Advanced Review

Embodiment as a unifying perspective for psychology

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A basic claim of the embodiment framework is that all psychological processes are influenced by body morphology, sensory systems, motor systems, and emotions. As such, the framework holds the promise of providing a unifying perspective for psychological research. This article begins with a sketch of several arguments, from evolution to philosophy, as to why the embodiment framework is a good bet. These arguments are followed by a review of approaches to embodiment, including those from cognitive linguistics, perceptual symbol theory, and action-based theories. Finally, examples are provided for how a unifying perspective might work for cognition (including language and memory), cognitive and social development, social psychology, neuroscience, clinical psychology, and psychology applied to education. © 2010 John Wiley & Sons, Ltd. *WIREs Cogn Sci* 2010 1 586–596

Why is progress slow in psychology? Perhaps it is because there is so little agreement among the content areas (e.g., cognitive psychology, developmental psychology, social, and so on), or perhaps, as Mischel[1] speculates, the drive for individual recognition and theory development precludes a cumulative advance. A third, but related, possibility is that areas do not talk the same language; they do not have the same organizing principles and metaphors, and hence it is difficult to ascertain commonalities in approach, data, and theory. The embodied approach to psychology offers the possibility of unification of language, problems, and theory. In this article, I begin with some reasons as to why embodiment might be a unifying force, followed by a review of several approaches to embodied psychology. Finally, the main section of the article consists of a selective review of research showing how embodiment provides coherence to research in psychology.

HOW CAN THE BODY UNIFY?

Although there are different versions of embodiment theory, for the most part, they take as a starting point that psychological processes are influenced by the body, including body morphology, sensory systems, and motor systems. How can this starting point provide a suitable beginning for the multiple concerns of psychologists? How can the body help when many of these concerns seem to be unrelated to the body, concerns such as abstract cognition, language and communication, social processes, and psychological dysfunction, to name but a few?

First, it is almost a certainty that psychological processes or their underlying substrates (e.g., the ability to engage in high-level cognition), evolved. And, in the main, evolution is driven by the dual imperatives of survival and reproduction. These imperatives require direct interaction with the physical and social world, and that interaction is only through the body. In fact, the biologist, Rudolfo Llinas[2] asserts that 'A nervous system is only necessary for multicellular creatures. . .that can orchestrate and express active movement. . .' (page 15). That is, brains are for guiding interaction with the world, and that interaction is mediated by the body.

Along the same lines, consider the necessity of the coevolution of body and cognition. When faced with a predator, if a mole were to attempt to fly away, that mole would not survive to contribute to the gene pool. Similarly, if a bird attempted to dive into a hole in the ground, it would not contribute to the gene pool. In general, how we analyze and react to a situation must take into account bodily abilities. Given that a nervous system is only necessary for action, and given that action requires a body and consideration of that body's abilities, it is a good bet that many

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DOI: 10.1002/wcs.55

psychological processes have their roots (if not their trunk, limbs, and leaves) in the need for action

Second, consider an argument from the philosopher Merleau-Ponty (see Ref 3) concerning similarity. The argument is based on the idea that similarity is related to the number of features in common for the objects being judged: the more features in common, the greater the similarity. But, if one is free to pick features, then any two objects or events can be made as similar as one wishes, that is, the two can have an infinite number of features in common. For example, a lion and my computer are similar in that they both exist on earth, they do not exist on the moon, they do not exist on Mars. . .they exist at a time point after 1,000,000 BCE, after 999,999.99 BCE, after 999,999.98 BCE, and so on. One might object, however, that these are arbitrary and silly features. But, why are the features arbitrary and silly? It is because they have little to do with human interactions with objects. Those interactions are guided by features such as perceived color, and how objects can be gripped, or eaten, or used. Note, however, that the humanly relevant features depend on having human bodies that perceive particular wavelengths and human bodies that effect particular actions (e.g., gripping and eating). Thus, similarity, a basic and central component of cognition and social interaction, depends on the particulars of the body.

Finally, it is clear that humans are symbolic creatures: our lives are dominated by the symbols of language, and many societies spend enormous sums educating their children in how to make meaning out of linguistic and mathematical symbols. But how do symbols work? At one time, psychological theory asserted that symbols become meaningful by participating in a network of other symbols, such as semantic networks or high-dimensional spaces. It is now relatively well-accepted that this story won't do.[4] Consider, for example, Harnad's[5] symbol merry-go-round argument. Imagine that you just landed in a foreign country, and you don't speak the language. At your disposal, you have a dictionary for that language. As you enter the airport terminal, you see a sign written in the foreign language and you decide to figure out its meaning. You look up the first word in the dictionary only to find that it is defined using other words in the language that you do not understand. Undaunted, you look up the first word in the definition, and it too is defined only in terms of words of the language you do not understand. One can imagine looking up word after word after word, that is, tracing the relations in the semantic network defined by the dictionary. And yet, no matter how many words you look up, you will never uncover the meaning of the first word in the sign, let alone the meaning of the sign itself. In short, symbols must be grounded, that is, related to something other than additional symbols. The sensory, action, and emotion systems of our bodies provide that grounding: words, phrases, and mathematical and logical symbols all become meaningful through how we perceive and interact with the objects and situations those symbols denote.

VARIETIES OF EMBODIMENT

All approaches to embodiment agree that behavior is produced by more than a disembodied Cartesian mind manipulating symbols according to rules. In other words, embodiment is in strong contrast to cognitive psychology as developed in the 1960s, 1970s, and 1980s.[6,7] Various approaches to embodiment emphasize, to greater and lesser degrees, contributions of evolution to the shaping of cognition, the coevolution of body and behavior, culture, the specific environment in which the organism is acting, emotional states, details of perceptual systems, action systems, and neural systems.

Lakoff[8] and Gallese and Lakoff[9] provide one example of embodied meaning. Part of Lakoff's project is to understand why so much language is metaphorical. For example, we talk about theories as if they were buildings with a structure, a foundation, supporting members, and so on; and we talk about relationships as if they were journeys with beginnings, middles, ends, rocky parts, as well as smooth parts; and we talk about mood and emotion as having a spatial dimension as when a happy person is described as up or flying high and a sad person is down in the dumps. On Lakoff's analysis, the use of metaphor is much more than just a way of talking; instead metaphors reveal the way people represent and think about abstract concepts, and importantly, those representations result from literal interactions of the body with the world. When people are sad, they literally slump, sit, or lie down, whereas when someone is joyous, they literally carry themselves erect and may literally jump for joy. Thus, the way we think about emotions may reflect the literal interactions of our bodies with the environment.

Another example from Lakoff's work is his analysis of logical expressions such as 'either a or b, but not both.' Much of our early experiences involve interactions with containers, such as cups, bottles, boxes, and even our own bodies. Part of the consistent experiences with containers involves putting things in and taking things out. According to Lakoff, the fact that these experiences have a consistent structure

(e.g., something is in the container or out of the container, but not both) results in an 'image schema' for containers, and the structure of the schema reflects our bodily interactions with containers. Finally, we learn to metaphorically extend the basic, embodied schemas toward more abstract concepts that have the same structure. In this way, we come to understand abstract logical expressions such as 'either a or b, but not both' as container-like, in that something can be in or out of the container, but not both.

The notion that abstract cognition metaphorically hinges on bodily activity has been further developed and tested by Gibbs[10] and Boroditsky and Ramscar.[11] Lindeman and Abramson[12] apply a Lakoffian analysis in clinical psychology, as described below.

A second approach to embodied cognition is Barsalou's[13] notion of a perceptual symbol system. In contrast to the standard cognitive science notion of symbols as abstract, point-like entities, perceptual symbols are analogical in the sense that they are composed of components of neural activity arising from the perception of the symbol's referent. For example, a perceptual symbol of a car might consist of neural activity in the visual system that arises from seeing a car, neural activity in the auditory system corresponding to the sound of a car, and so on. The perceptual symbol is not an exact copy of the neural activity arising from perception; instead it consists of the neural activity underlying the attended components of the experience.

An important idea associated with perceptual symbol systems is that they are used in simulation or reenactment. It is the simulation, constrained by particular contextual features (e.g., the location of the car, its speed, etc.), that corresponds to particular exemplars of a category.

Barsalou's approach has generated a tremendous amount of research, most of which is consistent with the theory. One of the most striking findings was reported by Pecher et al.[14] They noted that there are switching costs when moving attention from one modality to another. For example, in detecting whether a stimulus is on the left or the right, if the previous stimulus and the current stimulus are both visual, participants are faster than if the previous stimulus is auditory and the current stimulus visual.[15] If perceptual symbols are constructed from activity in different sensory systems, then there should be switching costs when making conceptual judgments as well. For example, in verifying properties such as a BLENDER is loud, people should be faster when the previous trial was in the same modality (e.g., LEAVES are rustling) compared to a different modality (e.g., CRANBERRIES are tart), and that is just what was found.

A third approach has emphasized the contribution of action to cognition and meaning. For example, Glenberg and Kaschak[16] tested the hypothesis that sentence understanding involves a simulation not just of perceptual qualities but also of action. They asked participants to judge the sensibility of sentences describing transfer away from the participant (e.g., 'You give Art the pencil') or toward the participant (e.g., 'Art gives you the pencil') in contrast to a nonsense sentence (e.g., 'You give the pencil Art'). To indicate that a sentence was sensible, half of the participants moved the hand to a response button away from the body and half moved the hand toward the body. The major result was that participants were faster to judge a sentence as sensible when the implied direction of the sentence (toward or away) matched the literal direction of the response.

Glenberg et al.[17] had participants judge sensibility of transfer sentences by simple key presses using two fingers of the left hand without hand movements. Transcranial magnetic stimulation was used to measure any effects of sentence processing on right hand muscles. Sentences that described transfer produced more muscle activation than sentences that did not (e.g., 'You and Art look at the pencil'), as if the neuromuscular system used in literal grasping and transfer was also used in simulating transfer. Importantly, the same results were found for sentences describing transfer of information (e.g., 'You delegate the responsibilities to Anna'). That is, even the understanding of abstract sentences seems to involve a sensorimotor simulation.

Zwaan and Taylor[18] developed another procedure for studying the role of action in language comprehension that allows a finer-grain analysis. In their experiments, participants turned a knob either clockwise or counterclockwise to advance through a text. Some sentences described an action that is typically clockwise (increase the volume on a radio) or counterclockwise (decrease the volume). Zwaan and Taylor were able to demonstrate that the major source of interference between literal movement and implied movement was at the verb, although the duration of interference could be extended if the sentence continued to focus on the action.

The experiments by Glenberg et al. and Zwaan and Taylor are consistent with results from neural imaging. For example, Hauk et al.[19] demonstrated greater activation of motor cortex controlling the hand while listening to verbs such as 'pick,' and greater activation of motor cortex controlling the leg while listening to 'kick.'

In the following sections, I present examples of how principles of embodiment, such as those discussed above, can be applied to development, language and memory, emotion and social psychology, theory of mind, psychological disorders, and educational psychology. Each section begins with a claim about the body's contribution to the psychological processes and then a review of some of the relevant research.

UNIFYING PSYCHOLOGY: COGNITIVE AND SOCIAL DEVELOPMENT

The embodiment claim is that cognitive and social development is driven by physical development and associated changes in action. That is, as infants learn control over different types of movement, the infants literally generate different information structures for themselves that can change both cognition and emotion. One example is provided by an investigation of patterns of attention.[20] In that research, 3-month-old infants observed a hand reaching for one of two objects in a particular location. This procedure continued until the infant stopped looking (habituated). Then, infants were shown two new events. In the new goal event, the hand reached for the other object (a new goal for the reach), but at the old location. In the new path event, the hand reached for the original object, but at a new location. The question is what were the infants attending during habituation: the goal or the path? If infants were attending to the path (i.e., the physical movement), then the new path should be a change and produce dishabituation and longer looking times. In contrast, if the infants were attending the goal, then the new goal event should be particularly interesting and produce longer looking times.

The key to the Somerville et al. experiment was what infants did before the habituation trials. Half of the infants were given experience wearing and using 'sticky' mittens, that is, mittens with Velcro that could be swiped at toys with the matching Velcro. Thus, the mittens allowed infants to capture and examine toys in ways that were not yet in the infants' repertoire. Amazingly, infants who had experience with the mittens showed longer looking times to the new goal event compared to the new path event. Infants without the experience showed no preference. That is, being able to manipulate and examine objects changed the nature of the infant's attention from movements to goals. This recognition of the goals underlying actions is basic not only to cognitive development but also to social development in that it allows the infant to understand what others are doing.

Another example, with older infants, was reported by Campos et al.[21] When an infant is being carried, there is little correlation between self movement (e.g., of the arms and legs) and changes in the visual information, such as optical flow. However, when the infant learns to locomote, there is a strong correlation between action and optical flow that is used in guiding direction of travel and maintaining balance. It is also the case that infants with little self-locomotion experience show little fear in crossing the visual cliff. That is, these infants can be induced to cross a glass-covered opening on a raised crawling surface. Infants with extensive experience will not cross the cliff. Campos reasoned that for self-locomoting infants, the cliff creates a discontinuity in the correlation between motion and optic flow, as if the world is operating under different rules, which in turn generates fear. To test this claim, prelocomoting infants were given experience sitting in a wheeled device that the infants could move by kicking against the floor. Once these infants had experience using this device (and in building the correlation between locomotion and optic flow), they too displayed fear of the visual cliff. Thus, learning a new form of bodily activity, self-locomotion, changes the way the infant sees the world and affects emotional and social responses.

Smith[22] examined the relation between action and categorization. In her experiment, 3-year-old toddlers were given a slightly asymmetric, elongated object and told it was a 'wug.' Half of the toddlers were induced to play with the object in a symmetric fashion by using both hands to hold the wug and rotate it back and forth using symmetric wrist turns. The other toddlers were induced to play with the wug using an asymmetric action: holding the wug in one hand and waving it. After playing, the toddlers were asked if other objects were wugs. Some of these other objects were more symmetric than the original and some were less symmetric. The infants who had played with the original using a symmetric action were more likely to call the symmetric new objects wugs, whereas the infants who had played with the original in an asymmetric fashion were more likely to call the asymmetric new objects wugs. Thus, the way the toddler physically manipulates the object affects similarity judgments and categorization.

UNIFYING PSYCHOLOGY: LANGUAGE

The embodiment claim for language is that sentences are understood by simulating sentence content using neural systems ordinarily used for perception, action, and emotion. Research described above demonstrates

the connection between language comprehension and action (for more, see Ref 23).

Kaschak et al.[24] were among the first to demonstrate a role for the use of perceptual information during sentence comprehension. In those experiments, participants listened to sentences describing motion in a particular direction (e.g., 'The car approached you') and verified their sensibility. At the same time, participants were looking at a visual stimulus that appeared to be moving in the same direction as that implied in the sentence or the opposite direction. The important finding was an interaction between the direction of motion implied in the sentence and the direction of motion in the visual stimulus in determining the time taken to judge the sensibility of the sentence. Apparently, understanding sentences describing motion requires the same neural systems that are used in perceiving motion.

Vigliocco et al.[25,26] have demonstrated striking contributions of perceptual systems to language understanding. Namely, hearing verbs implying visual motion (e.g., 'rise') affects detection of literal motion, and a motion detection task can interfere with judgments of the lexical status of motion words.

An embodied approach to language also addresses aspects of language that have long been characterized as abstract (e.g., syntax and emotion) and hence beyond an embodied analysis. For example, Chambers et al.[27] studied the relation between tools, bodily capability, and syntactic analysis. Some types of clauses are ambiguous. For example, 'Move the whistle on the table. . .' might mean that a whistle should be moved onto a table, or that the whistle that is already on the table should be moved elsewhere. This latter interpretation is more common when there are two whistles in the scene so that 'on the table' serves as a reduced relative clause that identifies a particular whistle, namely, the one on the table. In the experiment, participants literally followed instructions to do things such as move whistles. In one condition, the hand was used to follow the instructions, and in another condition, participants used a hook. In addition, one whistle had a lanyard so that it could be picked up using the hook. Here is the critical result. When participants were using their hands so that either of the two whistles could be moved, they interpreted 'on the table' as a relative clause that differentiated the two whistles. However, when participants were holding the hook, they interpreted 'on the table' as the location to which the whistle with the lanyard (the only whistle that they could move) should be moved. That is, the grammatical analysis of the sentence was affected by the bodily capability to move the whistles.

Havas et al.[28] (see also Ref 29) adduced evidence that the emotional system is involved in comprehending sentences describing emotional events. Participants were told that the experiment was investigating the effect of blocking the articulators on reading. Then, participants either held a pen in the mouth using only the teeth, which forces a smile and brightens affect,[30] or they held the pen using only the lips, which prevents smiling and induces a frown. Havas et al. found that participants were faster to comprehend sentences describing events likely to make one happy when they were smiling, and that the participants were faster to comprehend sentences describing events likely to make one sad when they were frowning. Apparently, having the body in a matching emotional state facilitates comprehension of sentences describing emotionally congruent events, just as if part of understanding the sentence depends on simulating the emotional state.

UNIFYING PSYCHOLOGY: MEMORY

The embodiment claim regarding memory is that memory reflects modality-specific and effector-specific interactions with the world. As reviewed previously, Pecher et al.[31] demonstrated just this in regard to conceptual information in memory. The two studies reviewed below demonstrate the claim for episodic memory, that is, memory for particular episodes.

Brunel et al.[32] demonstrated how particulars of perceptual experience become incorporated into memories. In the first phase of the experiment, participants were presented with 80 trials consisting of 40 presentations of a square intermixed with 40 presentations of a circle. One of these visual stimuli, the critical stimulus, was associated with 500 ms of white noise on each of the 40 trials. In the next phase of the experiment, the two visual stimuli were used as warning signals for a tone perception task. When the critical stimulus that had been associated with the white noise was the warning signal, performance on tone perception was reduced. Furthermore, this reduction only occurred when the tone was presented within 500 ms of the warning stimulus. Apparently, the critical stimulus invokes a memorial representation of the white noise using the same neural systems as used in perception. Consequently, when the tone is presented during the duration of the memory (about 500 ms), performance is lowered because the neural system is already in use.

Yang et al.[33] demonstrated how effector-specific action information is used in memory. In their experiment, participants first memorized pairs of letters. Some pairs consisted of letters that could be typed with the same finger, whereas the other

pairs could be typed with different fingers on different hands (note, however, that there was no typing done in the experiment). When typing two letters with the same finger, one is less fluent than when typing two letters with different fingers on different hands, probably because the motor programs must be planned and executed serially in the former case. In the second phase of the experiment, participants were asked to recognize the pairs that were studied, and those pairs were intermixed with new pairs of letters of which half are typed with the same finger and half with different fingers. On the hypotheses that (1) recognition judgments reflect in part a familiarity or fluency judgment, and (2) that effector-specific motor codes are part of the memory, participants should be particularly likely to mistakenly respond 'old' to new pairs typed (fluently) with the different fingers. Indeed, this was the finding, but, as predicted, it was only true for expert typists, not for novice typists. Furthermore, when the experts' fingers were kept busy with a secondary task, the effect was eliminated. Apparently, well-learned motor codes play a role in memory even when those motor codes are not explicitly evoked during study.

UNIFYING PSYCHOLOGY: SOCIAL PSYCHOLOGY AND EMOTION

The embodiment claim for social psychology is that how we understand and interact with other people is influenced by one's own bodily states. Williams and Bargh[34] provide a compelling demonstration of how bodily states influence social judgments and behavior. They tested the hypothesis that physical warmth is metaphorically extended (as predicted by Lakoff) to dimensions of social warmth, such as friendliness and helpfulness. This extension might occur because of the association of literal warmth and social warmth during early experiences with caregivers. To test the hypothesis, participants were asked to hold for a few moments either a cup of hot coffee or iced coffee. Then, they were asked to read a resume and rate the person on various dimensions, some of which related to social warmth. As predicted, holding the hot coffee cup increased ratings on social warmth dimensions but not other dimensions. In a second study, the participants were asked to choose a gift either for themselves or for a friend. After holding a warm object, 54% chose the gift for a friend, whereas after holding a cold object, only 25% chose the gift for a friend. Thus, changing the body (the literal warmth of the hands) affects judgments of others as well as social behavior. Other examples of embodied effects on social cognition are provided by Mussweiller,[35] Jostmann et al.,[36] and Semin and Smith.[37]

Turning to emotion, consider first the mere exposure effect:[38] When novel stimuli are repeated, people tend to rate the repeated stimuli as more likeable than nonrepeated stimuli.[a] One well-supported explanation of the mere exposure effect is that repetition leads to more fluent processing, and that fluency leads to increased liking. But what, exactly, does fluency mean? Toplolinski and Strack[39] tested the hypothesis that fluency is literally the fluency of the specific neuromuscular system used in producing or simulating the stimulus. In the first phase of the experiment, the German participants read novel Greek words (e.g., 'pantokrator') and listened to novel flute melodies. Producing the words requires activity in the speech articulators (e.g., lips and tongue), whereas producing the melodies requires activity in the vocal folds (as if humming). While the participants were reading and listening, half were simultaneously moving the tongue and half were vocalizing 'Mm-hm' (as when signaling assent). In the second phase of the experiment, participants continued moving the tongue or saying 'Mm-hm' while they rated how much they liked old and new words and old and new melodies. For participants moving the tongue, there was no mere exposure effect (no difference between ratings of old and new stimuli) for the words, but there was an effect for the melodies. In contrast, for the participants vocalizing 'Mm-hm' there was no mere exposure effect for the melodies, but there was an effect for the words. Thus, interfering with the development of fluency in particular neuromuscular systems interferes with the mere exposure effect.

Emotion is another area of research that is associated with social psychology, but should be of concern to all psychologists. For example, as noted above, Havas et al.[28] demonstrated a link between emotional reactivity and language comprehension. Niedenthal et al.[40–42] make a compelling case that emotions are strongly embodied. That is, emotions are not just things we think about. Instead, emotions involve bodily changes that have a strong effect on cognition and action.[43,44]

As one instance of how bodily state influences emotions in a social context, consider Oberman et al.[45] They tested the hypothesis that facial mimicry contributes to emotion recognition. That is, if A smiles, B tends to mimic that smile generating a similar state in B. This hypothesis predicts that if activity in a facial muscle used in producing (and mimicking) a particular emotional expression is blocked, then recognition of that emotion should be reduced. In the experiment, participants determined the emotion

being expressed in a picture of a face. In one condition, the participants were biting on a pen using only the teeth in order to block smiling (cf. Ref 28). As predicted, biting on the pen selectively reduced the recognition of happiness, but not fear, or sadness.

UNIFYING PSYCHOLOGY: MOTOR RESONANCE, NEUROSCIENCE, NEUROPSYCHOLOGY, THEORY OF MIND, AND AUTISM

Much of the work reviewed above is consistent with the discovery (and speculation about) mirror neurons (see Ref 46, and Ref 47 for a review). The defining feature of mirror neurons is that they are active both when an animal is engaged in a task and when the animal observes another engaged in the same or related task. With macaques, the evidence for mirror neurons is very strong. That is, using an electrode to record from a single mirror neuron reveals that the neuron is equally active when the animal is acting or observing another engaging in similar actions.

Mirror neurons may indicate how motor resonance can be used to recognize the actions, emotions, and intents of others. When A observes B acting, there is resonance in A's mirror neurons that are active when A takes the same action. Because A knows A's goal in taking that action, A can impute that goal to B. If this hypothesis is correct, then mirror neurons are likely to play an important role in greasing the wheels of social interaction and cooperation.

A human mirror neuron system (MNS) may play a similar role in social interaction, contributing to theory of mind and language processes, and mirror neuron functioning may contribute to the symptoms of autism spectrum disorder. However, research on potential human MNS is more inferential, given the relative scarcity of single cell recording (but see Ref 48). When using functional magnetic resonance imaging, an MNS is inferred when activity in a particular cortical area (as reflected in the BOLD signal) is similar during action recognition and action production, and when the cortical area is a likely homolog of an area in macaque cortex in which mirror neurons have been identified. Using this or a similar logic, it appears that the human MNS responds more to actions that the perceiver can perform than to actions the perceiver is familiar with through vision alone (e.g., see Ref 49); the MNS is more sensitive to social actions than similar nonsocial actions;[50] the MNS responds to both visually perceived actions and the linguistic description of actions;[51] the MNS plays a role in speech perception;[52] activity in the MNS is positively correlated with empathy[53] and negatively correlated with autistic behaviors.[54]

Neuropsychological data have also played a role in investigating the function of MNS. For example, Pazzaglia et al.[55] demonstrated that patients with lesions that produce buccofacial apraxia have difficulty in recognizing the meaning of mouth-produced sounds, but not hand-produced sounds, whereas just the opposite is found for patients with lesions that produce limb apraxia. Fazio et al.[56] demonstrated that patients with aphasia due to lesions in Broca's area (an area previously associated with speech production) had difficulty reordering pictures taken from a movie of hierarchical human actions (e.g., opening a door), but not pictures taken from movies of equally complex physical events (e.g., a bicycle falling over). That is, lesions in Broca's area, the human homolog of macaque area F5 where mirror neurons were first identified, affect action recognition even when there is no verbal content in the task.

On the basis of data such as these, Gallese et al.[57] suggest that mirror neurons provide a unifying base for social cognition. That is, mirror neurons associated with action provide a mechanism for mimicking others (e.g, the Chameleon effect of Chartrand & Bargh[58]) that leads to the understanding of the other's action goals. Similarly, there is evidence that the insula and perhaps other neural structures associated with emotional reactivity use mirror mechanisms. As Gallese et al.[57] summarize, 'Social cognition is not only *thinking* about the contents of someone else's mind. . .Our brains, and those of other primates, appear to have developed a basic functional mechanism, a mirror mechanism, which gives us an experiential insight into other minds. This mechanism could provide the first unifying perspective of the neural basis of social cognition' (page 401, emphasis in the original).

UNIFYING PSYCHOLOGY: PSYCHOPATHOLOGY AND CLINICAL PSYCHOLOGY

The embodiment claim for clinical psychology is that characteristics of the body can be used to understand clinical symptoms. For example, Lindeman and Abramson[12] propose a theory of motor incapacity in depression by combining the notions of simulation with Lakoff's[8] analysis of conceptual metaphors. They begin by asking how hopelessness associated with depression leads to slow motor movements and lethargy. The proposed answer has three components. The first is that hopelessness is conceptualized (by the

person feeling hopeless) as a type of motor incapacity. That is, one's understanding of hopelessness is based on (i.e., metaphorically related to in Lakoff's terminology) the understanding of physical incapacity: Just as one cannot affect the world when physically incapacitated, one cannot affect the world when hopeless. Second, when feeling hopeless, one simulates the sensorimotor experience of physical incapacity. That is, much as understanding a sentence such as 'Anna delegated the responsibilities to you' requires a simulation of physical giving,[17] when feeling hopeless, one simulates physical incapacity. Third, this simulation produces the physiological changes that underlie low energy and psychomotor retardation typical of hopelessness depression. What gives this analysis force is the impressive amount of data that Lindeman and Abramson bring to bear, and their demonstrations of how the theory can account for extant data and make other testable predictions.

UNIFYING PSYCHOLOGY: APPLIED EDUCATIONAL PSYCHOLOGY

The embodiment claim for education is that the abstract symbols used in formal education—words and syntax in reading, numbers and operators in math—need to be grounded in bodily experience. A more thorough review of this approach to education can be found in Ref 59 and the relation between educational games and embodiment can be found in Refs 60–63. Lillard[64] reviews the relation between embodiment and methods used in Montessori schools. Here I will review just some of the research addressing embodiment and the teaching of reading comprehension.

Why do some children hate to read when they love other uses of language such as talking, watching movies, and being read to? There are several answers derived from cognitive theory that almost certainly have some truth in them: some children may need extensive practice in reading to develop fluency, and some children may simply not have the cognitive capacity (e.g., working memory capacity) to enjoy reading. Another possibility, however, is based on the notion of grounding symbols in bodily experience. Consider that when an infant is first exposed to language, the words and their referents are frequently paired. For example, a mother might say, 'Here is your bottle', and literally give a bottle to the child. Or, when a father says, 'Wave bye-bye', the father performs waving gestures.

In contrast, when children are learning to read, they must (at least with an opaque orthography as in English) spend considerable time in learning the arbitrary sounds of letters and how to blend those sounds. For most children, this is a difficult task, and even when a child succeeds in pronouncing a word (e,g., 'duh.....oh....g'), the pronunciation is often strained and unlike the fluid pronunciation in conversation. Furthermore, consider that in contrast to oral language learning, when the child succeeds in reading a word such as 'dog', there are no dogs in the environment, there is no barking, there is no petting. Even when reading in a picture book, reference to the pictures is haphazard at best. In other words, when a child is learning to read, the connection between the symbol (the written word) and the referent is often missing. For those children who do not pick up on the need to forge that connection, reading becomes a boring exercise in name-calling, much as an adult might find reading in an unknown foreign language to be boring. On this analysis, one way of enhancing reading comprehension is to enforce the connection between the symbols and their embodied meanings, and to teach children how to make that connection on their own.

We[65,66] have developed a reading comprehension intervention, *Moved by Reading*, that does just that. In the first phase, children read texts situated in a particular scenario, such as a farm. In addition to the text, in front of the child is a set of toys (e.g., a toy barn, corral, tractor, animals) that can be used to ground aspects of the text. In the physical manipulation condition, a child reads a sentence (e.g., 'The farmer drives the tractor to the barn') and then physically manipulates the toys to simulate the sentence. This activity forces the child to map the words (e.g., 'tractor') to objects, and to map syntactic relations (e.g., who did what to whom) to their actions: it is the farmer who drives the tractor, not vice versa. In a control condition, children read the same texts with the same toys, but instead of acting out the sentences they are asked to reread them. The basic finding is that physical manipulation greatly improves comprehension, often with an effect size (Cohen's *d*) of 1.0 or more. Furthermore, the effect is found for information from the simulated sentences themselves and for information from other parts of the text.

In the second phase of *Moved by Reading*, the toys are removed and children are taught to engage in imagined manipulation (IM). That is, they are asked to imagine manipulating the toys. We believe that this IM instruction is more easily understood than other imagery instructions used with children such as 'make pictures in your head.' Because children have physically manipulated the toys, the content of what should be imagined during IM is clear to the children.

Children in the first and second grades are able to use the IM instruction to achieve large (again, often with effect sizes of 1.0 or more) gains in comprehension when reading new stories from the same scenario. Children in the third and fourth grades are able to use IM both for stories from the original scenario and for stories from new scenarios.[67]

We believe that a similar analysis applies when adults are reading in novel domains (e.g., science). The adult must learn the meanings of new terms such as 'force.' Although a verbal definition could be memorized, learning the meaning in a way that is useful in further understanding requires grounding the term in bodily experiences, in this case, experiences of pushing and being pushed (cf. Ref 68).

SUMMARY: PSYCHOLOGY AS THE SCIENCE OF BEHAVIOR

Work on embodiment has a long way to go to unify psychology. Nonetheless, given that research on embodiment has begun only recently, and given that it has been adopted (to date) by only a small percentage of psychologists, progress has been swift. This rate of progress suggests that embodiment is on the right track.

Another reason to suspect that embodiment is on the right track is that it brings psychology back to its roots. Although students are asked to memorize the definition of psychology as the science of behavior, they are not given many ways to ground that definition. As noted by Baumeister et al.[69] much of psychology has become 'the science of self-reports and finger movements.' Embodiment works toward regrounding psychology in behavior. This is not to say that embodiment is a renamed behaviorism in which it is impermissible to study processes such as attention, memory, and so on. Instead, embodiment is a call to analyze those processes as arising from the recurrent, dynamic interactions of behavior, brain, bodily processes, and changes in the physical and social world. Thus, the promise of embodiment is twofold. By focusing on these interactions, behavior will be brought back into psychology. At the same time, this focus will provide psychologists with a unifying conceptual framework.

NOTE

[a] Why is the mere exposure effect considered to be a phenomenon in social psychology? There is little reason other than it was first report by Zajonc, a social psychologist. This sort of unproductive parceling of phenomena is what an embodied approach to psychology can avoid.

ACKNOWLEDGEMENTS

This article is an expanded version of a presentation as part of the Architecture of Cognition symposium presented at the meeting of the Association for Psychological Science in 2009. Work on this article was supported 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 author and do not necessarily reflect the views of the National Science Foundation.

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