CN Chapter 11

CT The Embodied Emotional Mind

Piotr Winkielman[1]

Paula M. Niedenthal[2]

Lindsay Oberman[1]

[1]Department of Psychology, University of California, San Diego, CA, USA

[2]Centre National de la Recherche Scientifique (CNRS) and University of Clermont-Ferrand, France.

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The environment is filled with emotionally significant information. On a walk in a forest, an individual might encounter a friendly dog or a disgruntled bear. In nearly every social interaction, an individual might be confronted with facial, vocal, and postural signs of emotion. Thus, spouses smile, colleagues frown, children pout, babies gurgle, and students tremble with anxiety or giggle with joy. Even computers deliver “just joking” faces by e-mail whereas stores and snacks lure with smiley faces. The importance of such information is now well documented: Emotionally-charged objects can capture attention, bias perception, modify memory, and guide judgments and decisions (for an overview, see Eich, Kihlstrom, Bower, Forgas, & Niedenthal, 2000; Winkielman, Knutson, Paulus, & Trujillo, 2007).

Even abstract symbols that refer to emotional events, such as language, can rapidly shape an individual’s behavior and trigger physiological responses. For example, most children learn through language rather than direct emotional experience that they should not put their fingers in electrical outlets or stand under a tree in a storm. Such information retains its heat in thought and language, and can be generalized to novel events (Olsson & Phelps, 2004). In adults, simple words like “the next tone will be followed by a shock” elicit a fear reaction (Phelps, O’Connor, Gateby, Grillon, Gore, & Davis, 2001) whereas terms of endearment trigger positive arousal (Harris, Ayçiçegi, & Gleason, 2003).

But how does this work? Just what happens when we see a smile, hear our partner say that special word, learn that an outlet can deliver a shock, or read about a wayward bear? In this chapter, we argue that new insights into how humans perceive, learn, understand, represent, and use emotionally significant information are offered by theories of embodied cognition. The structure of the chapter is roughly as follows. First, we place embodiment theories in the context of general debates about the nature of mental representation and discuss possible neural mechanisms. We then review evidence for the embodiment account in several domains of emotion processing. We cover research on emotional perception, comprehension, learning, influence, concepts, and language. Finally, we conclude with some observations about the strengths and limitations of the embodied theories of emotion and raise some questions for future research.

A-Head Theories of Embodied Cognition and Emotional Processing

Until recently, mainstream psychologists and cognitive scientists have spent little time and resources on the development of models explaining how people acquire and use emotional information. For many scientists, the topic of emotion has seemed fraught with vexing issues including how emotion differs from cognition, how many emotions are there, the subjective nature of feelings, and how to elicit and measure emotion in laboratory experiments (Zajonc, 1980). There was also a general sense that emotions are somehow disruptive to “basic” mental processes such as perception, attention, decision making, and reasoning and thus perhaps best left to clinical experts (Damasio, 1994).

B-Head Amodal Accounts

One way to avoid the problems with emotions is to make them trivial in the sense of being no different from cognition. Indeed, classic symbolic models of information processing in the cognitive sciences suggest that emotion is represented in an amodal fashion, devoid of its sensory and motor bases. Under these amodal accounts, emotional information, initially encoded in the different sense modalities (vision, olfaction, and audition), is represented and stored in a conceptual system that is functionally separated from its sensory origins. The resulting symbols bear no analogical relationship to the experienced event, and it is these symbols that enter into high-level cognitive processes such as thought and language (e.g., Fodor, 1975; Newell, 1980). Functionally, such amodal accounts of information processing render what individuals know about emotion equivalent to what they know about most other things. Just as people appear to know that *cars* possess the features engines, tires, and exhaust pipes, they know that *anger* involves the experience of a thwarted goal, a desire to strike out, and even that it is characterized by clenched fists and a rise in blood pressure.

B-Head Embodied Accounts

The last decade and a half witnessed a surge of interest in alternative models of representation clustered under the label *embodied cognition theories* (Barsalou, 1999; Wilson, 2002; chapters in this volume). The basic tenets underlying those models are quite old, with philosophical predecessors in Merleau-Ponty and Heidegger, and psychological roots in Vygotsky and Piaget (for a broader perspective, see Clark, 1997; Prinz, 2002). An assertion common to modern instantiations of such theories is that high-level cognitive processes such as thought and language are *modal*, i.e., involve partial reactivations of states in modality-specific, sensorimotor systems. That is, the grounding for knowledge – what it refers to – is in the original neural states that occurred when the information was originally acquired. In such an embodied account, there is no need for states of activation in perceptual, motor, and introspective systems to be redescribed into abstract symbols that represent knowledge. Knowledge is in a sense partially "reliving" experience in its sensory, motor, and introspective modalities.

Recently, embodied accounts have been applied to understand the processing of emotional information (Barrett, this volume; Damasio, 1994; Decety & Jackson, 2004; Gallese, 2003; Niedenthal, Barsalou, Ric, & Krauth-Gruber, 2005; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). One such application proposes that sensorimotor and affective states triggered during the encounter with an emotion-eliciting stimulus (e.g., a bear) are captured and stored in modality-specific association areas (see Figure 11.1). Later, during recovery of the experience in consciousness (e.g., thinking about a bear), the original pattern of sensorimotor and affective states that occurred during the encounter can be reactivated. Critically for such an account, the reactivation can be partial and involves a dynamic, online use of modality-specific information. That is, what gets reactivated depends on how selective attention is allocated and what information is currently relevant to the individual (Barsalou, 1999). For embodied cognition theories, using knowledge – as in recalling memories, drawing inferences, and making plans – is thus called “embodied simulation” because parts of prior experience are reproduced in the originally implicated neural systems as if the individual were there in the very situation (Gallese, 2003). For example, an embodied simulation of anger could involve simulating the experience of anger, including the activation of arm muscles that clench a fist or facial muscles that form a scowl.

A-Head Neural Basis of Embodiment

Many theories of embodied cognition suppose processes such as “re-experience” and “simulation.” There is also a wide discussion of “mirroring” and “resonance.” An in-depth review of the proposed neural architecture supporting these processes is outside the scope of this chapter. However, let us indicate some areas of current debate. We will also come back to the neural instantiation issues when reviewing specific findings.

One debate concerns the relative role of central and peripheral mechanisms. Early embodiment theories (e.g., James, 1896/1994,). as well as some modern versions (Zajonc & Markus, 1984), highlight the role of input from the autonomic nervous system. However, starting with Cannon’s (1927) rebuttal of James-Lange emotion theory, critics have argued that bodily feedback is too undifferentiated and slow to support emotional experience. In fact, some of these criticisms are misplaced.

For example, facial musculature is refined and can respond quickly (Tassinary & Cacioppo, 2000). Further, recent research suggests that the autonomic feedback indeed contributes to emotional experience (Craig, 2002; Nicotra, Critchley, Mathias, & Dolan, 2006). More importantly, modern embodiment theories highlight that peripheral input works together with the brain's modality-specific systems, which can quickly simulate the necessary changes. For example, embodied states can be speedily and flexibly represented by "as-if loops" linking the ventromedial pre-frontal cortex, the limbic system, and the somatosensory and motor cortex (Damasio, 1994).

Another important debate concerns the exact substrates of the "simulation" mechanisms. Some researchers find it sufficient to assume that the brain represents information across a hierarchy of widely distributed associative areas, sometimes called *convergence zones* (Damasio, 1989). Those areas retain information about the modal (sensorimotor) features of the stimulus, with progressively "higher" areas tuned to more abstract aspects of the representation. This way of representing information preserves its modal contents and allows sensorimotor representations to be selectively reactivated, via attentional mechanisms, whenever the perceiver needs to construct a simulation (Barsalou, 1999). Note that on this account, there is no anatomically unique "simulation" or "mirroring" system. In a way, the whole brain can function as a simulation machine, with different modality areas being recruited depending on the goals in a particular task (Grush, 2004).

Others argue that simulation is supported by specialized *mirror neurons*, or even an entire *mirror neuron system*, which maps the correspondences between the observed and performed actions. However, there is much disagreement about the exact location of the mirror neurons, whether these neurons actually constitute a "system" (in the sense of interconnected elements), and whether there actually are specialized neurons dedicated to mirroring or whether regular neurons can simply perform a mirroring function. Some of the original work in monkeys emphasized a unique role of neurons located in the inferior parietal and inferior frontal cortex, which discharge both when a monkey performs an action and when it observes another individual's action (Gallese, Keysers, & Rizzolatti, 2004). The implications of this work were quickly extended to humans. Some scientists argue that humans have a dedicated "mirror neuron area," located around the Broadmann area 44 (human homologue of the monkey F5 region). This mirror area may compute complex operations such as mapping the correspondence between self and other, or differentiating between goal-oriented versus non-intentional action (Gallese et al., 2004). However, the empirical picture is a bit more complex, as we will discuss in more detail. Whereas there are some human studies that find activation in the putative mirror neuron area (which we discuss later), there are also many studies suggesting that mirror-like responses, in the sense of an area's involvement in both perception and action, can be observed in other regions of the brain. These may include a variety of emotion-related areas (insula, anterior cingulate), the somatosensory cortex, the superior temporal sulcus, the extrastriate body area, or the dentate of the cerebellum (for a review, see Decety & Jackson, 2004). Of course, this could suggest that the mirror neurons are scattered throughout the brain, perhaps forming a distributed mirror neuron system. However, it could also suggest that there is no “system,” and mirroring is just a function that can be instantiated by many areas. In fact, one principle explaining these effects holds that neural coding generally tends to co-localize similar functions. For example, the neural representation of a visual image and linguistic concept of a “leg” is partially co-localized with the neural representation of the physical leg because of Hebbian learning (seeing one’s leg move and moving it at the same time). Thus, it is not surprising that the same area can be active during perception and action (Buccino et al., 2001; Pulvermüller, this volume). We will come back to these issues throughout the chapter.

A-Head Emotion and Embodiment

Since the beginning of scientific psychology, writers have been fascinated by the tight connection between body, cognition, and emotion. In 1890, James observed that “Every representation of a movement awakens in some degree the actual movement which is its object.” One hundred years later, Zajonc and Markus (1984, p. 74) wondered why “people engaged in an arithmetic problem often gnash their teeth, bite their pencils, scratch their heads, furrow their brows or lick their lips?” and “why do people who are angry squint their eyes and scratch their shoulders?”

There is now much systematic evidence for a link between emotion and embodiment. For example, merely thinking about emotional content elicits incipient facial expressions (Cacioppo, Petty, Martzke, & Tassinary, 1988) and brain activations similar to those accompanying encounters with real emotional objects (Damasio et al., 2000). Similarly, a large number of studies found that observers tend to overtly and covertly mimic behavior of those around them, including gestures and body postures (Chartrand & Bargh, 1999), facial expressions (Dimberg, Thunberg, & Elmehed, 2000; Wallbott, 1991) and even emotional tone of voice (Neumann & Strack, 2000). However, why do people make emotional faces and postures when thinking about emotion? Why do they activate similar neural circuitry? Why do they mimic other's expressions and gestures?

Some views, like the associative account, emphasize that the role of previously established stimulus-response links (Lipps, 1907). For example, people spontaneously smile when they observe another person smile because seeing and making a smile is frequently paired in the environment. Several studies have now clearly documented the role of experience in phenomena such as automatic imitation (e.g., Heyes, Bird, Johnson, & Haggard, 2005). This possibility makes some think that sensorimotor effects are causally inefficacious byproducts of higher-order processes (Fodor & Pylyshyn, 1988). Others think that a system based on associative learning can play a causal role in the recognition and understanding of action and emotion, but doubt there is a need for assumptions beyond the standard associative approach (Heyes, 2001).

In contrast, theories of embodied cognition suggest that the active engagement of sensorimotor processes is part and parcel of the process of emotional perception, understanding, learning, and influence. On that account, the vicarious re-creation of the other's state provides information about the stimulus meaning, and can go beyond the previously established associations. If so, manipulation (inhibition or facilitation) of somatosensory resources should influence the perception and understanding of emotional stimuli. Evidence for this interpretation has been now obtained in multiple domains, as we review next.

A-Head Emotional Perception

The evidence for the role of embodied simulation in emotion perception comes from a variety of behavioral and neuroscience studies (for a review, see Adolphs, 2006; Goldman & Sripada, 2005). Those studies examined the involvement of somatosensory resources by manipulating and measuring both peripheral and central mechanism.

B-Head Peripheral Mechanisms

Focusing on the role of feedback from facial muscles, Niedenthal and colleagues (2001) examined the possibility that mimicry (reproducing the observed stimulus using one's own muscles) is causally involved in the perception of the facial expression of emotion. Participants were asked to identify the point at which a morphed face changed from happy to sad and vice versa. During this task, some participants were free to move their faces naturally, whereas other were holding a pen sideways in their mouths, between their teeth and lips (see Figure 11.2, left panel). This manipulation prevents facial mimicry and thus reduces somatic feedback that supports the detection of change in the observed expressions. Participants whose facial movements were blocked by the pen detected the change in expression later in both directions (happy to sad and sad to happy) than those who were able to move their face freely, supporting the role of facial mimicry in the recognition of facial expressions.

Oberman, Winkielman, and Ramachandran (2007) extended this study by adding several controls and, more importantly, examining the specificity of the mimicry-blocking effect. Note that the embodiment account predicts that recognition of a specific type of facial expressions should be impaired by blocking mimicry in the group of facial muscles used in the production of this type of expression. The authors tested this hypothesis using four expressions (happy, disgust, fear, and sad) and four manipulations of facial mimicry: holding a pen sideways between the teeth, chewing gum, holding the pen just with the lips, and no task. Experiment 1 employed electromyography (EMG) and found that holding a pen sideways between the teeth selectively activates muscles involved in producing expressions of happiness (Figure 11.2, middle panel). In contrast, the gum manipulation broadly activates several facial muscles, but only intermittently (the lip manipulation had no effect on EMG). Testing for the accuracy of emotion discrimination, Experiment 2 found that the pen-biting manipulation selectively impaired the recognition of happiness, but had no effect on the recognition accuracy for disgust, fear, and sad expressions. This finding suggests that recognition of a specific type of facial expression involves the selective recruitment of muscles used to produce that expression, as predicted by embodiment accounts.

B-Head Central Mechanisms

Several studies have investigated the role of central mechanisms underlying embodied simulation. In a pioneering study, Adolphs and colleagues (2000) asked 108 patients with a variety of focal brain lesions and 30 normal control participants to perform three visual emotion recognition tasks. In the first task, participants rated the intensity of basic emotional facial expressions. In the second task, participants matched a facial expression to its name. In the third task, participants sorted facial expressions into emotional categories. Though each task identified a slightly different group of regions, damage to primary and secondary somatosensory cortices impaired performance in all three tasks. This finding is consistent with the embodiment view in which emotion perception involves simulating the relevant state in the perceiver using somatosensory resources.

The previous lesion study did not report a particularly critical role of the classic mirror neuron areas (BA 44) in the recognition of facial expressions. However, such suggestions have been made in the functional magnetic resonance imaging (fMRI) literature. Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi (2003) asked participants to just observe or to observe and imitate emotional facial expressions.

Compared to rest, both observation and imitation tasks activated a similar group of regions, including the inferior frontal cortex (the mirror neuron area) as well as the superior temporal cortex, insula, and amygdala.

Finally, there is some evidence for the selectivity of central mechanisms in the embodied simulation of specific emotions. Wicker, Keysers, Plailly, Royet, Gallese, and Rizzolatti (2003) asked participants to inhale odors that generated strong feelings of disgust. The same participants then watched videos displaying other individuals expressing disgust. Results showed that the areas of the anterior insula and, to some extent, the anterior cingulate cortex were activated both when individuals experienced disgust themselves and when individuals observed disgust in others, presumably reflecting simulation. This interpretation is further supported by evidence that damage to the insula results in a paired impairment in the experience and recognition of disgust (Calder et al., 2000).

A-Head Emotion Comprehension

Going beyond the perception of specific emotional stimuli, such as facial expressions, the idea of embodied simulation can shed light on a more general process of emotional understanding and empathy. Social psychologists have long argued that empathy – “putting oneself in some else’s shoes” – can facilitate understanding (for review, see Batson, 1991). There is now evidence that this process might be supported by embodied simulation (Decety & Jackson, 2004). Much of the relevant data come from the perceiver's reaction to another person's pain.

One early study assessed activity in areas related to the experience of pain with a precise technique for neural mapping – single cell recording. This study found the activation of pain-related neurons when a painful stimulus was applied to the participant's own hand, and also when the patient watched the painful stimulus applied to the experimenter's hand (Hutchison, Davis, Lozano, Tasker, & Dostrovsky, 1999). This finding was extended by a recent fMRI study that revealed similar changes in pain-related brain regions (anterior cingulate and insula) of female participants while painful stimulation was applied to their own hand and to their partners' hand (Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith, 2004). Further, the study showed that the change in relevant brain activations was related to the participants' level of empathy, suggesting the role of motivation to stimulate. Indeed, this interpretation is consistent with recent studies from the same laboratory, which found an increase in activation of pain-related regions to the observation of a confederate receiving a painful stimulus, but only if the confederate had played fairly in a previous economic game (Singer et al., 2004). This finding highlights the goal- and context-dependent nature of simulation that is emphasized by modern embodiment theories. That is, the responses to another person are not simply automatic but are situated in a particular context that reflect the relationship with the person, or shared group memberships, and require active engagement of the perceiver in the process of constructing a simulation.

A-Head Social Functioning

If the ability to construct an embodied simulation is critical for emotion perception and understanding, one would expect that it would be related to social functioning. Evidence that this might indeed be the case comes from research on individuals with typical and atypical social functioning.

B-Head Typical Individuals

One early suggestion comes from a study by Zajonc, Adelman, Murphy, and Niedenthal (1987), who investigated the facial similarity of couples at the time of their marriage compared to after 25 or more years of marriage. Zajonc and colleagues reasoned that if mimicry occurs in the service of empathy, then married partners should frequently mimic each other's facial expressions because they are particularly motivated to empathize with and understand each other. As a consequence of this frequent mimicry, the couple's facial morphology should grow more and more similar over time. After 25 years, the similarity of their faces should be greater than at the time of their marriage, and also more similar than random people of the same age. The researchers indeed found that facial similarity increased within couples over time, implicating the constant presence of facial mimicry. Furthermore, this effect was correlated with the quality of the marriage, and therefore presumably success in empathizing.

Recent research in social psychology suggests that one way embodiment relates to social functioning is because it modifies (and is modified by) self-other overlap. The idea here is that engaging in, say, mimicry, or even in a simple exchange of touch, can reduce the psychological distance with which the other is represented mentally to the representation of the self. Consistent with this idea, participants showed greater positivity toward a stereotyped group after being unobtrusively touched by a member of that group (Schubert, this volume; Smith, this volume). Interestingly, as highlighted by Semin and Cacioppo (this volume), a better match between the representation of the self and the other can promote social functioning because it facilitates "offloading" of social cognition across interaction participants.

B-Head Individuals with Autism

A link between embodiment and social functioning is also suggested by the literature on autism – a disorder characterized by severe deficits in social and emotional understanding. Several authors have suggested that these deficits could result from reduced imitative abilities (for a review, see Williams, Whiten, & Singh, 2004). In fact, there is now substantial evidence that individuals with autism spectrum disorder (ASD) have deficits in the spontaneous imitation of both emotional and non-emotional stimuli (Hamilton, Brindley, & Frith, 2007). For example, McIntosh, Reichmann-Decker, Winkielman, and Wilbarger (2006) showed pictures of happy and angry facial expressions to adults with ASD and matched controls. In one condition, participants were simply asked to "watch the pictures as they appear on the screen." In another condition, participants were asked to "make an expression just like this one." Mimicry was measured by EMG, with electrodes placed over the cheek (smiling) and brow (frowning) regions. In the voluntary condition, there were no group differences, with ASD participants showing a normal pattern of voluntary mimicry (smile to a smile, frown to a frown). However, in the spontaneous condition, only typical participants mimicked, with ASD showing no differential responses.

It has been proposed that the imitation deficits of ASD individuals result from impairments in their mirror neuron system (Oberman & Ramachandran, 2007) and their inability to spontaneously map the mental representation of the self to the representation of the other (Williams et al., 2004). Evidence consistent with these proposals has been obtained by several research groups using different techniques. First, there are reports of anatomical differences in the mirror neuron system. For example, Hadjikhani and colleagues (2006) found that ASD individuals have local decreases of gray matter in the mirror neuron system areas, and that the cortical thinning of those areas was correlated with severity of ASD symptoms. Similarly, Villalobos et al. (2005) found that ASD individuals have reduced functional connectivity between the primary visual cortex and area 44, the prefrontal mirror neuron area. Second, several studies observed functional differences in the activity of the mirror neuron system. Most of this research focused on simple, non-emotional gestures. Nishitani et al. (2004) showed Asperger's syndrome (AS) and control participants pictures of a woman performing orofacial gestures and asked them to imitate these gestures. Cortical activations were recorded using magnetoencephalography (MEG), an electrophysiological technique that offers good temporal resolution. Compared to controls, the AS group showed weaker activations in the inferior frontal lobe and primary motor cortex, suggesting a reduced mirror neuron activity. Focusing on spontaneous imitation, Oberman et al. (2005) asked typical and ASD individuals to simply view videos of a person executing simple actions, or to perform the same actions. During these tasks, the experimenters recorded mu wave suppression, an electroencephalogram (EEG) index of activity in the primary motor cortex, and proposed it to be indicative of activity in the premotor “mirror neuron area” during the observation of action. The typically developing individuals showed mu wave suppression to both the execution and observation of action. However, individuals with ASD showed mu wave suppression when performing their own actual movement but not when observing movement (i.e., reduced mirror neuron activity).

Interestingly, and consistent with social psychological literature on the role of self-other overlap, there is evidence that autistic impairment in spontaneous mirroring might relate to a deficit in mapping the representation of the observed action to the self. Theoret et al. (2005) asked typical and ASD groups to view videos of index finger and thumb movements that were directed either toward or away from the participants. During these tasks, the experimenters recorded motor evoked potentials (MEP) induced by transcranial magnetic stimulation (TMS). In the typical group, both participant-directed and other-directed actions increased MEPs recorded from the participant’s muscles, suggesting spontaneous mirroring. However, the ASD group showed increased MEPs (spontaneous mirroring) when viewing actions directed toward the participant,but not when viewing actions directed away from the participant. This suggests that ASD participants’ mirroring failures might be due to a reduction in self-other mapping.

Finally, a recent fMRI study investigated the role of mirror neurons in the imitation of emotion stimuli in individuals with ASD and controls (Dapretto et al., 2005). Participants were asked to both imitate and observe emotional facial expressions. As compared to controls, ASD participants showed lower activation in a wide variety of regions, including visual cortices, primary motor, limbic, cerebellum, and the presumed “mirror neuron region” (inferior frontal gyrus). Though the group differences in brain activations were fairly broad, one intriguing finding is a negative correlation of the activity in the mirror neuron region with the severity of autism symptoms, measured by the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview (ADI). Again, these findings suggest that deficits in social and emotional understanding in autism could be due to a reduction in spontaneous simulation.

A-Head Emotional Influence

The embodiment perspective can also help explain how emotional stimuli influence behavior that is less automatic and immediate than spontaneous mimicry.

Specifically, there is a large amount of evidence that salient emotional stimuli can shape how individuals act toward a variety of targets (for review, see Winkielman et al, 2007). This influence is often explored using an affective priming paradigm. In this paradigm, researchers first expose participants to emotional stimuli (e.g., emotional faces, scenes, or words) and then test the impact of these stimuli on a target behavior. For example, Winkielman, Berridge, and Wilbarger (2005) first exposed participants to a series of subliminal happy or angry faces and then asked them to perform a set of simple consumption behaviors (pour and drink a novel beverage). The results showed that participants poured and drank more after being exposed to happy than angry faces, especially when they were thirsty. But what is the mechanism of such an effect?

Many researchers treat affective priming in the same framework as any other type of “cold” semantic priming. Affective primes activate valence-congruent material in semantic memory, which then facilitates valence-congruent judgments and behaviors (Forgas, 2002). In contrast, the embodiment framework suggests that exposure to affective primes can elicit somatosensory reactions, which then bias and guide the processing of subsequent stimuli (e.g., Niedenthal, Rohman, & Dalle, 2002). These considerations generate an interesting prediction regarding the impact of affective primes on behavior. Stimuli that trigger an embodied response should have greater impact on subsequent behavior than stimuli that are comparable in semantic aspects of valence but do not trigger an embodied response. This should be particularly true for behaviors that require some form of evaluative engagement with the stimulus, rather than just simply associative responding (we will return to this point later).

Winkielman and Gogolushko (under review) tested these predictions in a study that compared the impact of emotional faces and scenes versus emotional words on consumption behavior (pouring and drinking a novel beverage). The priming stimuli were equated on valence and frequency, but emotional faces and scenes were more likely to trigger a physiological response than emotional words (Larsen, Norris, & Cacioppo, 2003). In Experiment 1, both subliminal and supraliminal emotional facial expressions influenced consumption behavior in a valence-congruent way, with happy primes leading to more pouring and drinking than angry primes. This effect was replicated in Experiment 2 with supraliminal pictures of high- and low-frequency emotional objects. In contrast, emotional words had no systematic effects on behavior in either study. There were also no differences between pictorial and word primes on more interpretive responses, such as ratings of the beverage. In sum, these studies suggest that to influence a somewhat complex hedonic behavior (like the consumption of a novel drink), an affective stimulus might need to first elicit an embodied response (for further discussion, see Winkielman et al., 2007).

A-Head Learning and Expression of Value

Over the last two decades, social psychologists have conducted a series of ingenious experiments that reveal the role of embodiment in both the formation and expression of value, as expressed in people's preferences and attitudes.

B-Head Attitude Formation

In an early demonstration of the role of embodiment, Wells and Petty (1980) instructed participants to nod their heads vertically or to shake their heads horizontally while wearing headphones, under the pretext that the research was designed to investigate whether the headphones moved around if listeners danced while listening to music. While nodding or shaking their heads, participants then heard either a disagreeable or an agreeable message about a university-related topic. Later, they rated how much they agreed with the message. Results suggested that the earlier head movements moderated their judgments. Specifically, participants who had nodded while hearing the message were more favorable than participants who had shaken their heads.

Researchers have also shown that one can enhance an attitude toward an object by covertly inducing individuals to smile (Strack, Martin, & Stepper, 1988). In the study, participants were asked to rate different novel cartoons while holding a pencil between their front teeth (Figure 11.2, right panel), making it easier for the participants to smile. Other participants were instructed to hold a pencil between their lips without touching the pencil with their teeth, making it more difficult to smile.

Results revealed that cartoons were evaluated as higher by individuals with facilitated smiling rather than inhibited smiling.

Cacioppo et al. (1993) asked participants to view and evaluate neutral Chinese ideographs. During this task, the researchers manipulated the engagement of muscles involved in arm flexion and arm extension by having participants press against the bottom or the top of the table. Arm flexion was associated with higher rating of ideographs than muscle extension, presumably because of differential association of these actions with evaluative outcomes.

B-Head Expression of Attitudes

One of the first studies that examined the role of embodied responses in attitude expressions was conducted by Solarz (1960). He asked participants to move cards with words that were mounted on a movable stage either toward or away from themselves. Participants responded faster with the pulling movement (typically associated with approach) to positive than to negative words, and faster with the pushing movement (typically associated with avoidance) to negative than to positive words (see also Chen & Bargh, 1999).

B-Head Flexible Embodiment

Importantly, although findings like the ones we just discussed may suggest a relatively fixed link between valence and a specific muscle action or a specific direction of movement, this relationship is more complex. For example, Centerbar and Clore (2006) replicated the procedure of the Cacioppo at al. (1993) study with positively and negatively valenced ideographs and found that the impact of specific muscle movement on later evaluation depended on the initial stimulus valence. Thus, with initially negative stimuli, muscle extension (pushing away) led to more positive attitude than muscle flexion (pulling toward). Presumably, pushing away a bad stimulus is a more compatible action rather than pulling it toward oneself. As a result, this action might feel more fluent and pleasant (Winkielman, Schwarz, Fazendeiro, & Reber, 2003).

Further, the exact impact of action on valence depends on the meaning of the movement for the participant. For example, using a modified version of the Solarz/Chen and Bargh paradigm, Wentura et al. (2000) asked participants to respond to positive and negative words by either reaching out their hand to press a button or by withdrawing their hand from the button. Note that in this case, pressing the button (i.e., approaching it) required an extension movement (away from the body). In contrast, not pressing a button (avoiding it) required a flexion movement, withdrawing the hand toward the body. Consistent with the primacy of the functional meaning of movement (rather than a specific muscle movement), participants pressed the button faster for positive than for negative stimuli but withdrew their hand faster for negative than for positive stimuli. Similarly, Markman and Brendl (2005) demonstrated that the evaluative meaning of the movement does not depend on the relation to the "physical body," but rather the relation to the more abstract representation of the "self." Specifically, they found that positive valence facilitates any motor action (push or pull) that brings the stimulus closer to the self, even when the self is represented as the participants' name on a screen.

In summary, multiple studies suggest that bodily postures and motor behavior that are associated with positive and negative inclinations and action tendencies toward objects influence acquisition and expression of attitudes toward those objects. Thus, it seems that attitudes are in part grounded in embodied responses. Importantly, the link between these embodied responses and valence is flexible, and depends on features of the current situation, the initial value of the stimuli, and how participants interpret the meaning of the specific action. This flexibility is consistent with the modern theories of embodied cognition that view the use of somatosensory and motor responses as a constructive, online process, which dynamically uses relevant resources (Barsalou, 1999, this volume).

A-Head Linguistically Represented Emotion Knowledge

Thus far, most of our discussion has focused on relatively concrete emotional stimuli (e.g., faces or scenes). However, what about more symbolic forms of emotion knowledge? Can emotional words and sentences be embodied?

B-Head Emotion Concepts

Recent findings from studies of emotion concepts suggest that embodied simulation is also involved in the representation of abstract emotion knowledge (Mondillon, Niedenthal, Vermeulen, & Winkielman, under review). In two experiments recently conducted in our laboratories, participants had to make judgments about whether concepts were associated with an emotion by providing a yes or no response. In the first study, the words referred to concrete objects (e.g., *party*, *vomit*) previously rated by other participants as being strongly associated with the emotions of joy, disgust, and anger, or as being very neutral. In a second study, the stimuli were abstract concepts, specifically, adjectives that referred to affective states and conditions (e.g., *delighted*, *nauseated*). During the judgment task, the activation of four different facial muscles was recorded with EMG. Previous research shows that the activity in the region of two muscles, the zygomaticus major and the orbicularis occuli, is elevated when an individual is smiling with happiness. The region of corrugator supercilli is activated when an individual is frowning with anger. The levator muscle is largely activated when an individual makes the grimace of disgust (Tassinary & Cacioppo, 2000).

Results of both of our studies suggest that in processing emotionally significant concepts, individuals simulated the relevant, discrete expressions of emotion on their faces. For example, the first study showed that in the very brief time (less than 3 seconds) it took participants to decide that, for example, *vomit* was related to an emotion, they activated disgust-related muscles on their faces. Similarly, the second study showed that when processing the concept *delighted*, individuals activated happiness-related muscles. Importantly, these EMG effects did not simply reflect an automatic response to the word but rather reflect a goal-dependent simulation of the word’s referent (concrete objects for the first study and abstract emotional states for the second). Support for such a conclusion comes from an additional control condition of each study where participants were asked to simply judge (yes or no) whether the words were written in capital letters. To make such judgments, these participants would not have to simulate the emotional meaning of the words, and indeed findings revealed that they showed no systematic activation of the facial musculature. This finding suggests that emotional simulation does not occur when the judgment can be based on simpler features – a point that has been made in other research as well (Solomon & Barsalou, 2004; Strack, Schwarz, & Gescheidinger, 1985).

Further evidence for the embodiment of emotion concepts comes from extensions of research on the costs of switching processing between sensory modalities to the area of emotion. Previous research has shown that shifting from processing in one modality to another involves temporal processing costs (e.g., Spence, Nicholls, & Driver, 2001). For example, individuals take longer to detect the location of a visual stimulus after having just detected the location of an auditory rather then another visual stimulus. For the present concerns, it is of interest that similar “switching costs” are also found when participants engage in conceptual tasks: Individuals are slower to verify that typical instances of object categories possess certain features if those features are processed in different modalities (Pecher et al., 2003). For example, they are slower to verify that a *bomb* can be *loud* when they have just confirmed that a *lemon* can be *tart*, than when they have just confirmed that *leaves* can be *rustling*. This provides support for the general assertion made by theories of embodied cognition that individuals simulate objects in the relevant modalities when they use them in thought and language.

Vermeulen and colleagues examined switching costs in verifying properties of positive and negative concepts such as *triumph* and *victim* (Vermeulen, Niedenthal & Luminet, 2007). Properties of these concepts were taken from vision, audition, and the affective system. Parallel to switching costs observed for neutral concepts, the study showed that for positive and negative concepts, verifying properties from different modalities produced costs such that reaction times were longer and error rates were higher than if no modality switching was required. Importantly, this effect was observed when participants had to switch from the affective system to sensory modalities, and vice versa. In other words, verifying that a *victim* can be *stricken* was less efficient if the previous trial involved verifying that a *spider* can be *black* than if the previous trial involved verifying that an *orphan* can be *hopeless.* And verifying that a *spider* can be *black* was less efficient when preceded by the judgment that an *orphan* can be *hopeless* than that a *wound* can be *open*. This provides evidence that affective properties of concepts are simulated in the emotional system when the properties are the subject of active thought.

B-Head Emotional Language

Finally, embodied cognition of language makes the claim that even the comprehension of complex sentences may involve embodied conceptualizations of the situations that language describes (Glenberg & Robinson, 2000; Zwaan, 2004). The first step in language comprehension then is to index words or phrases to embodied states that refer to these objects. Next, the observer simulates possible interactions with the objects. Finally, the message is understood when a coherent set of actions is created. Recently, Glenberg and colleagues provided some evidence for the simulation of emotions in sentence comprehension (Havas, Glenberg, & Rinck , in press; see Glenberg, this volume). Motivation for this research was the hypothesis that if the comprehension of sentences with emotional meaning requires the partial reenactment of emotional bodily states, then the simulation of congruent (or incongruent) emotions should facilitate (or inhibit) language comprehension. Participants had to judge whether the sentences described a pleasant or an unpleasant event while holding a pen between the teeth (again, to induce smiling) or between the lips (to induce frowning). Reading times for understanding sentences describing pleasant events were faster when participants were smiling than when they were frowning. Those that described unpleasant events were understood faster when participants were frowning than when they were smiling. The same effect was observed in a second experiment in which participants had to evaluate if the sentences were easy or difficult to understand. This research dovetails with other studies on comprehension of non-emotional language that have repeatedly demonstrated the role of embodied information (Glenberg, this volume; Zwaan, 2004).

A-Head Summary, Open Issues, and Future Directions

In this chapter, we argued that theories of embodied cognition offer a fruitful approach to the processing of emotional information. We started by highlighting the weaknesses of symbolic models that reduce emotion processing to operations within an amodal semantic network. As an alternative account, we proposed that emotion processing is grounded in modality-specific systems, in which conceptual operations involve the partial reactivation or even recreation (simulation) of the actual emotion experience. We then reviewed supporting evidence from the literature on emotion perception, learning, and comprehension. Importantly, several of the studies suggest a causal rather than correlational relationship between embodiment and the processing of emotion. Our understanding of this relationship has also grown to be more sophisticated, with researchers now appreciating that simulation is a dynamic, goal-dependent processes, and that the exact impact of the particular sensorimotor input depends on situated conceptualizations. There also has been remarkable progress in understanding the neural basis of embodiment and the specific peripheral and central mechanisms supporting processes of simulation. Finally, and perhaps most critically, the embodiment approach has been able to generate exciting and counterintuitive predictions across a variety of areas in psychology and neuroscience, including affective perception, influence, social functioning, and language comprehension.

Of course, open issues remain. One theoretical challenge for the embodiment account in general, not only of emotion, is the representation and processing of abstract information. For example, how do people understand social concepts, such as status, legal concepts, such as eminent domain, or logical concepts, such as recursion? There are some promising attempts to solve this issue (Barsalou, 2003), even for such abstract domains as mathematics, though some of these solutions assume fairly powerful abilities to process metaphorical information (Lakoff & Núñez, 2000). A similar challenge applies to emotion concepts. For example, how do people understand the differences between shame, embarrassment, and guilt? Such understanding certainly involves the ability to simulate a relevant experience, but also requires the ability to connect the simulation to a more abstract knowledge about respective eliciting conditions and consequences (e.g., understanding that shame and guilt, but not necessarily embarrassment, involve norm violation, and that guilt, but not shame, implies recognition of responsibility). Recently, in our laboratories we have begun to explore the idea that depending on their current goal, people represent an emotional concept (e.g., anger) in more modal or amodal fashion, and thus engage in different amount of perceptual simulation. These differences in representation can then change how the concept is used to interpret novel behaviors. For example, the activation of a modal, rather than amodal, representation of anger should invite different inferences about the causes of a target's violent behavior, perhaps leading to different judgments of responsibility.

Another challenge for emotional embodiment theory is clarifying the difference between emotion and non-emotion concepts. That is, embodiment effects have been shown in a variety of modalities, including the motor system (Tucker & Ellis, 1998), visual, auditory, and gustatory system (Barsalou, this volume), so a legitimate question is whether there is anything unique about emotion concepts. One difference is that emotion concepts recruit a unique modality – internal representation of bodily state – and are tightly connected to motivation. A related difference is that emotion concepts organize information across modalities according to principles of subjective value, rather than relation to the objective external world (see also Barrett, this volume). Finally, emotion concepts have a unique function and power in cognitive processing (e.g., they can prioritize processing according to the perceivers' internal goals, interrupt ongoing processing streams, and so on). In any case, exploring the differences between the embodiment of emotional and non-emotional concepts offers an exciting direction for future research.

Further, now that many emotion embodiment effects have been demonstrated, it is time to develop systematic models of their boundary conditions. For example, as we have discussed, there are now several demonstrations that peripheral manipulations of facial mimicry can influence emotion perception and judgment. However, there is little research directly contrasting inhibitory effects, such as impairment in the detection of happiness observed by Oberman et al. (2007) and

Niedenthal et al. (2001) versus facilitatory effects, such as the enhancement of cartoon judgments observed by Strack et al. (1988). One possible explanation is that forcing a participant’s face into a permanent smile (i.e., creating a constant level of muscular feedback) or immobilizing the face (i.e., removing muscular feedback) lowers a participant’s sensitivity to the presence versus absence of happy expressions by cutting out the differential information from the muscles (see left and middle panels of Figure 11.2). On the other hand, forming a half-smile (see right panels of Figure 11.2) creates a positivity bias – tendency toward happy responding toward ambiguous stimuli. Incidentally, some related cognitive research reports that similar embodiment manipulations can have both facilitatory and inhibitory effects, with subtle differences in timing and task requirements leading either to resource priming or resource competition (Reed & Farah, 1995; Reed & McGoldrick, 2007).

Though challenges remain, it is clear that recent years have seen remarkable progress in understanding the nature of emotion. Emotion is no longer ignored by psychology and cognitive science but, in fact, is one of the most studied topics. The embodiment account has inspired and is continuing to generate research that advances the understanding of emotional perception, learning, comprehension, attitudes, prejudice, empathy, and even certain behavioral deficits. So even if we restrict our judgment of the embodiment account of emotion purely to its generative value, it has served us extremely well and should continue to do so in the foreseeable future.

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A-Head Figure Captions

Figure 11.1. A schematic illustration of activation patterns in visual (left), affective (middle), and somatosensory (top) systems upon perception of a bear. Later, thinking about the bear reactivates parts of the original patterns.

Figure 11.2. Different ways in which facial expressions relevant to happiness have been manipulated in behavioral experiments. From left to right, the authors demonstrate manipulations used by Niedenthal et al. (2001), Oberman, et al., (2007) and Strack et al. (1988). Note that the sideways pen manipulations (left and middle) prevent participants from differential responding using facial muscles, whereas the straight pen manipulation (right) allows additional smiling.

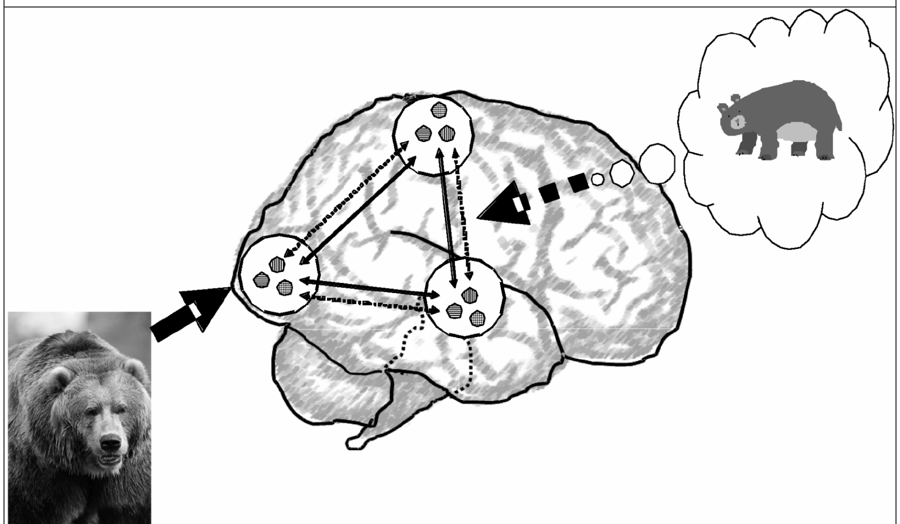

FIGURE 11-01. A schematic illustration of activation patterns in visual (left), affective (middle), and somatosensory (top) systems upon perception of a bear. Later, thinking about the bear reactivates parts of the original patterns.

FIGURE 11-02. Different ways in which facial expressions relevant to happiness have been manipulated in behavioral experiments. From left to right, the present authors demonstrate manipulations used by Niedenthal et al. (2001), Oberman et al, in press, and Strack et al (1988). Note that the sideways pen manipulations (left and middle) prevent participants from differential responding using facial muscles, whereas the straight pen manipulation (right) allows additional smiling.