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Embodiment of Emotion Concepts

Paula M. Niedenthal
CNRS and University of Clermont-Ferrand, France

Piotr Winkielman
University of California, San Diego

Laurie Mondillon
University of Clermont-Ferrand, France

Nicolas Vermeulen
Catholic University of Louvain-la-Neuve

Theories of embodied cognition hold that higher cognitive processes operate on perceptual symbols and that concept use involves partial reactivations of the sensory-motor states that occur during experience with the world. On this view, the processing of emotion knowledge involves a (partial) reexperience of an emotion, but only when access to the sensory basis of emotion knowledge is required by the task. In 2 experiments, participants judged emotional and neutral concepts corresponding to concrete objects (Experiment 1) and abstract states (Experiment 2) while facial electromyographic activity was recorded from the cheek, brow, eye, and nose regions. Results of both studies show embodiment of specific emotions in an emotion-focused but not a perceptual-focused processing task on the same words. A follow up in Experiment 3, which blocked selective facial expressions, suggests a causal, rather than simply a correlational, role for embodiment in emotion word processing. Experiment 4, using a property generation task, provided support for the conclusion that emotions embodied in conceptual tasks are context-dependent situated simulations rather than associated emotional reactions. Implications for theories of embodied simulation and for emotion theories are discussed.

Keywords: embodiment, emotion, concepts, facial expression, electromyographic recording (EMG)

Individuals possess an enormous amount of implicit and explicit knowledge about emotions. Children and adults alike can explain when and why emotions occur (e.g., Boucher, 1983; Brandt & Boucher, 1986; Keltner & Haidt, 2003; Scherer, Wallbott, Matsumoto, & Kudoh, 1988; Tangney, 1992). They can also describe their own emotions in some detail, and the descriptions show important similarities across individuals (e.g., Branstätter, 1981; Feldmant, 1995a, 1995b; Russell & Barrett, 1999) and across some cultures (e.g., Russell, 1991; Russell, Lewicka, & Nitt, 1989). In addition, emotion knowledge, at least as expressed in the English language, seems to be structured in hierarchically organized, fuzzy categories (Fehr & Russell, 1984; Keltner & Haidt, 2003; Shaver, Schwartz, Kirson, & O'Connor, 1987). However, what is unclear, and constitutes the topic of the present research, is how exactly such knowledge is represented. In the present research, we ask the question: What is the nature of mental representations that individuals use when accessing their knowledge about emotion?

Extant Models of the Representation of Emotion

There is a single class of models in which the way in which emotion is represented has been made explicit: semantic network models of emotion (Bower, 1981; Ingram, 1984; Lang, 1984; Teasdale, 1983; see also Niedenthal, 2008, for a discussion of relevant models). The variations on this class of models propose that knowledge is represented in a semantic network in which the units of representation, called "nodes" or, alternatively, "concepts," "categories," "traces," or "processors," store and transform information in propositional form. Nodes are linked by pathways that reflect the strength of their semantic association (Collins & Quillian, 1969). A particular idea comes to mind when its node is activated above a critical threshold, which can occur through the spread of activation from neighboring nodes or through direct sensory stimulation.

The semantic network models of emotion all hold that emotions impose organizational structure on information stored in the semantic network. Each emotion or affective state is represented by a central organizing node. Nodes that represent beliefs, antecedents, and physiological patterns associated, for instance, with fear are linked to the fear node in memory. When an emotion is experienced, the relevant node in the network is activated. Activation then spreads to associated nodes, making those ideas more

Paula M. Niedenthal, CNRS, Paris, France, and Department of Psychology, University of Clermont-Ferrand, France; Piotr Winkielman, University of California, San Diego; Laurie Mondillon, Department of Psychology, University of Clermont-Ferrand, France; Nicolas Vermeulen, Department of Psychology, Catholic University of Louvain-la-Neuve, Louvain-la-Neuve, Belgium.

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Correspondence concerning this article should be addressed to Paula M. Niedenthal, LAPSCO, Université Blaise Pascal, 34, avenue Carnot, 63037 Clermont-Ferrand Cedex, FRANCE or to Piotr Winkielman, Department of Psychology, University of California, San Diego, 9500 Gilman Drive, Mailcode 0109, La Jolla, CA 92093-0109. E-mail: niedenthal@wisc.edu or pwinkiel@ucsd.edu

likely to come to mind and to influence subsequent information processing. Conversely, activation of associated information in the emotion network can also generate the emotion itself. What emotion concepts are, then, are associations of propositions that stand for different parts of an emotion, including its likely antecedents and bodily features. A related view is that emotion knowledge is represented as feature lists and that such lists are represented in wordlike entries. For example, a feature list representation of the state of anger might look like this: *ANGER* [frustration, fists clenched, face red, yelling, cursing] (see Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Niedenthal, 2008).

Despite variations in their explicit purposes, all extant accounts of emotion concepts (such as appraisal theories, semantic network theories, and even some readings of prototype theories; see Niedenthal, 2008, for discussion) are grounded in a more general view of cognition that assumes that higher order mental content is represented in an abstract, languagelike code (e.g., Fodor, 1975). This view assumes that the symbols used in higher level cognitive processes are *amodal*; they do not preserve anything analogical about the perceptual experience of the object, event, or state, but are abstracted and abstract in format (see Rumelhart & Norman, 1988; E. E. Smith & Medin, 1981, for discussions of this view). Amodal models of representation constitute the view of knowledge that has dominated and continues to dominate explicit accounts of representation in the cognitive sciences. A principle assumption underlying the view is that representations result from a process of *transducing* modality-specific states in perception, action, and introspection into the symbols that represent knowledge (Barsalou, 1999). These symbols constitute conceptual content. Therefore, knowledge about anger, for instance, does not consist of the modality-specific states that constitute anger in perception, action, and introspection. Instead, the content of the concept of anger is the amodal symbols that have redescribed these different features of the emotional state.

Embodied Representation of Emotion Knowledge

There exist a number of recent accounts, sometimes called *theories of embodied cognition*, that view knowledge as grounded in modality-specific systems (Barsalou, 1999; Clore & Schnall, 2008; Damasio, 1999; Decety & Jackson, 2004; Gallese, 2003; Glenberg, 1997; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Semin & Cacioppo, 2008; E. R. Smith & Semin, 2007). Taken together, these approaches, which we call *embodied simulation accounts* propose that the modality-specific states that represent perception, action, and introspection when one is actually in interaction with a particular entity, or in a specific situation, are also used to represent these ideas when the original entity or situation is not present. For example, retrieving the memory of a specific person involves the reactivation of parts of the visual states that were active while perceiving him or her. In the same way, thinking about an action involves partial activation of the motor states that originally produced it.

From such an approach, emotional information processing involves reactivating parts of the neural states that occurred when one experienced that emotion or processed a particular emotional cue (Niedenthal, 2007; see also Cacioppo & Petty, 1981, and Lang, 1979, for earlier related arguments). In one view of how this can happen, during initial perception of an emotional stimulus, the induced modality-specific states (e.g., somatic responses) are partially captured by the brain's association areas (Damasio, 1989). Later, when information about that emotional stimulus is used in memory or categorization, conjunctive neurons partially reactivate the pattern of neural states across the relevant modalities (if such reactivation is necessitated by the task). Similarly, by this account, knowledge of an emotion concept is not reducible to an abstract, languagelike description, but involves simulation of experienced emotional states relevant to the concept. Although these simulations may not constitute full-blown emotions, and may not even be conscious, they nevertheless can contain enough information about the original states to support conceptual processing. Furthermore, these reenactments do not result from associative connections of emotion concept to somatic state. Instead, they comprise the fundamental content of emotion knowledge and are recruited when it is necessary to access the structure of the concept.

Comparing Representational Models

Object Concepts

Many studies provide support for the embodied simulation account of object concepts (Gallese & Metzinger, 2003; Glenberg & Kaschak, 2002; Pecher, Zeelenberg, & Barsalou, 2003; Stanfield & Zwann, 2001; for a review of the embodiment of linguistic meaning, see also Gibbs, 2003). The basic prediction that derives from the embodied simulation account, but not from the competing amodal account, is that behavioral and neuroimaging evidence will reveal the use of modality-specific systems in conceptual tasks that rely on those modalities.

Barsalou and colleagues (2003) compared predictions from amodal and modal accounts of concepts using two classic tasks, which we also used in the present studies. In a property verification task, participants indicate whether a member of a category possesses a given characteristic (Kosslyn, 1976). Using this task, Solomon and Barsalou (2004) showed that participants' verification performance was influenced by perceptual variables (e.g., the physical size of the verified property). Furthermore, Kan, Barsalou, Solomon, Minor, and Thompson-Schill (2003) found selective activation of modality-specific brain areas when participants verified a property typically processed in the respective modality (e.g., gustatory for "LEMON-sour," or auditory for "BOMB-loud"). These findings suggest that the property is indeed perceptually simulated in order to perform the verification task (see Pecher et al., 2003, for related behavioral findings described in the *Emotion Concepts* section).

In a property generation task, also known as a *feature listing task*, participants freely produce features of typical members of categories (Rosch & Mervis, 1975). Using this task, Wu and Barsalou (2004) found that participants produced concept features according to their perceptual experience. As an example, participants produced the features *seeds* and *red* more often when they were exposed to the concept "HALF" "WATERMELON" rather than "WATERMELON." Critically, the generation of perceptual properties could not be a function of stored associations, as different perceptual properties were produced even for completely novel concepts (e.g., "GLASS CAR" vs. "CAR"). The authors of a more recent study (Simmons, Hamann, Harenski, Hu, & Barsalou, 2008) also found that participants who performed a property generation task activated modality-specific brain areas (visual, auditory, tactile, etc.) corresponding to the processed concepts.

One important feature of embodied accounts is their assumption that the nature of the task influences whether simulation will be used, and if so, then what kind of simulation will be performed. More specifically, note that embodied simulation is not required to perform all tasks. For example, sometimes property verification tasks can be performed using "shallow" strategies like the detection of associations between words (Kosslyn, 1976). In such cases, embodied simulation is not necessary (e.g., Solomon & Barsalou, 2004). The use of a particular embodied simulation also depends on the specific situated conceptualization—or the context in which the concept is being processed (Barsalou, 2003). For example, if the task does not require generation of internal properties, then they are not simulated (Wu & Barsalou, 2004).

In summary, the results from research on object concepts using both property verification and property generation tasks suggest that when individuals use concepts, they simulate perceptual states involved in interacting with those concepts. More important, those simulations are task dependent and thus cannot reflect pure associative reactions to concept names. Overall, those results are not consistent with the predictions of an amodal model of representation.

Emotion Concepts

A large number of findings in the emotions and social psychology literatures are consistent with the embodied simulation account of emotion knowledge (Barsalou et al., 2003; Niedenthal, 2007). Some of these findings come from studies on the connection between the conceptual and motor system. Thus, Chen and Bargh (1999) had participants indicate the valence of presented words (e.g., *love*, *hate*) either by pulling a lever toward them or by pushing it away. Participants responded faster to positive words when pulling the lever toward them and to negative words when pushing it away, indicating that categorization of the words' valence is facilitated by a congruent bodily state. Similar findings have been reported by Neumann and Strack (2000); Förster and Strack (1997, 1998); Cacioppo, Priester, and Berntson (1993); and Alexopoulos and Ric (2007). In summary, the findings suggest that the meaning of emotional words is at least partially grounded in the motor states involved in the approach versus avoidance responses to the words' referents (Niedenthal, 2007).

Other findings consistent with the embodiment approach come from studies on the recognition of emotional facial expressions. Wicker et al. (2003) had participants inhale odors that generated feelings of disgust. The same participants then watched videos displaying other individuals expressing disgust. Neuroimaging results showed that the same areas of the anterior insula and also, to a lesser extent, the anterior cingulate cortex were activated both when individuals felt disgust and also when they perceived it. Along with the larger body of work on mirror neurons (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fogassi, & Gallese, 1997), this suggests that understanding someone else's actions or experience and performing an action or having an experience oneself recruit similar systems (for related evidence with other facial expressions, see Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006).

The work with recognition of facial expression also provides some evidence for the causal role of embodied simulation in emotion processing. For example, preventing participants from engaging expression-relevant facial muscles can impair accuracy of detection of facial expressions that involve that muscle (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007). In summary, both correlational and causal evidence suggests that embodied simulation is involved in perception of facial expression of emotion (see Niedenthal, 2007, for a fuller discussion).

A final type of evidence for embodiment in emotion processing comes from an extension of research on perceptual "switching costs" to emotion. Researchers in perception have shown that shifting attention from processing in one sensory modality, such as vision, to another, such as audition, involves temporal processing costs (e.g., Spence, Nicholls, & Driver, 2001). Similar costs are also found when participants engage in a purely conceptual task. For example, Pecher and colleagues (2003; Pecher, Zeelenberg, & Barsalou, 2004) found that participants were slower in verifying properties of a concept from one modality after they had just verified a property from another modality (e.g., "BOMB-loud" followed by "LEMON-tart"), once again suggesting involvement of perceptual processes in conceptual representation (see Kan et al., 2003, for neuroimaging evidence). In recent work, Vermeulen and colleagues (e.g., Vermeulen, Niedenthal, & Luminet, 2007) examined switching costs in verifying affective properties of positive and negative concepts as well as some nonemotional concepts. Properties of emotional concepts were taken from vision, audition, and the affective system. Parallel to switching costs in neutral pairs, the study showed that for positive and negative concepts, verifying properties from different modalities produced processing costs such that reaction times were longer and error rates were higher. And, this effect was observed when switching from the affective system to sensory modalities, and vice versa. This provides some initial evidence for the possibility that affective properties of concepts must be simulated in order to verify them (see Havas, Glenberg, & Rinck, 2007, for related findings in the area of language comprehension).

Aims of the Present Research

Each of the studies in the previous subsection is consistent with the embodied simulation account according to which emotion concepts are grounded in the ability to at least partly reenact aspects of these states in somatosensory systems. However, none of the studies test the account directly by using standard conceptual tasks and specifically measuring indicators of embodied simulation of emotion. The primary purpose of the present experiments was to provide such evidence. We used the classic property verification task (Experiments 1 and 2) and the property generation task (Experiment 4), measured embodiment via facial electromyography (EMG), and tested the predictions from the embodiment account using both concrete and abstract emotion concepts. This allowed us to examine the role of simulation in the representation of emotion at different levels of the conceptual hierarchy, from the representation of individual emotion objects to the representation of arbitrary emotion labels, detached from any particular exemplars.

In Experiments 1 and 2, we also tested a specific prediction of the embodied emotion account that holds that somatic simulations of emotion should be required when emotional content is needed to perform the conceptual task, but not when the task is naturally based on simulation in other sensory or motor systems, or can be most efficiently performed by using associations in the lexical system (for related evidence, see Kosslyn, 1976; Solomon & Barsalou, 2004; for similar situated-simulation assumptions, see Semin & Cacioppo, 2008; E. R. Smith & Semin, 2007; Strack & Deutsch, 2004). Note that a selective emotion simulation hypothesis is not derived naturally from associative spreading activation accounts. In those models, somatic responses (if any) are by-products of central concept activation, and thus should occur in all tasks in which the words for somatic responses are primed directly or are activated through passive spread of activation. For example, when an individual is exposed to the word *happy*, spread of activation to the word *smile* would be predicted. If somatic responses occur automatically as a function of priming the concept, then in many different types of tasks, exposure to an emotion word (such as those used particularly in Experiment 2) should result in some evidence of a somatic response (e.g., a facial expression). A follow-up Experiment 3 was also conducted in order to evaluate the causal nature of embodiment in this task.

Finally, in Experiment 4, we explored in greater detail the situated nature of simulation, or the idea that the emergence of embodied simulation depends on whether such information is required for successful task performance. Accordingly, we manipulated task instructions so as to encourage or discourage the engagement of somatosensory resources during generation of properties of emotional concepts. Again, the task-dependent nature of simulation is incompatible with associative accounts, which view embodiment as automatic by-products of concept activation.

Experiments 1 and 2

Participants in the first two experiments performed a type of property verification in which they indicated whether concepts (e.g., "CADAVER," "GIFT," "TABLE") were or were not associated with an emotion. For the first experiment, we developed a list of concrete concepts that pretesting had shown were related to the specific emotions of anger, disgust, and joy and were high in ratings of imagery (e.g., "VOMIT" is related to disgust). The aim of the second experiment was to examine whether participants engage in simulation when processing abstract emotion concepts. Accordingly, the stimuli developed for this second experiment were emotion concepts consisting of synonyms of the three emotions (e.g., *GLEE* and *HAPPINESS* for *JOY*). Some participants in both experiments had to indicate whether the concept was related to an emotion. The emotion words in both experiments were of course presented among a number of neutral concepts that did not refer to emotions in any way.

As mentioned above, embodiment theories hold that the type of embodied simulations that arise in information-processing tasks depend on what is needed to perform the task. The main condition for the two studies—in which a judgment of a concept about being associated with an emotion was made—requires that somatosensory simulation occurs. Each of the first two experiments also included a processing condition in which participants had to indicate whether the concept was written in upper- or lowercase letters. Performance of such a task does not require somatosensory simulation. As shown in numerous studies on the automaticity of word reading, this task ensures that each item is primed in the lexical system and, therefore, could automatically prime strongly related lexical entries (MacLeod, 1991). However, because the task does not require access to emotional content, we expected no simulation in the condition and accordingly no EMG evidence of embodied reactions in relevant facial muscles.

We used EMG to assess embodied simulation of emotion. EMG activity has been shown to distinguish both the valence and intensity of an affective reaction (e.g., Cacioppo, Petty, Losch, & Kim, 1986). Additional research has demonstrated that EMG is a sensitive indicator of affective reactions to visual and auditory stimuli (e.g., Larsen, Norris, & Cacioppo, 2003). In particular, anger-relevant stimuli elicit activity over the *corrugator supercilii*, or brow muscle (Dimberg, 1986; Dimberg & Thell, 1988), whereas joy-relevant stimuli increase activity over *zygomaticus major*, or cheek muscle (Dimberg & Karlsson, 1997; Dimberg & Ulrich, 1995) and *orbicularis oculi* (Ekman, Davidson, & Friesen, 1990). Finally, disgust, in addition to other negative emotions, is accompanied by increased activity in the *corrugator supercilii* and, more specifically, in *levator labii superioris*, which is one of the muscles involved in lifting the upper lip and wrinkling the nose (Vrana, 1993). The interpretation of levator activity is less clear than other muscles, probably because the upper lip region is involved in multiple expressions (Wolf et al., 2005). These, then, were the muscles that were monitored in the present two experiments.

If somatosensory simulation is required to answer the question "Is this concept associated with an emotion?" then EMG activity in the relevant muscle(s) for each of the three specific emotions of anger, disgust, and joy should be observed. Because such processing is not necessary for making a judgment about the way in which a word appears visually, the muscles should not be selectively activated in the letter processing condition.

Experiment 1

Method

Participants

Forty-five participants (17 men and 28 women) took part in the experiment. All were recruited on the campus of the University of Clermont-Ferrand, Clermont-Ferrand France via announcements.

Material

Task. Concepts were represented by 60 concrete words. Thirty words were emotion related, with 10 words associated with each of the three emotion concepts "joy" (e.g., *SMILE*, *SUN*, *CUDDLE*), "disgust" (e.g., *EXCREMENT*, *VOMIT*, *SLUG*), and "anger" (e.g., *FIGHT*, *TORTURER*, *MURDER*). Thirty words were unrelated to any emotion concept (e.g., *POCKET*, *CHAIR*, *CUBE*). All were pilot tested for their relation to specific emotions and how easy it was to imagine their referent (see Table 1).

EMG measurements. Electrodes were applied to the four muscles of interest according to standard placement recommendations of Fridlund and Cacioppo (1986). The reference ground clip electrode was placed on the ear lobe. Muscle activity was measured using bipolar placements of Med Associates Inc. (East Fairfeld,

Table 1
Average Emotion and Imageability Ratings for Abstract Concepts Used in Experiment 1

Concept	Joy		Disgust		Anger		Imageability	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Joy words	4.64	0.70	1.13	0.40	1.19	0.57	3.87	1.10
Disgust words	1.11	0.38	4.13	1.07	2.20	1.36	3.24	1.23
Anger words	1.04	0.26	3.72	1.44	4.31	1.10	3.53	1.18
Neutral words	1.72	1.02	1.28	0.63	1.24	0.62	4.10	1.03

VT). TDE-23-Y-ZZ-S Ag/AgCl (i.e., silver/silver chloride surface) miniature surface electrodes were filled with Med Associates Inc. electrolyte gel (TD41) and attached by Med Associates Inc. 5-mm TD-23 collars. The impedance of all electrodes was reduced to less than 10 kOhms. The participants' skin resistance was first decreased with a cleaning and rubbing sebum-removing lotion, and then with prep pads drenched with 70% alcohol.

The acquisition of EMG signals was controlled by ADInstruments equipment (ML880 Powerlab 16/30). A Multi-Channel Bio Amps GT201 was used to amplify the raw EMG signals. The signals were filtered online with a low-pass filter set to 500 Hz, a high-pass filter set to 50 Hz (minimizing the collection of electrocardiogram [EKG] and electroencephalogram [EEG] signals), sampled at 1000 Hz and stored to disk with Chart Software for MacOSX. After the signals were integrated and smoothed offline (time constant of 0.02 s), the average EMG activity in periods of interest was calculated.

In order to establish a baseline measure of EMG for each participant, the activity for each muscle was calculated in predefined pre- and posttest periods. Specifically, the first baseline period was defined as the 10 s before the first "start signal" of the first trial of the critical (nonpractice) trials (e.g., Suraka & Hietanen, 1998). The second baseline period was the 10 s that began 5 s upon completion of the last trial, during which participants were told to relax. Baseline scores for each muscle were calculated by taking the average activation of each muscle during this 20-s period. Muscular activation was measured on a given trial from the time that a word was presented until 50 ms before a response was emitted. This cut off shortly before the response was imposed in order to avoid analyzing responses that occurred during an effortful motor behavior. For analysis, activity across trials in the same theoretical category (concepts associated with anger, joy, disgust, and neutral emotion) were averaged for each of the four muscles separately. The baseline activation of each muscle was then subtracted from those means in order to produce change scores that were used in the analyses.

Procedure

On arriving at the laboratory, participants were led to a quiet room where they signed an informed consent form. To prevent participants from focusing on their facial muscles, they were told that the study concerned sweat gland (electrodermal) activity during word reading (following Dimberg, 1982, 1990). Electrodes were then attached over the orbicularis oculi, zygomaticus major, corrugator supercilli, and levator labii muscle regions. Once the participant was connected to the EMG equipment, he (or she) was left for several minutes to habituate to the room and the electrodes. The experimenter then provided instructions for the task.

Participants were randomly assigned to one of the two task conditions. Participants in the letter focus task were instructed to indicate whether each word presented on the computer screen during the task was written in capital or small letters. The remaining participants performed the emotion focus task, in which they indicated whether the referent of each word was associated with an emotion or not. After hearing the instructions and indicating that they had understood, participants performed five practice trials while the experimenter stood nearby in order to respond to any questions that might arise.

During the test phase, the words were presented in a random order using PsyScope for Macintosh (Cohen, MacWhinney, Flatt, & Provost, 1993). They were displayed on a 17-in. (43.18-cm) monitor located approximately 1 m from the participant. A trial started with a fixation cross, shown for 3 s, immediately followed by the target. The participant responded to the stimulus on the keyboard by pressing either the *D* or *K* button. The "D"/"K" response position was counterbalanced across participants and conditions. After the judgment, there was a 5-s pause, and the next trial began. At the conclusion of the experiment, participants were asked to generate ideas that they had about the aims of the experiment. Consistent with the cover story, all of the participants proposed hypotheses concerning their electrodermal activity.

Results

We excluded data from 2 participants from analyses due to movement artifacts. In the letter task condition, participants were highly accurate, with only 0.625% errors in indicating the case in which the letters were written. Participants in the emotion task condition were also accurate, with only 3.86% of the responses being inconsistent with the a priori expected responses. We eliminated the EMG measures on trials on which participants were incorrect.

Response latencies were also recorded, as they constituted the time over which EMG measures were made. On average, participants in the letter task condition responded within 1158.08 ms (SD = 364.12 ms). Participants in the emotion task condition responded on average within 2300.16 ms (SD = 908.09 ms). Note that these time windows give sufficient opportunity to detect EMG responses to simple stimuli, such as words. In fact, many researchers report EMG effects within time windows shorter than the average response latencies of our participants (Dimberg, Thunberg, & Grunedal, 2002). However, to ensure that any differences in EMG responding across conditions were not due to the time window differences, our main analyses evaluated the effects of this variable statistically. Because there were no interactions with response latency, however, this variable is not mentioned further.

Of the collected data, we excluded 2.03% from analyses using the SD method (for a review of the different methods, see Wilcox, 1992), with the criterion value standing at 3 standard deviations per muscle for assuring variance homogeneity and attenuating the impact of highly reactive individuals on the overall score.

Figure 1 shows participants' EMG activity plotted against emotion category. As discussed above, the data represent the change from the mean baseline period to the period going from immediately after the onset of the stimulus to 50 ms before the response was made. The scores were first explored with a 4 × 4 × 2 overall analysis of variance (ANOVA), using emotion category (i.e., neutral, joy, anger, and disgust) and muscle (i.e., corrugator, levator, orbicularis, and zygomaticus) as within-subjects factors and task (i.e., emotion task vs. letter task) as the between-subjects factor. This primary analysis revealed an Emotion × Muscle × Task three-way interaction, $F(9, 333) = 5.58$, $p < .001$, indicating that muscles activity did not occur homogeneously across emotion category and that this pattern was not identical for different tasks. Decomposing the three-way interaction revealed a two-way interaction between muscle and emotion in the emotion task condition, $F(9, 153) = 2.88$, $p < .01$. In contrast, and consistent with predictions, analysis of the letter focused task condition did not reveal a significant Muscle × Emotion interaction, $F(9, 171) = 1.14$, *ns*.

The follow-up analyses focused on the activity of the individual muscles. First, we performed separate 4 × 2 ANOVAs, with emotion category and task on each of the four muscles. Each of these ANOVAs revealed a significant Emotion × Task interaction (all ps $< .05$). We then decomposed this interaction using post hoc contrasts tests performed within each type of task on each muscle. In the emotion task condition, within-subjects post hoc contrasts on muscles (+1, +1, −1, −1, for anger, disgust, neutral, and joy) indicated that the corrugator region showed greater activity for words associated with anger and disgust compared with neutral and joy, $F(1, 22) = 13.21$, $p < .001$. Furthermore, post hoc contrasts (+3, −1, −1, −1, for joy, neutral, anger, and disgust) showed that zygomaticus major activity was higher for words related to joy than any of the three other emotional concepts, $F(1, 19) = 8.5$, $p < .01$. Concerning orbicularis oculi activity, the relevant contrasts (+3, −1, −1, −1, for joy, disgust, anger, and neutral) showed that activity was greater for joy than for disgust, anger, and neutral words, $F(1, 21) = 12.14$, $p < .01$. Finally, levator activity was higher for disgust than for anger, neutral, and joy words (+3, −1, −1, −1, for disgust, anger, neutral, and joy), $F(1, 21) = 14.54$, $p < .001$. Surprisingly, the second contrast (0, −2, +1, +1) was marginal, $F(1, 21) = 4.07$, $p = .057$, indicating that the levator activity that occurred during processing of the anger words was also greater than during the processing of neutral and joy words.

Discussion

The first experiment obtained results consistent with predictions of an embodied simulation approach to the representation of emotion concepts. Participants made judgments about words referring to concrete objects that in the real world typically elicit a particular emotion. Participants who made judgments in which the emotion component of the concept was relevant recruited somatic components of emotions, as reflected in the presence of EMG activity. We did not observe such responses with the same-word stimuli when the task did not require consideration of the emotional content of the concept. This finding suggests that embodied responses to an emotional symbol (e.g., a word) are not automatically elicited upon encountering that symbol, but occur when the task requires simulation in a particular system.

Of importance, the somatic responses were quite emotion specific. Judgments about whether objects that typically evoke joy were associated with an emotion were accompanied by activation of the zygomaticus and orbicularis oculi muscles, whereas judgments about objects that tend to elicit disgust were accompanied by activation of the levator muscle. We note that the processing of concrete objects associated with anger were accompanied by activation of both the levator muscle and the corrugator region. Thus,

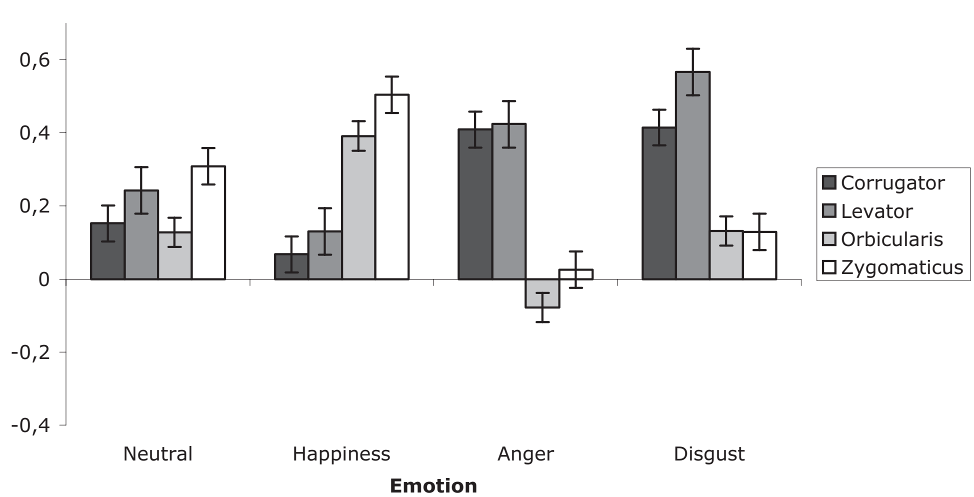

Figure 1. Mean muscles activity plotted against stimulus emotion (concrete words) for the emotion-focused task conditions.

the anger judgments showed the least emotion-specific response. We think this is likely due to the nature of the stimuli chosen. Generally, concrete objects tend not to elicit anger, and more specifically, some of our anger concepts were also evocative of disgust (see Table 1). However, we were able to address this possible shortcoming in the stimulus selection of Experiment 2.

Experiment 2

The motivation for Experiment 2 was to provide a stronger test of an embodied theory of emotion knowledge by examining whether emotion-specific somatic responses are observed even when individuals process words that denote abstract emotion concepts. This is an important test because supportive findings would suggest that somatic simulations are involved in representing emotion knowledge even at very abstract levels in a conceptual hierarchy, at which emotion terms do not refer to any particular emotion object or exemplar. Again, we measured EMG activity as participants performed either a task that in theory required emotional simulation versus not. We expected to find emotion-specific embodiment only in the task that involved judgment about emotion, and not perceptual features of the words.

Method

Participants

Thirty-eight undergraduate students (4 men and 34 women) took part in this study in exchange for course credit. All were recruited from the University of Clermont-Ferrand, France.

Material and Procedure

The equipment and procedure were the same as for Experiment 1 except that the stimuli were 60 abstract words (i.e., adjectives), including 10 words related to each of the three emotion concepts "joy" (e.g., *JOYFUL*, *DELIGHTED*, *HAPPY*), "disgust" (e.g., *REPELLED*, *NAUSEOUS*, *FOUL*), and "anger" (e.g., *ENRAGED*, *FURIOUS*, *IRRITABLE*), and 30 neutral words (e.g., *SUBSTANTIVE*, *QUANITFIED*, *PROGRAMMED*)—unrelated to any emotion (see pretest data reported in Table 2). Participants in the two task conditions made the same judgments as did participants in the first experiment.

Results

We exclueded 3 participants from analyses: 2 due to equipment failure and 1 due to failure to understand the instructions.

As in Experiment 1, participants' responses were highly accurate, with only 0.75% errors in indicating the case in which the letters were written. Participants in the emotion-focus task condition were also quite accurate, with 4.01% of the responses being inconsistent with the a priori expected responses. We eliminated the EMG measures on trials on which participants were incorrect.

We also recorded response latencies, as they constituted the time over which EMG measures were made. On average, whereas participants in the letter focus task condition responded within 884.8 ms (SD = 459.56 ms), participants in the emotion focus task condition responded within 2476.4 ms (SD = 740.48 ms). As in Experiment 1, the possible role of response latency differences was addressed statistically, but the variable did not interact with any of the others. Finally, as in the previous experiment, we excluded 2.15% of the responses from analyses using the same SD-method, with a criterion value standing at three standard deviations per muscle.

Figure 2 shows EMG activity plotted against emotion category. Again, the data represent the change from the mean baseline period to the period going from immediately after the onset of the stimulus to 50 ms before the response. As before, this cutoff shortly before the response was imposed in order to avoid analyzing responses that occurred during an effortful motor behavior. We first examined the scores with a 4 × 4 × 2 overall ANOVA, using emotion (i.e., neutral, joy, anger, and disgust) and muscle (i.e., corrugator, levator, orbicularis, and zygomaticus) as within-subjects factors and task (i.e., letter task vs. emotion task) as the between-subjects factor.

This primary analysis revealed an Emotion × Muscle × Task three-way interaction, $F(9, 243) = 3.08$, $p < .01$. The result indicates that the muscular activity did not occur homogeneously across emotional stimuli, that this pattern was not identical across task, and not influenced by response latency. Decomposing the interaction revealed a two-way interaction between muscle and emotion in the emotion task condition, $F(9, 117) = 2.55$, $p < .05$. In contrast, as predicted, this interaction was not significant in the letter task condition, $F(9, 117) < 1$.

As in Experiment 1, the follow-up analyses focused on the activity of the individual muscles. First, we performed separate 4 × 2 ANOVAs, with emotion category and task on each of the four muscles. Each of these ANOVAs revealed a significant Emotion × Task interaction (all $ps < .05$). We then decomposed this interaction using post hoc contrasts performed within each type of task on each muscle. Analysis of the corrugator region showed greater activity for words related to anger and disgust compared with neutrality and joy (−1, −1, +1, +1 for neutral, joy, anger,

Table 2
Average Emotion and Imageability Ratings for Abstract Concepts Used in Experiment 2

	Joy		Disgust		Anger		Imageability	
Concept	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Joy words	4.33	0.86	1.03	0.20	1.05	0.21	4.22	0.94
Disgust words	1.05	0.15	4.22	0.93	2.43	1.23	3.10	1.42
Anger words	1.04	0.21	2.38	1.28	4.07	0.95	3.64	1.27
Neutral words	1.82	1.04	1.39	0.75	1.39	0.79	2.04	1.38

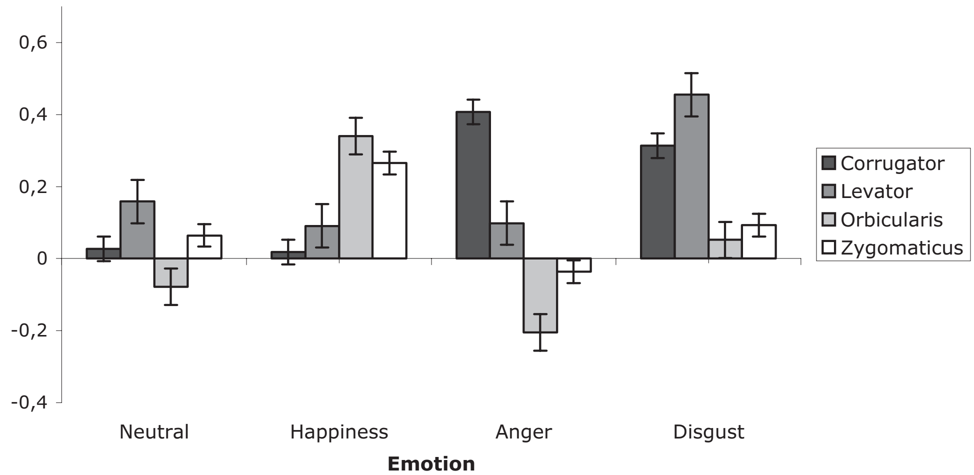

Figure 2. Mean muscles activity plotted against stimulus emotion (abstract words) for the emotion-focused task conditions.

and disgust), $F(1, 16) = 30.92$, $p < .001$. Analysis of the zygomaticus major revealed that activity was higher for joy than for anger, neutral, and disgust words (+3, −1, −1, −1 for joy, disgust, anger, and neutral), $F(1, 17) = 33.88$, $p < .001$. Furthermore, the second contrast (0, 0, −1, +1) remained significant, $F(1, 17) = 11.16$, $p < .01$, indicating that the zygomaticus activity that occurred during the anger stimuli processing was lower than during neutral stimuli processing.

Analysis of the orbicularis oculi activity with the relevant contrast (+3, −1, −1, −1 for joy, neutral, anger, and disgust) showed that activity was greater for joy than for disgust, anger, and neutral words, $F(1, 17) = 21.84$, $p < .001$. The second contrast (0, −2, +1, +1) remained significant as well, $F(1, 17) = 7.4$, $p < .05$, indicating that orbicularis oculi activity during the processing of anger words was lower than during the processing of neutral and disgust words. Finally, analysis of the levator region revealed that greater activity for stimuli related to disgust and joy than to concepts related to the other three emotional concepts (+3, −1, −1, −1 for disgust, anger, neutral, and joy), $F(1, 18) = 26.91$, $p < .001$. Overall, these findings are largely consistent with predictions as well as with the findings of Experiment 1, and are discussed further in the General Discussion section.

Experiment 3: Follow-Up Study of Causal Role for Embodiments

The first two experiments show evidence of embodiment in the processing of emotion content and not the processing of the perceptual features of emotionally charged words. However, an objection can be made that these two studies provide correlational rather than causal evidence for the present hypotheses. Although existing studies, such as those summarized in the introduction, have indeed manipulated embodiment and demonstrated its contribution to perceptual and cognitive processes, embodiment was not manipulated in the present ones.

In order to address this limitation, we recruited 30 participants for a brief follow-up study at the University of California, San Diego. Participants were all exposed to a series of 180 words similar to those used in Experiments 1 and 2, but they were in English. Participants made an emotion-focused judgment that was similar to that in Experiments 1 and 2, but with one change. Specifically, participants were instructed to indicate whether the concepts were "related to emotion" rather to "an" emotion. That is, the present participants evaluated the relation of words to emotion generally rather than a relation to a particular emotion. The abstract phrasing of the question in the present study invited more errors than in Studies 1 and 2 so that we could analyze accuracy (see the *Results* section), and, more theoretically, it also provided a test of causal role for embodiment with more abstract judgment.

As in other studies of embodiment effects on recognition, accuracy served as the dependent variables of interest (Niedenthal et al., 2001; Oberman et al., 2007). To establish an objective criterion for accurate classification of words as emotional or nonemotional, we used performance of participants in the condition where embodiment was free (i.e., not constrained) and analyzed only words where at least 75% of participants agreed on the classification (leaving 77% of words for the analysis).[1]

In order to assess the causal contribution of embodiment to conceptual processing, half the participants could move their faces freely during the task, and half were prevented from certain facial responses. Specifically, we used a manipulation of embodiment that requires that participants hold a pen laterally between lips and teeth—a technique successfully used in previous work on visual emotion recognition (e.g., Niedenthal et al., 2001; Oberman et al., 2007). Specifically, the instructions said the following:

> In this task, we are also interested in one additional thing. Previous research has shown that face movement can change how people

[1] For exploratory purposes, participants also performed an additional block of living/nonliving judgments on these words. However, the classification agreement on these words was quite low, with only 63% of words passing the 75% agreement criterion. Furthermore, the living–nonliving judgment was nonorthogonal to emotion judgment. Therefore, we report only analysis of emotion/nonemotion judgment (as explored in Experiments 1 and 2).

> respond. Therefore, we need participants to not move their faces throughout the task. The following method has been designed to help you do so. Please take a fresh pen out of the box (you can keep it afterwards). Put it sideways in your mouth and hold it lightly using both your teeth and your lips. Please maintain the position throughout the task, so that you minimize any possible movements of the face. The picture below illustrates the proper way of holding the pen.

Figure 3 reproduces the image that the participants were instructed to use as a model.

Note, however, that the inhibitory effects of the pen manipulation should be limited to particular emotions—those where production of expressions involves muscles blocked by the pen (see Oberman et al., 2007, for evidence of such selectivity from EMG and emotion recognition). Specifically, holding a pen, as instructed, primarily influences the activity in the lower part of the face, limiting the ability to raise the lip in smile, lower it in sadness, or to wrinkle the nose in disgust. In contrast, the brow or other parts of the upper face is not affected by the manipulation. Accordingly, we expected that, if simulations of emotional experience are used to represent emotion concepts, then processing of joy- and disgust-related concepts should be impaired by the pen manipulation, but processing of anger or neutral concepts should be relatively unaffected.

Analyses revealed a main effect of word type on accuracy, $F(3, 84) = 8.15$, $p < .01$, and a main effect of pen manipulation, $F(1, 28) = 11.48$, $p < .01$. These effects were qualified by the predicted Pen Manipulation × Word Type interaction on judgment accuracy, $F(3, 84) = 7.02$, $p < .01$ As depicted in Figure 4, preventing disgust and joy expressions significantly lowered accuracy of judgments of whether a concept is "related to emotion." There were no significant effects of the pen on judgments of anger-related or neutral concepts, suggesting that the blocking effects were limited to emotions that engage relevant muscles.

Figure 3. Model provided for participants that illustrates the proper position of the pen in the embodiment-blocking condition.

In conclusion, the findings from the follow-up study indicate that the production of facial expressions contributes causally to accurate processing of emotion concepts. This evidence addresses the possible concern that facial reactions observed in Experiments 1 and 2 were simply associative by-products of thinking about emotion words (though, again, a purely associative account would also predict embodiments to occur in the letter focused condition, which we did not observe). Finally, the findings from the follow-up Experiment 3 nicely extend to the lexical domain previous work on visual perception of facial expressions that documented selective impairments in recognition accuracy when participants were blocked from using facial muscles involved in production of corresponding expressions (Niedenthal et al., 2001; Oberman et al., 2007).

Experiment 4

Experiments 1 and 2 provided evidence of embodiment in processing of emotion concepts using a property verification task. In Experiment 4, we extended these findings to another classic conceptual task—a property generation task, in which participants are asked to list features of concepts (Rosch & Mervis, 1975). In addition, we aimed to further explore the idea that embodiment plays a functional, rather than an associative, role in processing of emotion concepts. According to our theoretical model, an emotional reaction is simulated in order to provide a *grounding* (conceptual content) for the judgment in question, but only if performing the task requires generation of this type of information.

In Experiment 4, we evaluated the question of simulation by manipulating the situation in which participants performed the very same task—the listing of emotional concept properties. Specifically, some participants were implicitly encouraged to use an embodied simulation strategy, whereas others were encouraged to use a more associative strategy. While participants performed the task, we assessed embodied reactions. The logic of this paradigm has been applied in studies by Barsalou and colleagues (see Wu & Barsalou, 2004). In those studies, some participants were asked to perform a feature generation task by listing words associated to the concept label (lexical condition), whereas other participants were asked to perform this task via generation of typical features (simulation condition). The results of those studies showed that fewer modality-specific properties were generated in the lexical compared with the simulation condition.

To manipulate the use of different strategies for representing emotional concepts and generating their features, we varied the *audience* for whom the properties of the concepts were supposedly being communicated (Schwarz, 2002). We expected that participants informed about an audience interested in "hot" emotional features of emotional concepts would engage in more embodied simulation, as evidenced by EMG responses. In contrast, we expected that participants informed about an audience interested in more "cold" lexical features of parts of emotional concept would engage in a more associative strategy. Of importance, the differences should be obtained even when participants are able to perform the task successfully in both conditions, as evidenced by the number and valence of properties generated for each emotion concept.

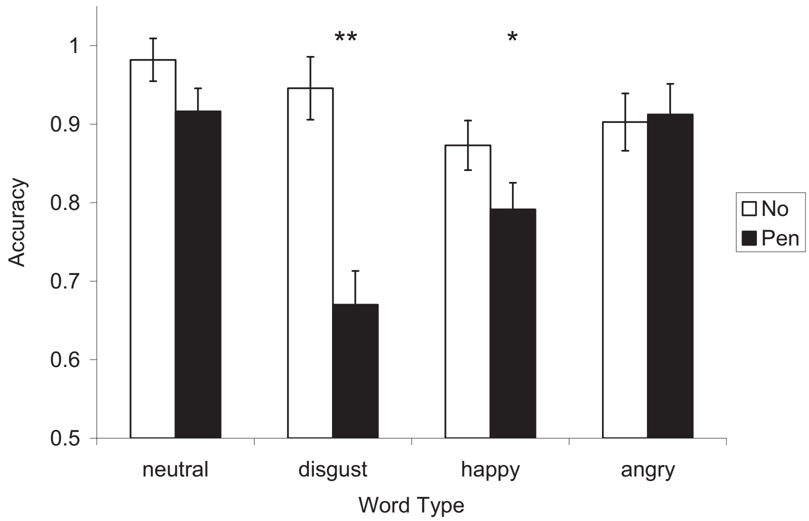

Figure 4. Accuracy of word classification as a function of word type and expression-blocking manipulation (pen). Error bars represent ± 1 *SE*. * $p < .05$ (one-tailed). ** $p < .001$.

Method

Participants

Eighteen undergraduates participated individually for course credit at the University of California, San Diego. The task was presented as an investigation about how individuals think about concepts and the electrical signals that accompany mental activity.

Property Generation Task

Participants were instructed to first think of, and then list, properties of three classes of concepts. Two classes of concepts related to emotion: joy and anger. One class, which served as a control set, related to nonemotional mental states. Each class of concepts was represented by eight terms, resulting in 24 items total.

Joy-related concepts included *HAPPINESS, JOY, DELIGHT, PLEASURE, BLISS, ENJOYMENT, CHEERFULNESS,* and *ELATION.* Anger-related concepts included *ANGER, RAGE, ANNOYANCE, IRRITATION, FURY, WRATH, IRE,* and *AGGRAVATION*. Control concepts were nonemotional mental states and included *IDEA*, *OPINION*, *DECISION*, *GUESS*, *CONCLUSION*, *BELIEF*, *CERTAINTY*, and *CONFIDENCE*. In addition, participants completed four practice trials, on which they listed the properties of *excitement, anticipation, fatigue,* and *wish*.

Each trial began with a 3-se“get ready” signal, followed by a concept (e.g., *DELIGHT*) with the instructions to “think quietly about the typical features of that concept” and “what attributes or features are characteristic of that concept.” The instructions encouraged participants to think about internal, external, psychological, and situational features. Participants had 30 s to do so. Next, participants had another 30 s to list their thoughts in a prepared booklet that contained one sheet of paper for each of the 24 concepts. The listed properties constituted a behavioral manipulation check. After the time allotted for property generation had elapsed, the participants were alerted with a brief tone to turn back to the computer screen and get ready for the next concept.

The 24 concept terms were presented in two blocks. Each block contained 12 terms: 4 randomly selected terms from each of the three classes of concepts. The order of blocks, the assignment of concepts to a block, and the order of concepts within a block was fully randomized. The instruction manipulation presented before each block constituted the within-subject manipulation of simulation.

Process Manipulation

The process for representing the concepts was manipulated by instructions that encouraged either embodied or associative-lexical processing. Specifically, participants were informed at the beginning of the study that the experiment concerned “how people explain concepts in various situations.” Then, at the beginning of each block, the instructions asked participants to think about concepts as if they were explaining them to an intended audience.

To avoid possible confounds associated with a particular manipulation of intended audience, two sets of instructions were created that emphasized different characteristics of the “recipient.” For half the participants, the instructions manipulated processing through the nature of the relationship with the recipient (with no information about his or her personality). Specifically, some participants were instructed to generate properties of concepts as if they were conveying the content to a “good friend with whom you have a close relationship and with whom you can share anything.” Other participants were instructed to generate properties of concepts as if they were conveying the content to a “supervisor with whom you have a formal relationship and with whom you maintain professional attitude.” The expectation here was that the former recipient would provide a context in which individuals would use embodied simulation to generate features of emotion. In contrast, the latter recipient should provide a context in which individuals would embody very little and would generate lexical associates in order to perform the task adequately. This manipulation was thus consistent both with the already established ideas that people respond differently to different audiences (e.g., Fridlund, 1994) and that in situations in which people should be more "polite," such as with superiors, they tend to constrain their emotional expression in general (Brown & Levinson, 1987).

For the other half of the participants, the instructions manipulated processing by varying the implied interest of the recipient rather than the participant's relationship with him or her. This is because the relationship (formal vs. informal) might moderate the extremity of the concept constructed for use in the two conditions or change participants' willingness to express facially. Specifically, some participants were instructed to generate properties of concepts as if they were conveying the content to a friend who was "artistically oriented," whereas other participants were instructed to generate properties of concepts as if they were describing the content to a friend who was "technically oriented." Again, the expectation was that the "artistic" recipient would provide a context in which individuals would embody specific instances of an emotion and use that simulation to generate its features. In contrast, the "technical" recipient should provide a context in which individuals would embody very little and would generate lexical associates in order to perform the task adequately. To anticipate the results, none of the analyses revealed an effect of the relationship versus interest focus of the instructions on the behavioral or physiological measures, so they were combined in the final analysis.

EMG Measurement

After site preparation such that impedance was reduced to below 15 kOhm, 4-mm silver/silver chloride surface electrodes were placed on the left side of the face following standards of Fridlund and Cacioppo (1986). Smiling was assessed by the activity over the region of zygomaticus major (cheek), and frowning was assessed by the activity over the region of corrugator supercilii (eyebrow). The ground electrode was placed on the forehead. Signals were applied using BIOPAC MP150 modules (BIOPAC Systems, Inc., Goleta, CA) set at a sample rate of 2,000 samples per second, with gain set to 2,000, low-pass filter set to 5 kHz, and high-pass filter set to 1 Hz. The acquisition of the EMG signals was controlled by BIOPAC's AcqKnowledge software Version 3.81 (Mindware Technologies LTD., Gahanna, OH), and further processing was performed with software from Mindware Corporation. The signals were filtered from 10 to 500 Hz, rectified, and integrated. Finally, activity within 200ms intervals was calculated and then standardized (i.e., expressed as Z scores) within participants and muscle sites.

A *baseline* was defined as the activity during the last 800 ms in the prestimulus period, before the presentation of the concept word. This period was selected because it was free of artifacts reflecting the orienting reaction to acoustic signal about the end of the previous and onset of the new trial. As described next, the specific EMG analyses focused on both immediate and extended effects. For the immediate reactions after the presentation of the concept word, activity in the first 23 windows of 200 ms (the first 5 s, except the first 400 ms that were eliminated due to orienting artifacts). For the extended effects, during the whole 30 s of feature generation, activity was aggregated into six 5-s periods.

Results

Manipulation Check: Generated Properties

Concept features listed during the property generation task served as a check on whether participants properly performed the behavioral task and differentiated between the classes of joy, anger, and neutral concepts. On average, participants wrote down 10.8 words per concepts, for the total output of 261 words (SD = 81) for 24 concepts. These responses were transcribed and given to two independent raters, who were blind to conditions and hypotheses, for assessment on two critical dimensions, valence and emotionality, and two control dimensions, such as abstractness and richness.

Most important, the raters assessed the overall valence of descriptions on a scale ranging from 5 (*very positive*) to 1 (*very negative*). Confirming the differentiation between the concept classes, there was a very large effect of concept type on rated positivity of the listed property, $F(2, 34) = 428.5$, $p < .001$. Joy-related concepts received an average rating of 4.14, neutral concept 3.13, and anger concepts of 1.82, with the differences between classes being highly significant ($p < .001$). More important, there was no effect of processing condition (embodied vs. lexical) on the valence of listed concepts, suggesting that in both instruction conditions, participants could generate equally extreme positive and negative properties.

The raters also assessed whether the listed properties were related to emotion (5 = *very emotional*). As expected, there was a large effect of category, $F(2, 34) = 148.22$, $p < .001$, with joy (3.30) and angry (3.31) categories different from neutral (1.52), but not from each other. Again, there was no effect of the processing condition, suggesting that in both instructions conditions, participants listed properties relevant to emotion. Finally, we checked whether valence or audience condition influenced how rich or how abstract the descriptions were and found no effects of valence or audience condition. In summary, these results show that participants could properly perform the behavioral task in both processing conditions. However, our theoretical model assumes that behavior in different conditions reflects different processing mechanisms. The operation of these mechanisms should be visible in physiological data.

EMG Analyses

As noted, we analyzed the EMG data in two ways. First, we examined an initial response to the concept word, focusing on the first 5 s after the concept onset. To represent this more immediate or phasic EMG response precisely, we calculated average baseline-corrected activity in 23 consecutive time windows of 200 ms each (i.e., 600 ms–5,000 ms, with the first 400 ms excluded due to artifacts reflecting the orienting reaction to stimulus onset). We also wanted to understand the more sustained, or tonic responses across the entire 30-s period, as participants continued to generate concept features. To do so, we calculated average baseline-corrected activity in six consecutive time windows of 5 s each (see Simmons et al., 2008, for discussion of the time course of simulation responses).

In both analyses, we looked separately at the activity over the zygomaticus major and the corrugator muscles. However, our predictions primarily focused on the zygomaticus. This is because concept generation (e.g., "What are the features of joy?") is a complex thinking and memory task, which requires active generation of several distinct properties. This is in contrast to concept verification (e.g., "Is joy related to emotion?), which is a simpler thinking task that only requires mapping the concept to its category. The relative difficulty of concept generation task is relevant here because corrugator responds nonspecifically in thinking and retrieval tasks, with more difficult task resulting in more corrugator activity (e.g., van Boxtel & Jessurun 1993). Accordingly, we expected a high level of corrugator activation across time for all concepts and instruction conditions.

Initial response. As mentioned, the purpose of this analysis was to examine the initial phasic EMG response to the presentation of joy versus anger concept classes under different simulation conditions. Figure 5 shows the development of zygomaticus activity in the first 5 s after concept presentation. As one can see, in the simulation condition (see Figure 5, top panel), the zygomaticus response starts to become differentiated by valence (joy vs. anger) around 2 s and reaches the peak differentiation in seconds 3 and 4, and then returning to the tonic level around second 5. In the nonsimulation condition (see Figure 5, bottom panel), the zygomaticus response remains flat throughout each of these periods, including seconds 3, 4, and 5. Furthermore, one can also see that the overall activity level is somewhat elevated in the simulation condition. To examine this pattern statistically, we conducted a 2 (emotion concept) × 2 (processing condition) and 23 (time window) mixed model ANOVA. This analysis revealed a main effect for condition, with overall more muscle activity in the embodiment condition, $F(1, 396) = 7.88$, $p < .05$.

This main effect is qualified by a significant Processing Condition × Emotion Concept × Time interaction, $F(22, 396) = 1.6$, $p < .05$. Specifically, in the embodied simulation condition, there was a greater zygomaticus response to joy versus anger concepts in the later rather than earlier part of the trials (*p*s $< .05$, for joy vs. angry comparison in seconds 3 and 4). Similarly, in the embodied simulation condition, activity in seconds 3 and 4 was significantly elevated over baseline for joy concepts but not for angry concepts (*p*s $< .05$). No systematic elevation of zygomaticus activity was associated with mental states concepts in either condition.

Parallel analyses on the corrugator revealed no significant main effects or interactions involving valence or conditions. The only significant finding was a main effect of the time windows on the overall engagement of the corrugator, $F(22, 396) = 3.22$, $p < .05$. In fact, the overall activity of the corrugator was greatest at the very beginning (1–2 s) and then slightly declined and then went up again in the later portion of the trial (4–5 s, quadratic trend, $p < .01$). Given its nonspecificity, this effect probably reflects the corrugator response to task demands, with the immediate activity reflecting thinking about the concept, followed by recall activity that progressively becomes more difficult as the trial progresses (an interpretation consistent with the more macro analysis, discussed next).

Sustained response (30 s). The sustained EMG activity over the 30 sustained was analyzed in a 2 (processing condition) × 3 (emotion concept) × 6 (time windows of 5 seach) mixed model ANOVA. Critically, this analysis revealed an effect of condition, with the embodied condition associated with more zygomaticus activity than the lexical condition, $F(1, 180) = 5.49$, $p < .05$. This finding supports the prediction that conceptual contexts that should promote simulation are associated with more embodied reactions. Analysis of the zygomaticus also revealed a theoretically uninteresting effect of time, such that overall zygomaticus activation decreased over time, $F(5, 180) = 3.26$, $p < .01$. Analysis of the corrugator muscle revealed no significant effects of condition. However, consistent with the previously discussed analysis of the more immediate response, and the previous work on corrugator and task difficulty, the corrugator activity did not decline over the 30-s period but remained significantly elevated over baseline throughout the trial. This indicates again that participants were actively thinking about the concept features throughout the task.

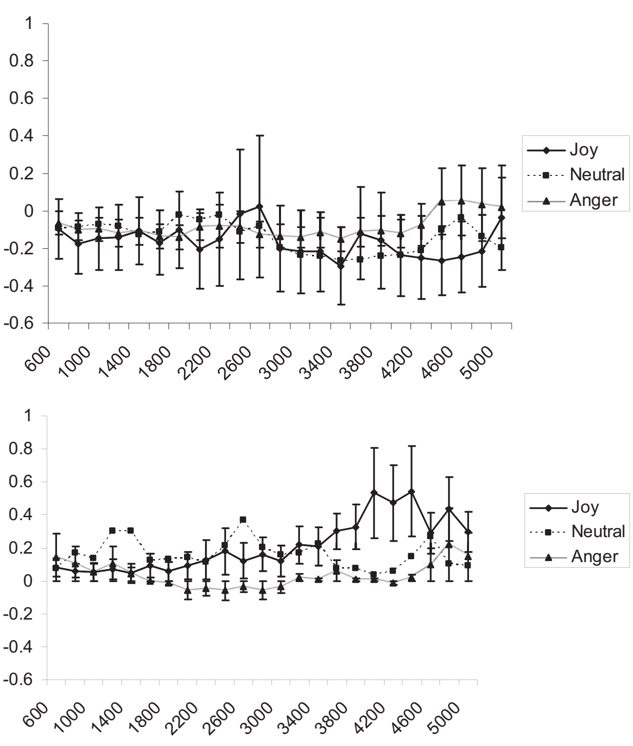

Figure 5. Mean zygomaticus activity by time as a function of emotion concept and simulation condition (top panel, embodied; bottom panel, lexical). For simplicity, error bars (±1 *SE*) are shown only for joy and anger concepts.

Discussion

In Experiment 4, participants performed a property generation task in which they listed the features of joy and anger emotions as well as other abstract mental concepts. Furthermore, participants were to convey this conceptual content either to a "hot" audience that was informal and presumably more interested in bodily aspects of emotion or to a "cold" audience that was formal and presumably more interested in lexical aspects of emotion. EMG activity of muscles related to smiling and frowning was used as an indicator of embodied simulation. We observed that all participants performed the feature generation task equally well, as reflected in the valence and number of generated features. However, those participants who considered the "hot" audience engaged in more facial activity in general and embodied positive emotions (i.e., smiled) when generating positively valenced properties of concepts, as compared with individuals who considered the "cold" audience. Taken together, this demonstration supports a situated cognition view in which the current (social or other) context influences the way in which a concept is represented in a conceptual task and the extent people recruit embodied information to solve it.

General Discussion

The present research was designed to test several novel predictions derived from an embodied simulation account of the processing of emotion concepts using two classic tasks from the concept literature: property verification and property generation. We predicted and found that the conceptual processing of emotion involves somatic responses, as evidenced by relatively discrete facial expressions of emotion. We also predicted and found that somatic responses occurred only when participants needed to access the emotion meaning of the concept but not when they needed to judge perceptual features of the word referent. Furthermore, we found that these findings generalize to concepts referring to concrete emotion objects and also to abstract emotion concepts. We next showed that the embodied responses play a causal role in the processing of emotional concepts and are not simply a side effect of being exposed to emotional information. And finally, the last experiment provided evidence that simulations are produced in a context-sensitive way that depend on requirements and needs of a particular conceptualization. In other words, concepts are situated (Barsalou, 2003; E. R. Smith & Semin, 2007), and emotion concepts derive specific shape in those situations (Clore & Schnall, 2008; Niedenthal et al., 2005).

Participants in our first two experiments performed either an emotion-focused or a letter focused task with concrete concepts of objects that typically elicit anger, disgust, and joy (Experiment 1) or with abstract emotion concepts that referred to the same three emotion categories (Experiment 2). In both studies, four facial muscles were measured that previous studies found to be differentially related to the three emotions. Across the two studies, no specific activation of the muscles occurred during the letter task even though participants were exposed to the words for a relatively long time—time enough for associated somatic responses to be primed automatically (Stroop, 1935). In contrast, in the emotion-focused task, in which participants explicitly judged the emotional nature of the concept, discrete facial expressions specifically related to the categories of emotion were observed, as assessed by EMG methods.

In Experiment 1, activity of zygomaticus (cheek region) and orbicularis oculi (eye region), indicative of smiling, was greater when participants processed concepts related to joy than the other concepts. In addition, the corrugator (brow region) activity was greater for concepts related to anger and disgust compared with neutral emotion and joy, which is expected because this muscle is involved in a number of expressions of negative emotion. Finally, the levator activity (nose region) was greater for concepts related to both disgust and anger than the other types of concepts. The only unpredicted finding in this set was the enhanced levator activity for anger than for the other concepts. This was not anticipated because some studies report levator activity to be associated specifically with disgust (Vrana, 1993), though other studies suggest that levator activity might be associated with multiple emotions (Wolf et al., 2005). However, a look at our stimulus list of concrete words suggests that some words associated with anger (such as *TORTURE* or *GUILLOTINE*) might also induce disgust. In fact, concrete objects, which we were interested in, tend not to elicit pure anger, which is more distinctly represented using abstract situation concepts such as "disrespect," "injustice," and "insult." Indeed, the pretest data are consistent with this interpretation and suggest that the anger category was the least specific of those used in the experiment. This problem was remedied in the second experiment in which we used abstract words that were more exclusively related to anger.

The results of the second experiment substantially replicated those of the first. In addition, however, increased activation in the levator muscle was not observed in the emotion-focused processing of anger concepts. The fact that increased levator activity was observed in the case of processing joy concepts is probably not of theoretical importance and, again, is consistent with evidence for involvement of levator activity in multiple emotions. The innervations of this muscle during joy processing can be due to variations in morphology of the participants from one study to the next. Some individuals, such as Elvis Presley, do indeed show the activation of this muscle in the expression of joy (Pessa & Brown, 1992).

The follow-up Experiment 3 provided evidence for the causal role of facial embodiments in emotion processing. Specifically, when individuals made judgments about whether concepts were related to emotion, they needed to be able to reenact the emotion in order to perform the job with the highest accuracy. Accuracy in this judgment suffered when the ability to express at least the facial expressions of joy and disgust was inhibited. This finding nicely extends the previous evidence for the involvement of facial expressions in emotion recognition to processing of emotion words (Niedenthal et al., 2001; Oberman et al., 2007).

Finally, Experiment 4 was conducted to more specifically address the hypothesis of context-dependent simulation as grounding for conceptual processing of emotion. In that experiment, processing was changed in the very same task (a property generation task) by a manipulation of the situation, via means of intended audience. Specifically, half the participants were led to believe that they were conveying the content of abstract concepts (including emotion ones) to a recipient to whom one would likely produce a "hot" and personal simulation to represent the concept. The remaining participants were led to convey this content to someone to whom one would likely produce a "cold" and impersonal representation, perhaps involving associations in lexical memory. Indeed, results showed that individuals who were in the condition that invited multimodal simulation showed elevated zygomaticus activity during property generation in general, and positive property generation in particular.

Summary of Contributions

These findings make a number of important contributions. First, note that in Experiments 1 and 2, the stimuli were simple words. Words are arbitrary symbols and thus do not have perceptual features that in some way naturally elicit somatic responses in the perceiver. In fact, we observed no such responses when participants in the letter task. The stimulus responsible for those responses, then, must have been the meaning of the word to be processed. Accordingly, we found that at least one component of emotion, the corresponding facial expression, was stimulated when the emotion content was required for task performance. This is particularly notable for the abstract concepts.

It is worth highlighting how this finding differs from earlier observations that emotional imagery triggers bodily signs of the corresponding emotion. For instance, Grossberg and Wilson (1968) asked participants to imagine themselves in various situations. Half of the situations had been evaluated by each participant as fearful and the other half as neutral. Results showed significantly greater changes in heart rate and skin conductance for fearful situations than for neutral ones (see Lang, Kozak, Miller, Levin, & McLean, 1980; Vrana, Cuthbert, & Lang, 1989; Vrana & Rollock, 2002). Schwartz and his colleagues extended these findings to positive and negative affect and found in a series of directed imagery experiments that pleasant imagery elicited greater activity over zygomaticus major, whereas unpleasant imagery elicited greater activity over corrugator supercilii (Brown & Schwarz, 1980; Schwartz, Fair, Salt, Mandel, & Klerman, 1976). Such results suggest that when individuals are directed to spend time imagining emotional situations, they show corresponding physiological responses. These previous results are consistent with an embodied simulation account, but they say little about how individuals represent conceptual content. We mentioned that in the view of amodal representational models, referents of words do not need to be simulated in sensory, motor, or affective systems. This is because concepts are mentally represented using a system of abstract propositions implemented as a semantic network or as feature lists. Thus, it is particularly telling that in our studies, even fast conceptual judgments about concrete words, and especially abstract words, were accompanied by embodied simulations of the emotion. Our interpretation is that the accompaniment is not epiphenomenal, but constitutes an indication that the conceptual content for the emotion concepts involves reenactments of the emotional states themselves. This interpretation is strengthened by the absence of simulation in the letter task condition, which exposed participants to the same emotion words but did not require access to their conceptual content. Note also that in this condition, participants did have to perform a task (i.e., they were not passive observers of the words, a condition that may have involved some somatic simulation), but this task could be performed on the basis of perceptual features of the words (i.e., whether they were written in capital or small letters) and not their emotional content.

Another novel contribution of these studies is the findings in both Experiments 1 and 2 that facial muscular responding during conceptual processing was emotion *specific*. This specificity, rather than the presence of a generalized somatic response, supports the interpretation that the embodied responses constituted the meaning of the concepts. Note that participants' task in both studies was to say whether the concept was linked to an emotion. Thus, participants were not obliged to indicate explicitly the type of emotional response or state that constituted the concept they were acting on. Even though the judgment itself was not emotion specific, the embodied response was. Such a finding suggests that participants simulated the concept in order to answer the more general emotion question. Because the concepts, both concrete and abstract, were related to discrete emotions, the simulations were also emotion specific.

Finally, taken together, the follow-up Experiment 3 and Experiment 4 provide convergent evidence for the conclusion that the embodiment of emotion serves as conceptual grounding and does not simply reflect automatic emotional responses to seeing emotion words or thinking about emotion concepts per se. Specifically, the follow-up study shows (as previous studies have) that embodiment is causally important in conceptual processing. And Experiment 4 shows, further, that the manipulation of situational factors can alter the nature of the process of representing a concept. An embodied simulation occurs only under the expected conditions: when generation of the embodied information would provide information that is useful for the task at hand.

Alternative Hypothesis Testing

The task conditions used in Experiments 1 and 2 were used in part to distinguish between hypotheses derived from an associative network account of the representation of emotion knowledge and an embodied simulation one. We suggested that the associative network model would most naturally predict emotional responding in all processing conditions used in our experiments, given the types of concept stimuli used. However, regarding the design used in Experiments 1 and 2, one could object that even an associative network model of emotion would predict emotional responding when making an emotion judgment but not when making a judgment about the physical appearance of a word with an emotional meaning. In other words, one might argue that the two models could be viewed as making equivalent predictions for Experiments 1 and 2.

We believe that such an objection relies on a too-facile understanding of associative network models. The remarkable thing about priming as accounted for by associative network models is its efficiency. The automatic spread of activation that occurs during priming is, by its name, automatic. Thus, these models do not a priori hold that task type influences the automatic spread of activation. Rather, they state that efficiency in priming is determined by strength of association. Our pilot testing assured that the words we selected for each category of emotion had a strong association to the emotion of theoretical interest. Thus, it would seem that exposure to the concepts would have produced facial expressions through automatic spread of activation, if such a process indeed occurs. In a more general way, semantic network models cannot make precise predictions about what type of embodied simulation should support what type of task. Instead, they predict that strength of association will determine what representation is primed. They further posit no causal role for embodiment in task performance, which is inconsistent with the findings of the follow-up Experiment 3.

Furthermore, the word stimuli used in Experiment 2 were actually synonyms for the three emotional states. Shaver et al. (1987), among other researchers, have shown that facial expressions are highly diagnostic features of emotion concepts. Because diagnostic features are in theory highly associated with the relevant concept in memory, an associative network account of the grounding of emotion concepts would therefore predict a spread of activation to the word *smile* (for instance) by the mere activation of the word *delight*. In other words, one would have to predict that even in the letter task condition of Experiment 2, automatic spread of activation from the concept to a facial expression would have occurred and been detectable. Thus, we maintain our contention that the associative network model of emotion concepts makes different predictions for the two tasks used in Experiments 1 and 2, and we also maintain that the specifics of the conditions of the reported experiments indeed permitted alternative hypothesis testing.

Emotional Responding or Emotion Simulation

One question that arises from all of the present studies concerns the notion of emotion simulation. An objection to the use of the term *simulation* could be that we have no evidence that emotions were being "partially reenacted" in order to perform the critical experimental tasks. It could be that our findings on EMG measures reflect the fact that the tasks provoked (new) emotional responding. For instance, according to our account, the judgment that a "slug" is associated with an emotion involves only a partial and fast reactivation of neural states that constitute "being there" with the slug (that is, a multimodal simulation). As we have argued, because it is required for the emotion task, part of the simulation would include affective responding to the slug. The present objection could hold that repeated associations of slug with disgust in the past would elicit the disgust (and attendant facial expression) in the experiment. What is the difference between this "new" real emotion and an emotion simulation?

In theory, there are a number of factors that distinguish simulation and a genuine, full-blown emotional response to an object. One has to do with efficiency. What is it like emotionally to actually, say, step barefoot on a slug? The tactile processing is followed by a focus of visual attention to the slimy brown (or yellow in the case of banana slugs) object. Sometime during this sensory processing, one feels the shudder of disgust and then makes expressive displays of that emotion. An energetic action of jumping away might also occur. Although a simulation, which we hold grounds the ability to say that a slug is associated with an emotion, should involve the activation of corresponding neural states, it would not involve the full-blown experience, as just described, unless there was time and motivation to relive the whole thing. A simulation can, according to the various possible accounts, be processed in "as if" central somatosensory loops, which take place in a more rapid and incomplete way than the coordinated peripheral and central processes of full-blown emotion (Damasio, 1994). A mirror system account also distinguishes between an actual emotional experience and a simulation. In empathic responding to pain or to emotion, mirror systems show overlapping, but not identical, activity during actual own experience versus perceived experience (e.g., Decety, Michalska, & Akitsuki, 2008; Jackson, Rainville, & Decety, 2006). The results of such studies do not point to the conclusion that people are in (freshly evoked) pain because they see another person feeling pain but rather suggest that individuals can understand and make inferences about this experience through simulation of partial aspects of the emotion.

Other empirical considerations are also worth mentioning. In Experiment 4 of the present research, we invited individuals to generate properties of emotion concepts. Participants who were put in a situation that would lead them to simulate the hotter aspects of an emotion, or, in other words, to produce features based on simulations of the state, showed a greater tendency to express emotion facially. However, individuals in a condition in which such simulation was not expected still performed the same task. They generated appropriate features of the emotional states in question. Why would the same task elicit a "new" emotion in participants in the former but not the latter condition? The more likely explanation is that those who construed an audience for whom hot features of emotion would be appropriate generated multimodal simulations and then "read off" the features of that emotional experience. In contrast, those who construed an audience for whom hot features were less appropriate used a different strategy that did not involve simulation in the affective system.

Conclusion

Emotion concepts are fundamental for an understanding of the social world, as they help individuals interpret the attitudes, behaviors, and intentions of other individuals. Emotion concepts are also fundamental to the development of an individual's behavioral repertoire. An example of this role of emotion concepts in the development of an individual's behavioral repertoire is that of instructed fear learning. Telling a child that a particular object or event will be frightening, he can, even relatively early in cognitive development, avoid that object or event without ever having to experience the pain or fear with which it is (said to be) associated. The example of instructed fear learning is noteworthy because it demonstrates that individuals' concepts of "fear" are powerful enough to importantly guide future behavior. This makes the understanding of emotion concepts vital for a full account of human behavior.

Surprisingly, the literature on the representation and processing of emotion concepts is quite small, but most accounts rely on the assumption that emotions are characterized mentally by a set of amodal symbols. An alternative account, an embodied simulation account, guided the present research. The reported findings suggest that the account is a viable one for the understanding of the processing and storing of emotional knowledge.

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