such a motor simulation, or how exactly it influences distance judgments, it presumably runs something like this. The subject tries to reenact the cognitive activity that would accompany the motor activity in question -- without actually setting any effectors in motion. During this series of steps -- or perhaps at the end -- the energetic or physiological states of the system are monitored. Distance judgments are arrived at partly as a function of the detected levels of these states. If this reconstruction is correct, then the processes of detecting and representing the indicated bodily-state levels qualify as cognitive activities that utilize one or more B-formats. Moreover, the output B-representations generated by these cognitive activities either during the simulation or at its end are then used or deployed for a <u>non-bodily</u> cognitive task, namely, estimating the (external) distance between self and target object. This, then, would be a clear case of reusing or redeploying B-formats to execute a fundamentally non-bodily cognitive task. Obviously, if this account is correct, it exemplifies the massive redeployment hypothesis applied to embodied cognitions.

Independent of this motor simulation hypothesis, Proffitt has in mind a general hypothesis that comports well with the ideas I have been advancing. Modifying the maxim of the Greek philosopher Protagoras, who famously held that "man is the measure of all things," Proffitt propounds the maxim that one's body is the measure of all things. In other words, one's own body is used to scale physical judgments about other (non-bodily) subject matters. As we have seen, dramatic demonstrations of this maxim are presented in the form of the visual shrinkage or growth of external objects when one's own hand -- but not another person's hand -- is brought into sight. As Linkenauger et al. express it, "the perceptual system uses the body as a perceptual ruler, and thus the sizes of graspable objects are perceived as a proportion of the hand's size. This proportion directly indicates for the perceiver how large objects are with respect to his or her hand's grasping capabilities." (Linkenauger, Ramenzoni, and Proffitt 2010)

The body-based scaling idea is also articulated in the following passage:

> [W]e argue that visual information is not [merely] combined with, but rather <u>is scaled by</u>, non-visual metrics derived from the body…. We do not perceive visual angles, retinal disparities, and ocular-motor adjustments, which are the stuff of visual information; rather, we perceive our environment. The angular units of visual information must be transformed into units appropriate for the specification of such parameters of surface layout as extent, size, and orientation. We propose that these scaling units derive from properties of the body in a way that makes perception, like all other biological functions, a phenotypic expression. (Proffitt and Lingenauger, in press)

Clearly, Proffitt and colleagues are not simply saying that the body and its parts are causally responsible for certain (antecedently) surprising effects. They are saying that <u>representations</u> of bodily parts are used to influence representations of non-bodily objects. This point is noteworthy because Proffitt was strongly influenced by J. J. Gibson, a major force in the embodied cognition movement who resisted <u>representations</u> as unhelpful theoretical tools for cognitive science. Yet Proffitt's writing on this topic seems to side more with orthodox cognitive science.

One line of criticism of Proffitt's work challenges his conclusions about bodily effects on perception. In particular, it questions whether subjects who made steeper slope estimates while wearing backpacks were genuinely influenced by the backpacks' weight, via physiological effects on the wearers. Durgin et al. (2009) argue that experimental demands of the situation might have led subjects to elevate their cognitive estimates of slope. In other words, perhaps the experimenters' hypotheses in Proffitt's studies were transparent to participants and their reported response differences reflected biases in judgment in compliance with experimental demand characteristics. If a new experiment were conducted that manipulated experimental demand characteristics and if it were to produce changes in judgment similar in magnitude to those previously attributed to backpacks, this would undermine the argument that the physical burden of the backpack affects perception directly. Durgin et al. conducted an experiment that purported to have exactly these results.

Proffitt (2009) offers a very ample reply to this challenge. First, there were enormous differences between the Bhalla-Proffitt experimental set-up and that of Durgin et al. In the former, hills were always of very considerable length and their crests were well above eye height. Thus, subjects could easily see that there would be a real energy cost to climbing the hill. In the Durgin et al. experiment, by contrast, the "hill" was a 1 meter x 2 meter ramp, which was viewed indoors. Proffitt concedes that Durgin's clever demand manipulations might have produced response differences in their experiment, especially because there was no serious energetic cost involved. But it does not follow that the prospect of energetic costs had no impact in Bhalla and Proffitt's very different experimental set-up. In fact, Proffitt had anticipated the kind of worry Durgin et al. tested, and had therefore used converging measures and manipulations in which the anticipated outcome would not be intuited by participants. In the third experiment reported in Bhalla and Proffitt (1999), for example, physical fitness was assessed using a cycle ergometer test, and they found that fitness was negatively correlated with slant judgments (for the two explicit measures). There was no experimental manipulation in this experiment; all participants were treated the same and the experimenter was blind to the participants' fitness status. More recently other experiments have been conducted using blood glucose as an indicator of bioenergetic condition. Schnall, Zadra, and Proffitt (2010) found that hills appear steeper to those with depleted levels of blood glucose. It would seem, then, that this line of research is methodologically very well grounded and extremely sound.

5. Conclusion

With only a few conceptual resources I have articulated a comprehensible and rather natural conception of embodied cognition. Moreover, drawing on a wide-ranging body of research, much of which has already attracted high levels of attention, a straightforward case has been presented for the very considerable role of embodiment in human cognition. Finally, it has been shown how the proposed conception of embodied cognition makes important points of contact with a number of other programs in embodied cognition. Perhaps it is time to converge on a single approach -- the B-format approach -- as a unifying and comprehensive one, rather than persist with the dispiriting balkanization of embodiment theory.

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[1] For additional supportive evidence of motor involvement in language understanding, see Pulvermuller and Fadiga (2010), Jirak et al. (2010), and Glenberg and Gallese (2011).

[2] Vignemont and Haggard (2008) pose the question of what specific representations are "shared" between sender and receiver in a mirror transaction. At what level of the hierarchical structure of the motor system do shared representations occur? This is a good question, to which they offer a complex array of interesting possible answers. However, the central question for present purposes does not concern the specific motoric level at which the observer's representations replicate those of the actor, but whether any different cognitive tasks <u>at all</u> are undertaken by the observer that are distinct from those of the actor. And that question can be addressed without settling the one that concerns Vignemont and Haggard.

[3] In the experiment by Iacoboni et al. (2005) subjects observed a person in three kinds of conditions: an action condition, a context condition, and an intention condition. The intention condition was one that may have suggested an intention beyond that of merely grasping a cup: an intention either to drink tea or to clean up (after tea). This condition yielded a significant signal increase in premotor mirroring areas where hand actions are represented. This was interpreted by the researchers as evidence that premotor mirroring areas are involved in understanding the <u>intentions</u> of others. There is room for doubt about this interpretation. However, even if the enhanced mirroring activity during the intention condition did not constitute an <u>intention</u> attribution by the observer, it very plausibly did constitute a prediction or expectation of a future <u>action</u> by the portrayed individual. Since an action is not a mental state, predicting an action would not qualify as mindreading.

[4] For details of evidence about pain, see Avenanti et al. (2006), Shanton and Goldman (2010). For details about emotions like disgust and fear, see Goldman and Sripada (2005), Goldman (2006, chap. 6), Jabbi et al. (2007). The main "special" evidence for mirror-based mindreading in the case of emotions is evidence involving patients with paired deficits in experiencing and attributing the same emotion. For example, Calder et al. (2000) found such a pairing in patient NK, who had suffered insula and basal ganglia damage. On a questionnaire to probe the experience of disgust, NK's score was significantly lower than that of controls. Similarly, in tests of his ability to recognize emotions from faces, NK showed a marked deficit in recognizing disgust but not other emotions. The natural inference (when conjoined with the Wicker et al. 2003 study) is that a normal subject who sees someone else's disgust-expressive face undergoes a mirrored experience of disgust and uses it to recognize disgust in the other. This is why an impaired disgust system leaves a subject (selectively) unable to mindread disgust normally based on a facial (or vocal) expression, i.e., because he does not undergo a mirrored disgust experience.

[5] Gallese had previously advanced the concept of reuse, one of the core elements of the B-format approach, as the linchpin of an account of embodiment (Gallese 2007, 2008, 2010). Note, however, that reuse by itself is neither necessary nor sufficient for embodiment. It isn't necessary because primary, or fundamental, uses of a B-format -- which do not constitutes reuses -- still qualify as instances of embodiment. It isn't sufficient because there may be many cognitions that reuse non-bodily formats. Such reuses are not instances of embodied cognition. Gallese and Sinigaglia take notice of the latter point, writing "The notion of reuse, however, is not sufficient to explain the MM [mirror mechanism]" (2011: 513).

[6] Proffitt and colleagues often speak of influences on visual "experience," and some might question whether this is fully supported by the evidence. The issue is whether their findings are merely post-perceptual phenomena rather than genuine perceptual phenomena. This matter has been tested and

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addressed in Witt, Proffitt and Epstein (2010). What they say seems quite re-assuring on this point, namely, that the findings do pertain to genuinely perceptual phenomena. The reader can judge for him/herself.