Focus Article

Embodied cognition

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Traditional views in philosophy of mind and cognitive science depict the mind as an information processor, one whose connections with the body and the world are of little theoretical importance. On the contrary, mounting empirical evidence shows that bodily states and modality-specific systems for perception and action underlie information processing, and that embodiment contributes to various aspects and effects of mental phenomena. This article will briefly review and discuss some of this evidence and what it implies. By challenging mainstream accounts of mind and cognition, embodiment views offer new ways of conceptualizing knowledge and suggest novel perspectives on cognitive variation and mind-body reductionism.

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INTRODUCTION

In the western philosophical tradition, the fact that we have bodies has been mostly regarded as irrelevant or peripheral to the understanding of knowledge and cognition. Cartesian dualism, the view that minds is constituted by a fundamentally different kind of substance than are bodies, evolved into an epistemological tradition that has informed various strands of cognitive science. One of these strands that has been particularly influential in the cognitive sciences is computationalism, the claim that cognition is, in essence, the manipulation of *abstract* information via formal rules.[1–3] On this view, an organism's body and its connection to the mind are of little theoretical importance; sensorimotor systems, although reasonable objects of inquiry in their own right, are of interest in understanding cognition only insofar as they provide sensory input and allow for behavioral output. Ideally, even organisms without a body, such as brains in a vat or sophisticated computer programs, could in principle exhibit extraordinary and sophisticated cognitive skills.

Proponents of the view known as 'embodied cognition', by contrast, emphasize the role of sensory and motor functions in cognition itself. By viewing the mind as grounded in the details of its sensory-motor embodiment, they model cognitive skills as the product of a dynamic interplay between neural and non-neural processes. On this view, there is no fracture between cognition, the agent's body, and real-life contexts. Consequently, the body intrinsically constrains, regulates, and shapes the nature of mental activity. Call this view the embodiment thesis about cognition.

Such constraint, regulation, and shaping need not involve the dependence of cognition on actual states of the body. Indeed, much current research on embodiment emphasizes less the body's direct role in cognition than its implied role in reenactments of experience in the brain's modality-specific systems for perception and action.[4–16] The activation of sensorimotor functions even in the absence of direct engagement with sensory input and behavioral output (for example, in imagery, planning, and remembering) suggests that, even when decoupled from the environment, knowledge representation and processing continue to be supported by patterns of embodied responses. As we will explain further below, even this articulation of the embodiment thesis marks a departure from traditional cognitive science.

More radical such departures have been made within the embodied cognition movement by those appealing to dynamic systems theory to advocate explicitly anti-representationalist views of cognition.[17–20] The central idea here is that the body has a fundamental feedback-driven role in mental functioning, and as long as a situated agent can sense the world and be directly influenced by it, complex behaviors and adaptive success do not require any

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reference to computation and representation at all.[21] Here we do not explore the implications of this more radical version of the embodiment thesis and its potential problems,[22] but simply acknowledge the diversity of work that falls under the heading 'embodied cognition'.

There is a continuing exploration of the embodiment thesis within the cognitive sciences. Here we provide an overview of some of the core empirical evidence that has been used to argue that the body is integral to *the nature of* cognitive processing itself and that mental activity, instead of being centralized and sharply distinct from low-level sensorimotor functions, is *body-based*, sometimes in quite surprising ways. We begin by elaborating on the general contrast we have sketched between traditional and embodied cognitive science.

EMBODIMENT VERSUS TRADITIONAL COGNITIVE SCIENCE

Despite the prevalence of robustly physicalist or materialist views within the philosophy of mind and cognitive science, at the heart of mainstream accounts lies a particular conception of cognition and mental representation. Central cognitive processing has been typically conceptualized in abstraction from bodily mechanisms of sensory processing and motor control. The traditional formulation holds that what makes something a mental process or event does not depend *in any deep way* on its physical realizer or internal constitution, and mental capacities and intelligent behavior *do not arise from* any specific bodily form or features.[23–25] Two implications of this formulation about cognition highlight its significance.

The first is the commitment to what Susan Hurley[26] dubbed the 'sandwich model', the view that the systems responsible for thinking are neatly segregated from, and 'sandwiched' between, the systems responsible for sensing and acting. The second, of more direct relevance to those focused on computational intelligence, linguistics, and neuroscience, is the commitment to a kind of isolationism about the understanding of cognition: the claim that an explanation of cognitive processing should be divorced from an appreciation of the physical realization of that processing. A mind portrayed as disembodied is a special realm, populated by symbolic structures (representations) with quasi-linguistic and combinatorial properties. These symbols have been taken to be amodal, abstract, and arbitrary[1,3,24,27,28]: amodal because they are independent of the brain's systems for perception and action; abstract because they result from the redescription of sensorimotor experience into a list of properties represented in propositional way; and arbitrary because the way in which they are linked to their referents in the world bears no relationship to the physical and functional features of the referents. On this view, not only is there a clear-cut distinction between the mental representations processed by, say, language, imagery, and memory, and those processed by the sensorimotor system, but also the meaning of such 'central' representations is completely divorced from embodied experience.

Traditional views, hence, are committed to at least three fundamental principles that proponents of the embodiment thesis reject:

- Information conveyed by a mental representation has no modality-specific features. In this sense, representations are autonomous from the sensorimotor system, and its operational details.
- Knowledge is represented propositionally, and meaning emerges from the relations among the constituent symbols.
- Internal representations instruct the motor system, which is essentially separate and independent of cognition, and so cognitive processing is not significantly limited, constrained, or shaped by bodily actions.

The embodiment thesis challenges these principles. Stressing the centrality of the body for cognition has at least three implications: (1) significant differences in embodiment often translate into differences in cognitive processing, (2) algorithms that constitute cognition sometimes reflect the peculiarities of the physical body, and (3) failure to include information about the body in the description of the mind leads to accounts that are fundamentally misleading and misguided. What advocates of the embodiment thesis aim to show is that systems for sensing, acting, and thinking are constitutively interdependent, and modality-specific representations are what our cognition is made of.

WHAT THE EMBODIMENT THESIS IS

The embodiment thesis is motivated by the following kinds of observations about behavior.

1. We typically gesture when we speak and gesturing does not just affect both interpersonal communication and language processing, but can feed back and change the gesturer's thinking. Gesturing while describing an action performed

on an object, for example, a light disk, brings action-related information into the speaker's mental representations, and components of the action reflected in the gesture alter the way the speaker reasons about and acts toward that object.[29]

2. Gesturing and finger counting help represent mathematical concepts and their contribution to a fast understanding of number concepts during arithmetical learning and calculation indicates that an active and direct involvement of the body in the execution of a cognitive task simplifies its computational workload.[30,31]
3. Visual perception is a skillful activity, and bodily movement and the feedback it generates are more tightly integrated into visual processing than traditional models of vision acknowledge. What we perceive is determined by what we do in order to perceive. For example, to be a mobile perceiver is to understand that much of the environment can be revealed and explored through appropriate movements of the head and limbs, or that to attain novel information one has to turn around in response to an unexpected noise.[32–35]
4. There are neurons, known as mirror neurons, that activate not only when we observe or understand an action performed by others, but also when we carry out the same action with our body.[36] The achievement of a motor equivalence suggests that the understanding of other minds is based on our capacity to act and would account for some complex aspects of our social life, such us the capacity to 'mentalize' about others. The understanding we have of one another would thus presuppose one's own motor system, and bodily states would provide the building blocks of empathy, social coordination, imitation, and language acquisition.[36–40] By way of performing a movement, therefore, we would not simply accomplish an action but accumulate the motor experience necessary to represent the minds of others.
5. We often perform cognitive tasks, such as remembering, problem solving or imagining, more effectively by using our bodies to offload information and simplify the nature of the cognitive processing. Holding specific body postures or facial expressions, for example, causally or constitutively facilitate both access to and retention of memories.[5,41–45]

Four implications specify the ways in which cognition is underpinned both by particular bodily states and modality-specific systems for perception and action. First, even when disconnected from the environment and its sensory information, cognition is body-scaled, that is, grounded in those systems that evolved to allow the interactions with the world—namely, the sensory and motor systems. Second, there are at least two grades of bodily involvement in cognition: one that requires the body directly (online embodiment), and the other that requires it indirectly, by way of neural simulations, (offline embodiment). Third, actual embodied responses can be stored and later used in offline processing. In this sense, non-neural parts of the body constitute the building blocks of conceptual knowledge. And fourth only a creature with certain bodily features and skills can possess certain kinds of cognitive capacities.

A useful way to articulate the embodiment thesis further is to ask what role or functions the body plays in cognition. At the most general level, there are at least two distinct but related roles, each with its own implications for how we think of, and study, cognition. The first stresses the idea that the body can function as a cognitive constraint: in this sense, talking or thinking about objects, either concrete or abstract, implies the appeal, deployment, or reactivation of specific patterns of bodily activity. The second role highlights the different ways in which the body acts as a *distributor* for cognitive processing, thus functioning as a partial realizer of cognition. The general idea of considering non-neural realizers for cognitive processing opens the door to more radical theories with some philosophical currency, such as the extended mind thesis, which holds that the mind itself extends beyond the boundaries of the individual organism.[15,16,46] We discuss each of these roles in more detail in the remainder of this paper.

Body as a Constraint on Cognition

As a constraint on cognition, the body shapes the nature of cognitive activity and the content of the representations processed. Consider color perception, sound localization, categorization, and spatial metaphor. Concepts and experiences of colors, for example, reflect the properties of the retinal cells and the features of the visual apparatus; sound detection owes its peculiarity to the distance between the ears; and spatial metaphors, whose locus is not language but the way we conceptualize the body, heavily draw on embodied experiences.[47–50]

An illustration of this idea comes from the joint work of George Lakoff and Mark Johnson. Beginning in their *Metaphors We Live By*,[50] Lakoff and Johnson argued that many central cognitive processes, such as those concerning space and time, are both expressed and influenced by metaphors, and that many metaphors reflect bodily features. Consider a well-known metaphor that they discuss: that of love as a kind of journey. Here the source domain (journey) is informed by our bodily physicality, and information about the body (such as its capacity for locomotion) shapes the way in which love is understood and conceptualized. Metaphors, hence, are not merely useful for embellishing communication, but reflect the embodied experience that we have as creatures that move through the world in particular ways.

Spatial concepts provide perhaps a clearer example: long and flat creatures would not be capable, as we are, of conceiving the world in terms on 'front', 'back', 'up', and down'. These concepts arise and are articulated thanks both to the particular body we have and the specific ways it navigates in and through space. Although in these examples the physicality of the body does not directly contribute to mental processing, the construction of metaphors shows nonetheless that (1) abstract domains are grounded in more concrete ones; (2) the grounding aspect of the body acts as a *scaffold* for articulating thoughts that otherwise would be difficult to communicate; and (3) information about the body is included in the representations that constitute cognition.

Further examples of the body functioning as a constraint on cognition come from findings in behavioral psychology. Our judgments about the usability of tools, about the physical properties of stairs, and about the graspability of objects indeed incorporate anticipated embodied interactions, and are affected both by our bodily features and the motor skills that allow us to cope with those objects and tools.[51–53]

Another example exemplifying the role of the body as a constraint on cognition comes from Lawrence Barsalou's perceptual symbols theory.[8,54,55] This theory rests on the assumption that human cognition does not consist of amodal representations that bear arbitrary relations to their referents in the world, but rather of representations whose activation patterns include information from various sensory modalities. For example, the symbolic structure that represents an object in its absence, say, during a memory task, depends upon the same neural system that is recruited when the object is actually perceived or acted upon. Thus, not only does cognitive processing essentially reactivate sensorimotor areas in the activity of remembering, but memory itself may be built up out of sensorimotor patterns and thus be modal rather than purely symbolic. On such a view, besides reflecting the nature of embodied interactions, multimodal representations stored in memory assist, control, and facilitate perceptual processing, reasoning, and situated actions.

The body's constraining effects on cognition can be also seen in relation to language. Sentence comprehension and construal of meaning are achieved through embodied responses and require knowing both the affordances offered by an object and whether they match our sensorimotor capabilities.[56–59] Judging the meaning of a sentence is faster and more accurate, for example, if the text meaning is compatible with the body's biomechanical features.

We should expect, therefore, that differently embodied agents will diverge in their conceptualization of identical situations and that understanding will vary if intelligent systems varied physically. Having a different sort of body thus facilitates a different kind of cognitive processing.

Body as Distributor for Cognitive Processing

As a cognitive distributor, the body spreads cognitive tasks between neural and non-neural structures, and functions as partial realizer of mental phenomena. Striking examples of how non-neural, anatomical structures and postures subserve cognitive operations come from work on language production, cortical plasticity, and hand motor skill acquisition.

Although a speaker's gestures have been mostly regarded as communicative, arm and hand movements in fact play a cognitive role in vocabulary growth and language development.[60,61] Cortical representations are also responsive to changes in the course of motor learning. Subjects practicing over a period of three weeks either a gross motor activity, such as squeezing a sponge, or a fine motor task, such as sequential movements of the middle three fingers, not only improve on unrelated tests of hand and wrist performance but also, more importantly, present a significant expansion of the primary motor and somatosensory cortex. The increase of the volume of cortical movement representations in parallel with the acquisition of behavioral abilities suggests that cortical organization is modeled by our embodied experiences, and that body-induced changes regulate brain enhancement, information processing, and cognitive development.[62]

Consider also studies indicating that motor activity provides individuals with knowledge subsequently used for spatial perception, studies that motivate a shift in emphasis concerning the primary function of the visual system[35,63]: rather than functioning to build an accurate three-dimensional representation of the world, as traditionally assumed,[64] the visual systems primary function is to guide and be guided by action. What we perceive is determined by what we do in order to perceive, not solely by what happens inside the brain. That we construct a visual representation of the world by taking into account our own movements suggest that, although the brain is still a central part of the visual information processing system, neural activity alone is insufficient to explain how perception is achieved. If we were embodied in a radically different manner, we would perceive differently, and in terms of our new set of bodily characteristics. A view that exclusively locates perceptual processing in the brain and sees the nervous system alone as the beginning and end of mental activity fails to appropriately acknowledge that bodily activity forms a stage in cognitive processing.

Bodily states also modulate attitude formation and social information processing. Nodding movements of one's head while hearing a message about a topic, as opposed to shaking, increase the likelihood to rate the message positively,[65] and accuracy in classifying facial expressions displayed in photographs depends on the extent to which individuals are free to mimic.[66] Comprehensive discussion of how bodily responses modulate processing of emotional stimuli and increase smoothness of social interaction can be found elsewhere.[6]

Viewing the role of the body as a distributor for cognitive processing implies that the body does not function merely to transduce perceptual inputs to cognition, and later to produce behavior from internal cognitive processing, but is more integral to the control of cognition. This form of the embodiment thesis, by allowing that cognitive systems can include both non-neural parts of the body and the beyond-the-body environment, also invites further exploration of the idea of extended cognitive systems, where the realizers for cognitive processing are 'wide'.[15,46,67–69]

CONCLUSIONS

Traditional accounts in cognitive science accept the view that cognition is, in essence, the same kind of process that one can find in a calculator. Yet if proponents of the embodiment thesis are correct that the body does more than conveying input and output to central systems, we should leave behind some methodological and conceptual commitments of traditional cognitive science. Furthermore, cognitive scientists can explore both embodied behavior and neural simulations in accounting for cognitive differences across and within species. Two final general points about the cognitive sciences are worth making in light of this point.

The constraints of embodiment are such that substantive cross-species psychological generalizations are likely to be more limited than traditional views in cognitive science, such as functionalism and computationalism have led us to expect. Put bluntly, differences in physical realization prevent or limit identities at the psychological level: conversely, differences in the kinds of bodies that organisms have trickle up to create differences in the corresponding psychology. Thus, cognitive sciences should aim to capture generalizations that reflect bodily variation in ways that, for the most part, they have not.

Finally, philosophers have tended to conceive of the reduction of mind to body and the autonomy of the psychological as mutually exclusive and exhaustive alternatives: the autonomy of psychology is true if and only if reductionism is false. The embodiment thesis provides an alternative perspective on mind-body reductionism that does not rely on this assumption. As psychology is embodied and computational psychology reflects the peculiarities of our bodies, psychology cannot but be grounded in the features of the agent's body. But as bodily features constrain or regulate, but rarely strictly determine, the precise nature of ensuing cognitive activity, there remains also a kind of autonomy to psychological processing.

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