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ORIGINAL PAPER

# The emotive neuroscience of embodiment

**Tom F. Price · Carly K. Peterson · Eddie Harmon-Jones**

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**Abstract** Embodiment in psychological research and theory often refers to the idea that the body plays a crucial role in emotive, motivational, and cognitive processes. We review past and recent embodiment research, focusing on neuroscientific work. In particular, we review a growing body of evidence supporting the notion that manipulated facial expressions, hand contractions, and changes in physical posture influence physiological activity related to approach motivation or the inclination to move toward a stimulus. Several other perspectives are also considered, such as work related to facial-feedback theories of emotion, theories of grounded or embodied cognition, and mirror neuron research. Ultimately, we conclude that bi-directionality may exist between certain bodily movements and other components of approach- or avoidance-related emotions. Avenues for new research are considered given these implications.

**Keywords** Embodiment · Emotion · Motivation · Neuroscience

## Introduction

The scientific study of emotion and motivation is no stranger to embodiment. Indeed, the English word "emotion" is derived from the French word "émouvoir," which is based on the Latin word "emovere," where e- (variant of ex-) means 'out' and movere means 'move'. The term "motivation" is also derived from "movere." Thus, the terms emotion and motivation, in lay definitions, are rooted in terms that mean to move and the body rarely acts without movement. We run toward dear friends we have not seen in a long while and run away from things we fear. We grimace at the sight of something disgusting, and grin from ear-to-ear when we experience something extremely pleasant.

In this review, we discuss work indicating that bodily manipulations influence self-reported emotions and motivational processes. Then, we review research attempting to uncover physiological mechanisms underlying these behavioral effects. Finally, we review research linking bodily movements with approach or avoidance inclinations. Based on this research, we arrive at three conclusions: (1) manipulated facial expressions, hand contractions, as well as body postures influence relative left frontal cortical activity, a physiological correlate of approach motivation; (2) postural manipulations also influence physiological correlates of motivated attention, sub-cortically driven processes, and neuroendocrine levels; and (3) manipulated postures may prompt approach or avoidance behaviors.

## Bodily manipulations influence self-reported emotions and motivational processes

For over a century, scientists have been curious about outward displays of emotion. For example, the innateness and universality of certain facial expressions was recognized by Charles Darwin (1872). The idea that these expressions share inherent connections with emotions was proposed by William James (1890). Building upon these earlier theoretical arguments, the facial feedback hypothesis (Laird 1974) suggests that manipulated facial expressions of emotion cause self-reported changes in emotions (for a review of the classical theoretical arguments, see

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67 Adelmann and Zajonc 1989). Support for this hypothesis
68 has traditionally come from experiments that manipulate
69 participants' facial expressions with instructions or non-
70 obtrusive methods, such as having them hold a pen
71 between their teeth to facilitate smiling. Afterwards, par-
72 ticipants are often presented with a stimulus and asked to
73 give their self-reported emotional reactions. For example,
74 facilitating as compared to inhibiting smiling has been
75 found to increase self-reported positive reactions toward
76 cartoons (Strack et al. 1988). More recent experiments
77 have also demonstrated that inhibiting muscle movements
78 interferes with emotional processes. For example, dener-
79 vating facial muscles with botulinum toxin-A (BTX) has
80 been found to slow the reading of emotional passages
81 (Havas et al. 2010) and decrease amygdala activation
82 during intentional facial mimicry (Hennenlotter et al.
83 2009).

84 Research on this topic, however, has come to involve
85 many other bodily manipulations aside from facial
86 expressions. For example, past work has indicated that
87 nodding one's head up and down, as compared to shaking
88 one's head from side to side, leads to the formation of
89 positive attitudes toward neutral objects (Tom et al. 1991)
90 as well as more agreement with persuasive messages
91 (Wells and Petty 1980). Furthermore, arm movements
92 associated with the acquisition of desired stimuli, flexion,
93 relative to arm movements not associated with such
94 actions, extension, have been found to influence judgments
95 of neutral ideographs; participants judged these ideographs
96 more positively when they engaged in arm flexion relative
97 to arm extension poses (Cacioppo et al. 1993).[1]

98 Researchers have also found that these arm movements
99 are associated with motivational responses, such as the
100 urge to approach or avoid a stimulus. Arm flexion, relative
101 to arm extension, has been associated with more of an
102 approach-motivated response (Rotteveel and Phaf 2004).
103 For example, an experiment by Van Peer et al. (2007)
104 demonstrated that administering cortisol versus placebo to
105 highly anxious individuals influences their behavioral and
106 physiological responses to threatening angry-face stimuli.
107 In this experiment, participants with high and low trait
108 anxiety were presented with approach-oriented happy and
109 threat-oriented angry faces. Participants were asked to
110 indicate, as quickly and accurately as possible, whether a
111 presented face was happy or angry. Participants made these
112 responses by pressing one of three buttons, which were
113 arranged vertically; the top button was physically further
114 away from the participant as compared to the second. The
115 bottom button was physically closer to the participant.
116 Thus, when pressing the top button, participants made an
117 arm-flexion pose indicative of pulling something toward
118 them (approach). When pressing the bottom button, how-
119 ever, participants made an arm-extension pose indicative of
120 pushing something away (avoidance). In addition, partici-
121 pants were either told congruent (press the top button to
122 indicate a happy face and the bottom to indicate an angry
123 face) or incongruent (the reverse) instructions for the task.

124 Results indicated that participants were faster to respond
125 to happy faces with approach as compared to avoidant arm
126 movements. In addition, participants were faster to respond
127 to angry-threat faces with avoidant as compared to approach
128 arm movements. Highly anxious participants given cortisol
129 versus placebo, additionally, were slower to respond to
130 angry faces with approach as compared to avoidant move-
131 ments. These results suggest that a combination of trait and
132 state dependent factors influence how individuals physi-
133 cally react to emotional stimuli. Motivational direction
134 (approach or avoidance) also underlies these types of
135 effects, which have been conceptually replicated in addi-
136 tional experiments (van Peer et al. 2009, 2010).

137 Other bodily manipulations have also been found to
138 influence motivational processes. For example, a series of
139 experiments by Riskind and Gotay (1982) examined if
140 different postures influence motivational behaviors. In two
141 experiments, participants were assigned, in an ostensibly
142 unrelated biofeedback study, to adopt a slumped/helpless
143 posture or an upright/expansive posture. Then, participants
144 completed a series of insolvable puzzle tasks measuring
145 task persistence. Results indicated that participants who
146 adopted the slumped posture persisted less on the insolv-
147 able tasks as compared to participants who adopted the
148 upright posture.[2]

## 149 Manipulated facial expressions influence physiological 150 correlates of emotion

151 Scientists have proposed that, in part, the mechanism that
152 allows facial expressions to influence self-reported emo-
153 tions has to do with how the movement of facial muscles
154 influences other physiological processes (Zajonc et al.
155 1989). Consider the downward movement of the corrugator
156 supercilii muscle (furrows the brow) that is often associ-
157 ated with negative expressions (e.g., anger, disgust).
158 Zajonc et al. (1989) theorized that downward movement of

1FL01 [1] Other research has indicated that the context (positive or negative)
1FL02 of the presented stimuli can influence these arm-flexion and arm-
1FL03 extension effects (Centerbar and Clore 2006). Furthermore, the
1FL04 meaning attributed to these types of motor actions is also an important
1FL05 factor (Eder and Klauer 2009).

2FL01 [2] Riskind (1984) went on to clarify that situational contexts (success
2FL02 or failure) can influence these posture effects as well. Context, it
2FL03 should be noted, is an important thing to consider with any bodily
2FL04 manipulation effect.

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the corrugator muscle might reduce air-intake into the nasal cavity, cause more mouth as compared to nose breathing, and raise the temperature of blood entering the brain. Furthermore, Zajonc et al. (1989) hypothesized that a rise in facial temperature due to downward corrugator activity would be associated with the experience of negative affect. Contrastingly, contraction of the zygomatic major muscle (moves the cheeks up and back to form a smile) was theorized to open the nasal cavity, improve nose breathing, and reduce the temperature of blood entering the brain. It was also hypothesized that a reduction in facial temperature due to contraction of the zygomatic muscle would be associated with the experience of positive affect. These predictions were based on the notion that thermoregulation of brain areas such as the hypothalamus could influence hedonic states and associated neurotransmitter (e.g., norepinephrine) activity.

In order to test these ideas, Zajonc et al. (1989) had participants recite neutral stories containing a high frequency of the German letter ü, or neutral stories without words containing this letter (Study 1). Reciting the German letter ü contracts the corrugator muscle downward while extending the zygomatic major muscle. Ü stories, therefore, were predicted to be less liked and raise facial temperature more so than the no- ü stories. Results were in line with these predictions. Several other important findings were uncovered: story comprehension was not necessary as these effects were observed in both German and non-German speaking participants (Study 2), simply repeating the letter ü relative to a control letter led to similar effects (Study 3), and repeating vowels (e, ah) that contracted the zygomatic muscle led to a reduction in facial temperature and a greater liking for the recitation of these vowels (Study 4). Finally, participants enjoyed the sensation of cool air entering their nasal cavities', thus reducing overall facial temperature (Study 5). Subsequent research directly manipulated hypothalamic cooling versus heating and found that cooling caused more feeding in rats but not more hedonic reactions to taste. These results led the researchers to conclude that hypothalamic cooling may increase the attractiveness of the food without modulating taste pleasure (Berridge and Zajonc 1991).

Thus, facial expressions might influence thermoregulation of the hypothalamus which, subsequently, can influence an organism's motivational state. Other researchers, however, have theorized that moving the face in certain ways leads to innate, parallel physiological changes in heart rate, skin conductance, and other measures of autonomic nervous system (ANS) activity (Ekman et al. 1983). These physiological changes, therefore, might influence self-reported emotions as well.

To test this idea, Levenson et al. (1990) had participants make several emotional facial expressions while their heart rate, skin conductance, finger temperature, and forearm muscle tension were recorded. Participants self-reported emotions' were also recorded. Results across several experiments indicated that patterns of heart rate and finger temperature were specific to manipulated facial expressions, in particular between negative expressions of anger, disgust, and fear. For example, heart rate acceleration was larger for anger as compared to disgust. In addition, heart rate acceleration was larger for fear as compared to disgust. Heart rate acceleration was also larger for sadness as compared to disgust. Lastly, finger temperature increased more for anger as compared to fear. The fact that different expressions required different muscle movements could not account for these differences in ANS activity; autonomic distinctions among emotions did not parallel the number of muscles used to create each emotional expression. In addition, participants reported experiencing the target emotion after making the associated facial expression. Furthermore, these differences in ANS activity and self-reported emotions were more pronounced when participants produced facial configurations that closely resembled the associated emotional expressions. Several other important findings were uncovered: similar results were seen for theater actors (Study 1), college students (Study 2), and participants from the general population (Study 3). Results were also similar when participants could see their facial expressions (Study 1) and when they could not see their expressions (Study 2). Studies that followed these original studies, which were conducted with American samples, revealed that many of these findings replicated with men of the Minangkabau from West Sumatra (Levenson et al. 1992).

These results, therefore, suggest that facial expressions might have direct effects on ANS activity. One might question how the body transforms ANS signals (or temperature changes resulting from facial muscle movements) into subjective emotional states, however. In other words, how do we perceive the feelings from our bodies? Researchers have proposed that projections from the brainstem (which carries sympathetic and parasympathetic bodily signals) to nuclei within the anterior insular cortex and the anterior cingulate cortex are likely involved in this process (for a review, see Craig 2002). Several studies have demonstrated that subjective ratings of temperature (Craig et al. 2000) and pain (Kong et al. 2006) correlates with cortical activity in the anterior insular cortex, whereas the objective intensity of these bodily signals is associated with more posterior activity of this brain region. These results suggest that the anterior insular cortex might be the primary neural mechanism for the integration of bodily signals and subjective emotional experiences (Craig 2009). The somatosensory cortex, furthermore, has also been implicated in these processes (Damasio 1993).

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265 As we have alluded to, however, emotional states are 266 also associated with motivational urges to approach or 267 avoid environmental stimuli. Below, we review research 268 testing whether bodily manipulations influence asymmetric 269 frontal cortical activity, a pattern of activity that relates to 270 the motivational direction, approach or withdrawal, of 271 emotional states.

## 272 Bodily manipulations influence physiological correlates 273 of approach motivation

274 Past observational studies indicated that lesions to the right 275 orbitofrontal cortex are often associated with the onset of 276 mania symptoms (Starkstein et al. 1988). Damage to the 277 left dorsolateral prefrontal cortex, on the other hand, has 278 been associated with depression symptoms (Turner et al. 279 2007). In addition, asymmetric frontal cortical activity 280 measured with electroencephalographic (EEG) neuroim-281 aging techniques has been associated with the motivational 282 direction of emotions (Harmon-Jones 2003; Harmon-Jones 283 et al. 2010). Relative right frontal activity has been asso-284 ciated with withdrawal-oriented emotions, such as fear and 285 disgust (Davidson et al. 1990; Jones and Fox 1992). Rel-286 ative left frontal activity, on the other hand, has been 287 associated with approach-oriented emotions, such as joy 288 (Davidson and Fox 1982) and anger (Harmon-Jones 2004; 289 Harmon-Jones and Allen 1998; Harmon-Jones and Sigel-290 man 2001; Harmon-Jones et al. 2004; Verona et al. 2009). 291 Approach and withdrawal states have also been found to 292 activate left and right prefrontal cortices as measured with 293 functional magnetic resonance imaging (Berkman and 294 Lieberman 2010). Research utilizing repetitive transcranial 295 magnetic stimulation (rTMS) has also indicated that elec-296 trically deactivating the left pre-frontal cortex reduces 297 participants' approach-oriented attention to angry faces 298 (van Honk and Schutter 2006). Work has also been con-299 ducted with bodily manipulations to further demonstrate 300 that asymmetric frontal cortical activity relates to the 301 motivational direction (approach or withdrawal) of emo-302 tional states, as we review below.

### 303 Facial expressions

304 Manipulated facial expressions, for example, influence 305 relative left frontal cortical activity. In one of the first 306 experiments to demonstrate this, Ekman and Davidson 307 (1993) instructed participants to form one of two smiles 308 during an EEG recording session. Genuine smiles often 309 involve Duchenne's marker, that is, movement of zygo-310 matic major (cheek) but also orbicularis oculi (underneath 311 the eye) muscles. Less genuine smiles, however, often 312 involve movement of zygomatic muscles only (Ekman 313 et al. 1988). Ekman and Davidson (1993) found that when 314 participants were instructed to form genuine smiles with 315 Duchenne's marker, as compared to less genuine smiles 316 without this marker, they had greater relative left frontal 317 cortical activity.

318 More recent experiments have also investigated how 319 manipulated facial expressions influence relative left 320 frontal cortical activity. For example, facial expressions 321 indicative of anger and joy, approach-oriented emotions, 322 cause greater relative left frontal cortical activity, whereas 323 facial expressions indicative of fear and disgust, with-324 drawal-oriented emotions, cause less relative left frontal 325 activity (Coan et al. 2001).

### 326 Unilateral muscle contractions

327 Researchers have suggested that there are close connec-328 tions between the motor and frontal cortex (Harmon-Jones 329 2006; Schiff and Lamon 1989, 1994). Thus, voluntarily 330 moving the body and increasing cortical activity in the 331 motor cortex may, through spreading of activation, 332 increase activity in frontal areas. Furthermore, given that 333 sensory and motor pathways are crossed (Rinn 1984), 334 unilaterally moving the right side of the body may lead to 335 an increase in left hemispheric activation, whereas moving 336 the left side of the body may lead to an increase in right 337 hemispheric activation.

338 Based on these ideas, Harmon-Jones (2006) demon-339 strated that left and right hand contractions influence right 340 and left hemispheric activation in the frontal cortex, 341 respectively. In this study, right-handed participants 342 squeezed a ball with either their right or left hand for two 343 45s periods and again while they listened to a mildly 344 positive, approach-oriented pilot radio broadcast concern-345 ing apartment living options for the participants. As pre-346 dicted, right-hand contractions compared to left-hand 347 contractions caused greater relative left frontal activation. 348 Similar effects also occurred over the motor cortex. Fur-349 thermore, right-hand contractions caused greater self-350 reported approach affect as indexed by scores on the 351 Positive and Negative Affect Schedule (PANAS; Watson 352 et al. 1988). Thus, manipulating regional brain activity 353 with hand contractions has been found to influence self-354 reported emotions as well.

355 Extending this earlier work, Peterson et al. (2008b) 356 demonstrated that unilateral hand contractions influence 357 behavioral responses. In this experiment, right-handed 358 participants wrote an essay on a controversial topic (e.g., 359 war in Iraq). Next, they received insulting feedback on 360 their essays from another participant. In actuality, every 361 participant received the same insulting feedback; the other 362 participant did not actually exist. However, prior to 363 receiving feedback, participants squeezed a ball with either

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their right or left hand in order to increase relative left or right frontal cortical activity, respectively. Then, participants were told they would play a reaction time game against the other participant who had given them insulting feedback. In this modified version of Taylor's (1966) aggression game, participants were able to aggress against the other player with noise blasts. Results indicated that participants who made right-hand contractions gave longer and louder noise blasts during the reaction time game compared to participants who made left-hand contractions. Also, these aggressive behavioral responses were correlated with greater relative left frontal cortical activation in the right-hand contraction condition. Further analyses suggested that right- and left-hand contractions differentially affected coherence between the motor cortex and other areas of the brain. Right-hand contractions caused more coherence between the motor cortex and frontal regions, whereas left-hand contractions caused greater coherence between the motor cortex and posterior regions.

Thus, unilateral movements of the body can influence asymmetric frontal brain activity as well as approach behavior; in the previous experiment, right-hand contractions and greater relative left frontal cortical activity led to more aggressive, approach-oriented responses in the form of longer and louder noise blasts. These findings clarify one way in which bodily manipulations might influence motivational processes.

## Manipulations of whole body posture

Past work has shown that whole-body manipulations also change motivational processes, such as task persistence (e.g., Riskind and Gotay 1982). The effects of posture, whole-body manipulations, may also play a significant role in neuroimaging studies investigating emotive processes. Some, but not all, functional magnetic resonance imaging (fMRI) studies have failed to find a connection between anger and relative left frontal activity (Tomarken and Zald 2009). In contrast, several EEG and rTMS studies have found an association between anger and relative left frontal activity (Carver and Harmon-Jones 2009; van Honk and Schutter 2006). One of the biggest differences between these two neuroimaging techniques is that fMRI scanning procedures require participants to be in a supine or reclining body posture. Participants normally sit upright for EEG and rTMS studies. Thus, the supine posture required by most current fMRI scanners may reduce, but not necessarily eliminate, the relative left frontal cortical activity associated with approach motivation.

To test whether reclining postures reduce relative left frontal cortical activation associated with approach-motivated anger, Harmon-Jones and Peterson (2009) had participants write an essay on a controversial topic under the guise that another ostensible participant would evaluate it. Prior to receiving feedback, participants either remained upright in their chair or reclined backward. All participants in the reclining condition and half the participants in the upright condition received insulting feedback. The remaining half of the participants in the upright condition received neutral feedback. Results replicated previous research in that greater relative left frontal cortical activity was found in the insult-upright condition compared to the neutral-upright condition. The insult-upright condition also produced greater relative left frontal cortical activity than did the insult-reclined condition.

Reclining backward relative to sitting upright, therefore, might reduce brain activity associated with approach-motivated anger. As previously stated, however, simply manipulating the face without an emotion eliciting stimulus can influence relative left frontal cortical activity (Coan et al. 2001). In order to extend this work on body posture, Price and Harmon-Jones (2010) created multiple postures hypothesized to be associated with different levels of approach motivation. Reclining backward was hypothesized to be associated with low approach motivation; reclining often occurs following the acquisition of a desired goal, such as after eating a delicious meal. Leaning forward was hypothesized to be associated with higher approach motivation; leaning forward often occurs during goal acquisition, such as leaning towards a delicious meal. Finally, sitting upright was hypothesized to be associated with a level of approach motivation somewhere between reclining backward and leaning forward. In this experiment, participants assumed one of these three postures while EEG was recorded for 1 min. Results indicated that reclining backward caused participants to have less relative left frontal cortical activity as compared to leaning forward. Sitting upright fell between these two conditions, as predicted.

In a follow up experiment, Harmon-Jones et al. (2011) examined if changes in physical posture would influence relative left frontal activity to appetitive emotional stimuli. Participants in this experiment leaned forward or reclined backward while viewing appetitive dessert and neutral rock pictures used in prior investigations of approach motivation (Gable and Harmon-Jones 2008). Consistent with the hypothesis that leaning forward increases approach motivation, leaning participants had greater relative left frontal activity to dessert as compared to neutral rock pictures, whereas reclining participants did not demonstrate this difference. Thus, posture influenced relative left frontal cortical activity to appetitive pictures, but not neutral pictures.

One might question the lack of an effect of body posture on responses to neutral pictures, because these postures have been found to influence relative left frontal cortical



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activity during a resting, baseline or "neutral" state (Price and Harmon-Jones 2010). One interpretation is that in a resting, baseline state where there are no other obvious stimuli to process, such as neutral pictures, the posture itself might have a stronger influence on asymmetric frontal cortical activity. When a neutral stimulus is presented, however, the neutral stimulus might override the effect of posture. Thus, the postural effects observed in a resting, baseline state might be subtle.

Given these findings, simply leaning forward might increase a persons' inclination to move toward something desirable, but not toward something neutral. In each of the experiments reviewed in this section, however, the physiological measure was always relative left frontal activity. In the next section, we review recent research demonstrating that postural manipulations also influence neural activity related to motivated attention and reflexive responses to emotional stimuli.

## Postural manipulations influence late positive potentials to emotional stimuli

The late positive potential (LPP), an event-related brain potential (ERP) starting approximately 300 ms after stimulus onset and lasting for several 100 ms, has been associated with motivated attention (for a review, see Hajcak et al. 2011). For example, LPPs are larger to erotic images compared to positive pictures less associated with basic motivational impulses, such as exciting sports scenes (Briggs and Martin 2009). In addition, mothers have larger LPPs to pictures of their own children's faces relative to pictures of familiar children, unfamiliar children, familiar adults, and unfamiliar adults (Grasso et al. 2009). Individuals who are currently in love with another person, furthermore, evince larger LPPs to pictures of that person relative to pictures of a friend or a beautiful but unknown person of the opposite sex (Langeslag et al. 2007). LPPs are also larger to scenes of mutilation and threat compared to scenes of contamination and loss (Schupp et al. 2004). Functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) studies have revealed multiple neural generators of the LPP, such as the occipito-temporal and parietal cortex (Keil et al. 2002; Sabatinelli et al. 2007).

To examine if postural manipulations influence this physiological correlate of motivated attention to emotional stimuli, Price et al. (2011) manipulated participants' posture while they viewed highly arousing positive (erotic images) and neutral pictures (images of persons). Participants viewed these pictures while leaning and reclining in a counterbalanced within-subjects design. Results indicated that leaning forward relative to reclining backward caused participants to have larger LPPs to the arousing positive pictures. On the other hand, posture did not influence LPPs to neutral stimuli.

## Postural manipulations influence startle responses to emotional stimuli

In addition, Price et al. (2011) found that these postural manipulations also influenced the sub-cortically driven startle reflex. The magnitude of the startle eyeblink reflex is another physiological measure reliably modulated by the emotive significance of stimuli (Bradley et al. 2001; Lang et al. 1990; Vrana et al. 1988). This reflex causes the orbicularis oculi muscle around the eye to contract to sudden aversive events, protecting the eye from potential harm. The startle response is typically induced by loud (100 db) bursts of white noise with instantaneous rise time (Blumenthal et al. 2005). When these startle probes are presented during the viewing of affective pictures, the magnitude of startle eyeblinks is potentiated by arousing negative pictures and attenuated by arousing positive pictures. This effect is explained by the response-matching hypothesis, which postulates that the startle eyeblink is a defensive reaction that is responsive to the presence of affective cues. Aversive cues, such as arousing negative pictures, exacerbate the congruent avoidant motivation elicited by the startling sound and lead to larger startle blinks. Appetitive cues, such as arousing positive pictures, contrast the avoidant motivation of the startling sound and these inconsistent motivational states lead to smaller startle blinks. Smaller startle responses, therefore, are considered more appetitive responses. Animal models, furthermore, have clarified the neural pathways involved in the acoustically-elicited startle response and found that nuclei within the amygdala play a critical role in the affective modulation of this response (Davis 2006).

Consistent with the response-matching hypothesis, the startle response has been linked with a persons' motivational disposition. High trait behavioral approach system (BAS) sensitivity, measured with Carver and White's (1994) scale, is correlated with smaller startle responses during arousing positive pictures (Hawk and Kowmas 2003). Furthermore, trait emotions associated with approach motivation (e.g., anger, enjoyment, surprise) are correlated with smaller startle responses during arousing positive pictures (Amodio and Harmon-Jones 2011). In addition, positive approach-motivated pictures (e.g., erotic images) are associated with smaller startle responses than positive pictures lower in basic motivational impulses (e.g., sports scenes; Gard et al. 2007).

Price et al. (2011) examined if postures varying in approach motivation would causally influence startle

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responses to arousing positive stimuli. In this experiment, participants leaned forward or reclined while viewing erotic and neutral people stimuli. Startle probes were presented at 3.5 or 4 s after picture onset for 60% of the erotic and neutral pictures within a condition. Replicating much past research, results indicated that picture type influenced startle eyeblink responses, with startle eyeblink responses being smaller during the viewing of arousing positive pictures than during the viewing of neutral pictures. In a novel extension of past research, results indicated that leaning forward compared with reclining caused even smaller startle responses during arousing positive pictures. Posture did not influence startle responses to motivationally less relevant neutral stimuli. Converging evidence, therefore, supports the idea that leaning forward is associated with heightened approach motivation relative to reclining backward, which may be associated with less approach motivation.

## Postural manipulations influence neuroendocrine levels

Researchers have also examined the effects of postural manipulations on feelings of power and neuroendocrine (e.g., testosterone and cortisol) changes (Carney et al. 2010). In this experiment, participants were randomly assigned to display two low-power or two high-power body postures for 1 min each. Low-power body postures contained contractive positions with closed limbs (e.g., standing and sitting in slumped positions), whereas the high-power body postures were expansive positions with open limbs (e.g., sitting with feet up and standing widely over a table). Saliva samples were collected 10 min before, and 17 min after the body posture manipulation. As predicted, high-power posers had an increase in testosterone compared to low-power posers. High-power posers also reported feeling more "powerful" and "in charge" and took greater risks in a gambling task compared to low-power posers. Furthermore, contractive low power positions resulted in increases in cortisol, whereas the high power positions resulted in decreases in cortisol.

## Theories of grounded or embodied cognition and emotion

In this section, we attempt to meld some of our findings with recent research investigating theories of grounded cognition. It is important to note, however, that bodily manipulation research is different from research directly supporting theories of grounded cognition. Each of these lines of inquiry may nevertheless complement one another.

Theories of grounded or embodied cognition rely on the non-dualist assumption that cognitions (e.g., memories) are specific types of neural activations. More specifically, when an object is encountered, people acquire sensory information (e.g., smells, sounds, tactile sensations) about it that presumably gets stored in sensorimotor areas within the brain. When the object is no longer present and the person thinks about it, these sensory signals are re-experienced or partially activated because they were stored for later use (Barsalou 1999). Mental imagery is a common example of how cognitions reflect the re-activation of modality (e.g., tactile, auditory, but in this case especially visual) specific sensations (Barsalou 2008).

Conceptual knowledge about emotion is also thought to lead to a partial activation of modality specific sensations previously associated with relevant emotional experiences. One interesting prediction from theories of grounded cognition is that conceptual knowledge can also influence more overt changes in behavior, such as outward bodily changes (Barsalou et al. 2003). Thus, generating information about emotions may lead to outward changes in bodily states. Consistent with the idea that failure and disappointment are often associated with a slumped body posture (e.g., Riskind and Gotay 1982), research has demonstrated that generating disappointment-related words causes participants to stoop down more so than generating pride-related words (Oosterwijk et al. 2009). In this experiment, participants verbally produced single words or phrases related to failure/disappointment and success/pride. Neutral conditions (e.g., generating information about kitchens) were also included before each of the experimental conditions. Each condition lasted 90 s and was counterbalanced in a within-subjects design. Changes in physical posture were recorded every 2 s during a specific condition. Results indicated that participants decreased their height along a vertical dimension more while generating disappointment-related as compared to pride-related words. Thus, generating conceptual information about disappointment led to the partial activation of the associated slumped or defeated body posture.

The research reviewed with posture and frontal cortical asymmetry demonstrates that manipulating a persons' posture influences approach-related brain activity. Thus, bodily manipulation research and research investigating theories of grounded cognition are distinct from one another. However, they may be similar in that they represent two-sides of the same process. It remains to be seen if postural manipulations (e.g., leaning, reclining) influence the extent to which a person can generate approach- or avoidance-related conceptual knowledge; the research reviewed here would support this prediction.

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## The mirror neuron system

But how do sensory signals get stored in the brain for later use? One possible neural mechanism is the mirror neuron system. Numerous studies have indicated that non-human primates have similar patterns of brain activity while performing certain actions and seeing others performing the same actions (Rizzolatti and Craighero 2004). This process involves the firing of mirror neurons, that is, cells within a complex frontoparietal network that enable the integration of sensory signals and motor actions (Iacoboni and Dapretto 2006). These researchers have also devised neural models to explain several forms of imitation-based learning in humans. It may very well be that seeing, feeling, and performing certain actions are related processes. The initial neural mechanism that makes this possible, furthermore, may be imitation-based learning established via the mirror neuron system.

One interesting theory is that the mirror neuron system is associated with far more than simple mimicry. Some work has suggested that mirror neurons not only code actions, but also the intentions of those actions in humans (Iacoboni and Dapretto 2006) and non-human primates (Rizzolatti et al. 2001). For example, seeing someone grasp a cup by the handle to drink, as compared to grasping it by the rim to clean, causes greater inferior frontal mirror neuron activity (Iacoboni et al. 2005). Other research, in addition, has supported the notion that the mirror neuron system is not only associated with motor-mimicry; it might also be responsive to the affective connotations of related actions. For example, individuals have similar patterns of facial muscle movements while unconsciously viewing emotional facial expressions (Dimberg et al. 2000) as well as emotional postures (Tamietto et al. 2009). The mirror neuron system, therefore, might be similarly activated by positive facial expressions as well as postures indicative of positive emotional states. Based on this research, it would be interesting to further investigate if the mirror neuron system is capable of coding the motivational direction (approach or withdrawal) of observed actions as well.

## Revisiting the idea "what is bodily feedback?"

Adelmann and Zajonc (1989) asked this question—"What is bodily feedback?"—over two decades ago. They later tested that facial expressions influence facial temperature alongside self-reported emotions. They theorized that these temperature changes could influence the subsequent release of different neurotransmitters involved in emotional experiences (Zajonc et al. 1989). As the authors stated, however, this is unlikely the sole physiological mechanism responsible for facial-feedback effects. Additionally, this line of work did not investigate other bodily manipulations. The evidence reviewed here suggests that bodily movements such as facial expressions (Coan et al. 2001; Ekman and Davidson 1993), hand movements (Harmon-Jones 2006; Peterson et al. 2008a), and changes in physical posture (Harmon-Jones and Peterson 2009; Harmon-Jones et al. 2011; Price and Harmon-Jones 2010) indicative of approach or avoidance influence asymmetric frontal brain activations associated with these motivational inclinations. Furthermore, changes in physical posture also influence sub-cortically driven emotive processes (Price et al. 2011) as well as changes in neuroendocrine levels (Cuddy et al. 2010). Thus, these types of whole bodily manipulations likely influence multiple emotion-related physiological processes occurring throughout the brain and body.

A daunting task for future researchers, however, may not be looking for additional mechanisms but, rather, developing methods that study the integration of already known neural mechanisms associated with embodiment. We have suggested that there may be a relationship between seeing and performing actions with the body, as well as feeling certain ways. What is the relationship between the underlying neural mechanisms associated with these processes? More specifically, what is the relationship between mirror neuron, anterior insula, and somatosensory activity? Work examining this notion will, hopefully, provide an over-arching model that explains the neural connection between seeing, doing, and feeling.

## Conclusions

In short, due to the complexity of these processes, more work is necessary. EEG methodologies may assist in these endeavors. fMRI techniques may assist as well. It is important to remember, however, that current fMRI techniques have participants in a supine posture. This, in and of itself, is an embodiment manipulation that has been found to reduce (but not eliminate) approach motivation (Harmon-Jones and Peterson 2009; Harmon-Jones et al. 2011; Price and Harmon-Jones 2010; Price et al. 2011). Nevertheless, future researchers should consider the motivational consequences of these postures and other bodily manipulations. In doing so, more complete theories addressing the mind–body connection are likely to develop.

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