Grounding Emotion in Situated Conceptualization

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Abstract

According to the Conceptual Act Theory of Emotion, the situated conceptualization used to construe a situation determines the emotion experienced. A neuroimaging experiment tested two core hypotheses of this theory: (1) different situated conceptualizations produce different forms of the same emotion in different situations, (2) the composition of a situated conceptualization emerges from shared multimodal circuitry distributed across the brain that produces emotional states generally. To test these hypotheses, the situation in which participants experienced an emotion was manipulated. On each trial, participants immersed themselves in a physical danger or social evaluation situation and then experienced *fear* or *anger*. According to Hypothesis 1, the brain activations for the same emotion should differ as a function of the preceding situation (after removing activations that arose while constructing the situation). According to Hypothesis 2, the critical activations should reflect conceptual processing relevant to the emotion in the current situation, drawn from shared multimodal circuitry underlying emotion. The results supported these predictions and demonstrated the compositional process that produces situated conceptualizations dynamically.

Until recently, conceptualization has played a relatively peripheral role in theories of emotion (but see Fehr & Russell 1984; Russell, 1991; Russell & Fehr, 1994). In basic emotion approaches (e.g., Allport, 1924; Ekman, 1972; Izard, 1971; MacDougall, 1928/1908; Panksepp, 1998; Tomkins, 1962, 1963), the central hypotheses are that emotions reflect an inborn instinct, and that the mere presence of relevant external conditions triggers evolved brain mechanisms in a stereotyped and obligatory way (e.g., a snake triggers the fear circuit; Ohman, Carlsson, Lundqvist, & Ingvar, 2007; Ohman & Mineka, 2001). In appraisal approaches to emotion (e.g., Arnold, 1960a,b; Ellsworth & Scherer, 2003; Frijda, 1986; Lazarus, 1991; Roseman, 1991), the central hypotheses are that emotions arise from a meaning analysis of the situation in terms of goals, needs, or concerns, and that these conceptualizations of external situational conditions elicit basic emotions independent of any further conceptual processing. In both basic emotion approaches, emotions exist independently of human concepts for them. The cognitive system might conceptually represent what an emotion is and what is likely to occur when one is elicited, but these conceptualizations do not play central roles in emotion itself.

Recent theoretical developments, however, give conceptualization a central role in the construction of emotional episodes (Barrett, 2006a, 2009a). According to this approach, conceptualizing a situation in a particular way causes it to be experienced as an emotion (where by *situation* we mean not only an environmental setting and the physical entities and agents it contains, but also the dynamic actions that agents perform, and the events, interoceptive sensations, and mentalizing they experience). As the brain represents successive situations one after another, conceptual interpretation of each situation—sometimes taking the form of an emotion—creates a unified, meaningful representation of subjective experience, cognition, and the body in context, and then controls subsequent experience, cognition, and action.

In this article, we begin by presenting a grounded theory of the conceptual system that underlies our account of how conceptualization produces emotion. The theory's central assumptions are: (1) a concept is grounded in the systems for perception, action, and internal states that process its instances; (2) the situated conceptualization that represents a concept on a specific occasion emerges from a network of concepts to represent the concept coherently in the current situation; (3) situated conceptualizations represent abstract concepts, including emotion concepts; (4) once active, situated conceptualizations produce subsequent actions, internal states, and perceptual construals. After laying this theoretical groundwork, we present the Conceptual Act Theory of Emotion in which situated conceptualizations for emotion concepts play the central role in producing emotion. Finally, we present an experiment that tests two key hypotheses of Conceptual Act Theory: (1) different situated conceptualizations represent an emotion concept (e.g., fear) in different situations; and (2) the composition of situated conceptualizations reflects diverse contributions from distributed neural circuitry that produces emotional states dynamically.

A Grounded Theory of the Human Conceptual System

In this section, we summarize a theory of concepts developed elsewhere (e.g., Barsalou, 1999, 2003a,b, 2005a,b, 2008a,b,c; Simmons & Barsalou, 2003). Specifically, this theory assumes that concepts are grounded in situations, the body, and the brain's modal systems for perception, action, and internal states[1] (e.g., Anderson, in press; Martin, 2001, 2007; Damasio, 1989; Meyer & Damasio, 2009). We focus on non-emotion concepts initially to illustrate properties of the human conceptual system. In the subsequent section, we extend these properties to emotion concepts in the Conceptual Act Theory of Emotion. Much detail will be omitted from these accounts that can be found in the articles referenced (and especially in Barrett, 2006a; Barrett, Barsalou, Lindquist, & Wilson-Mendenhall, 2010).

Concepts. A concept aggregates information about category instances into some sort of integrated representation (e.g., Barsalou, 2003a, 2005a; Barsalou & Hale, 1993; Murphy, 2002). The concept of *car*, for example, aggregates diverse information about cars into a loosely organized representation that includes properties (e.g., engine), relations (e.g., drivers operate cars), prototypes (e.g., the typical car is a sedan), rules (e.g., for something to be a car, it must use an engine that drives four wheels to transport a small number of people along a road), and exemplars (e.g., instances of sedans, coupes, station wagons, etc.).[2]

Concepts develop for aspects of experience that are relevant repeatedly across situations. Because cars are a frequently relevant aspect of experience, a concept develops in memory to represent them. Concepts similarly develop for other diverse aspects of human experience, including objects, agents, and settings in physical situations (e.g., *keys, mechanics, garage*). Additionally, concepts develop to represent the behavior of objects, agents, and settings (e.g., *skidding, driving, bustling*). From simpler concepts, more complex concepts emerge for events (e.g., *trip*). Concepts similarly develop for a wide variety of internal states including interoceptions and mentalizing (e.g., *thirst, fatigue, doubt*), as well as for the properties and relations that describe instances of concepts (e.g., *blue, slow, intense, above, after, cause, intend*). Although concepts reflect experience to a considerable extent, they undoubtedly have biological bases that scaffold learning (Barsalou, 1999, 2008a; Carey, 2009; Rips, 2010; Simmons & Barsalou, 2003).

Theory and research strongly suggest that concepts do not have conceptual cores, namely, conceptual content that is necessary and sufficient for membership in the associated category. In a famous philosophical argument, Wittgenstein's (1953) concluded that a conceptual core cannot be found for the category of *games* (e.g., no property is true of all category members). Since then, researchers have similarly argued that natural categories do not typically have conceptual cores. Instead, loosely distributed similarity relations between category members—taking the form of a family resemblance or radial category—appear to structure most categories (e.g., Lakoff, 1987; Rosch & Mervis, 1975).[3] Nevertheless, people often believe mistakenly that categories do have cores, even when clear exceptions exist (e.g., Brooks & Hannah, 2006), perhaps because a word for the category that always takes the same form implies that a stable conceptual core analogously represents its meaning (e.g., Barsalou, 1989; James, 1950/1890). Theories of psychological essentialism similarly note people's (often unjustified) propensity for creating conceptual cores (e.g., Gelman, 2003).

Exemplar theories of categorization further illustrate that loose collections of memories for category members can produce sophisticated classification behavior, demonstrating that abstractions for prototypes and rules are not necessary (e.g., Medin & Schaffer, 1978; Nosofksy, 1984). Neural net systems similarly demonstrate that only loose statistical coherence is necessary for sophisticated categorization (e.g., McClelland & Rumelhart, 1985). To the extent that abstraction does occur for a category, it may only occur partially across small sets of category instances (e.g., Medin & Ross, 1989; Spalding & Ross, 1994); it may primarily reflect the abstraction of non-defining properties and relations that can be used to describe category members in a dynamcial manner (e.g., Barsalou, 2003a, 2005a); it may reflect online abstraction at retrieval, rather than stored abstractions in memory (e.g., Hintzman, 1986).

The absence of conceptual cores will play a central role in our account of emotion concepts. From hereon, our treatment of concepts assumes that they do not have cores but are instead represented by loose collections of situated exemplars, accompanied by the various forms of limited abstraction just noted.

Once concepts become established in memory, they play central roles throughout cognition, supporting perception, categorization, inference, and many other processes (e.g., Barsalou, 2003b; Murphy, 2002). As people experience a situation, they categorize the agents, objects, setting, behaviors, events, properties, relations, bodily states, mental states, and so forth that are present. As some aspect of experience is perceived, it projects onto all concepts in parallel, with concepts competing to categorize the aspect, with the best-fitting concept winning (e.g., McClelland & Rumelhart, 1981). Once an entity has been categorized, categorical inferences follow, including inferences about how the entity is likely to behave, how one can best interact with the entity, the likely value to be obtained from interacting with the entity, and so forth. Such inferences result from accessing category knowledge associated with the concept used to categorize the current instance, and then generalizing this knowledge to the instance.

Multiple modalities underlie concepts. Concepts originate and operate in the context of continuous situated activity (Barsalou, 2003b, 2005b, 2008c; Barsalou, Breazeal, & Smith, 2007; Yeh & Barsalou, 2006). As situated activity unfolds, numerous modalities and systems that process perception, action, and internal states respond continually (e.g., vision, audition, motor planning and execution, interoception, mentalizing, attention, reward, affect, executive processing, language, memory, reasoning). Depending on the concept, a particular profile of modalities and systems is more or less relevant (e.g., Cree & McRae, 2003). For example, the modality of audition is often relevant for *musical instruments* but not for *fruit,* whereas the modalities of taste and smell are often relevant for *fruit* but not for *musical instruments (*which is not to say that audition is unimportant for representing a crunchy apple or that smell is irrelevant for representing an old wooden guitar). In general, the informational content of a concept can be viewed as a collection of the multimodal information that has been experienced and processed for its instances. Depending on the particular modalities relevant, the resulting profile of activity becomes stored in distributed neural circuitry that processes the concept, thereby creating a multimodal representation of the relevant processing that typically occurs.

Extensive evidence now exists that different kinds of concepts emerge from different multimodal systems in the brain (cf. McClelland, 2010). Depending on the modalities relevant for processing a concept's instances, particular modal areas of the brain store information about the category and can later represent the category in the absence of actual instances. Martin (2001, 2007), for example, has shown that different multimodal profiles represent living vs. non-living things. Other research has similarly established the multimodal profiles that represent the self and others (e.g., Northoff et al., 2006; Van Overwalle, 2009; cf. Legrande & Ruby, 2009), people, buildings, and tools (e.g., Simmons, Reddish, Bellgowan, & Martin, 2010), the external world vs. internal states (e.g., Golland, Golland, Bentin, & Malach, 2008), and so forth.

Situated conceptualizations. Concepts are rarely represented in a vacuum. When the concept for *car* becomes active, it is not represented in isolation, floating in space, but is instead represented in a meaningful background situation (e.g., Barsalou, 2003b, 2005b, 2008c; Barsalou, Niedenthal, Barbey, & Ruppert, 2003). A *car*, for example, might be represented in a garage, parking lot, or gas station, or on a dirt road or highway. Many empirical studies demonstrate the extensive presence of situational information as people represent and use concepts (e.g., Bar, 2004; Barsalou & Wiemer-Hastings, 2005; Chaigneau, Barsalou, & Zamani, 2009; Wu & Barsalou, 2009; for a review, see Yeh & Barsalou, 2006).

We refer to the representation of a concept in a background situation as a *situated conceptualization*. Typically, situated conceptualizations include a setting, agents, objects, behaviors, events, and internal states, each represented by relevant concepts. Thus, the representation of a car on a particular occasion exists within a network of background concepts that represent elements of the entire situation. Furthermore, tremendous diversity exists in the particular background concepts that situate a concept on different occasions. Rather than the concept being represented in a rigid manner across situations, it is represented in widely varying sets of background concepts that contextualize it in each situation.

From the perspective of grounded cognition, situated conceptualizations are also responsible for producing the action, internal states, and perceptual construals that underlie goal-related activity in the current situation. Because modalities for action, internals states, and perceptual construals are typically active when a concept is learned, situated conceptualizations generate activity in these systems as they become active on later occasions. On activating the concept for *apple,* a situated conceptualization might activate representations of actions for eating the apple, representations of internal states such as satiation and pleasure, and perceptual construals that distort taste toward the typical taste of an apple (e.g., Goldstone, 1995; Hansen, Olkkonen, Walter, Gegenfurtner, 2006). Not only does *apple* represent instances of the concept, it also controls interactions with instances and predicts the resultant events.

In Barrett et al. (2010), we further proposed a distinction between concepts that have situated conceptualizations as backgrounds vs. concepts that *are* situated conceptualizations. In general, concrete concepts such as *chair* refer to part of a situation and are contextualized when surrounding background concepts represent the remainder of a situation in a situated conceptualization (e.g., concepts for living room, sitting, feeling comfortable). Conversely, abstract concepts such as *convince* typically refer to an entire situation, not just to part of one, such that an entire situated conceptualization represents them. C*onvince*, for example, integrates an agent, other people, an idea, communicative acts, and possible changes in belief, all organized with a variety of relations, such as the relation of one person having an idea, talking with another, conveying the idea to the other, attempting to change a belief, and so forth (Wilson-Mendenhall, Simmons, Martin, & Barsalou, 2010). In other words, abstract concepts like *convince* are relational structures that integrate many different concepts in a situated conceptualization.

Finally, we assume that many situated conceptualizations are associated with a given concept, reflecting the variety of situations in which it is experienced (Barsalou, 2003b, 2008c). For *convince,* different situated conceptualizations represent convincing a friend, parent, policeman, mugger, audience, and so forth. In each situation, the respective conceptualization supports situated interaction in the relevant situation. Rather than the category having a conceptual core, a set of situated exemplars represents it that exhibit family resemblance and radial structure, accompanied by limited abstractions.

The Conceptual Act Theory of Emotion

In the Conceptual Act Theory of Emotion, we propose that emotion concepts are abstract concepts that work in fundamentally the same as way as other kinds of abstract concepts. Like other abstract concepts, emotion concepts aggregate diverse information within an instance, referring to an entire situation, not just to part of one. Like other abstract concepts, emotion concepts support categorization and inference, and also control subsequent action, internal states, and perceptual construals. Like other concepts, emotion concepts do not have conceptual cores but are represented by loose collections of situated conceptualizations. In this section, we first address the role of situated conceptualizations in representing emotion, and then address multimodal contributions to emotion concepts. Finally we address the roles of emotion concepts in producing the conceptual acts that generate emotion. Further detail on this account can be found in Barrett (2006a) and Barrett et al. (2010).

Situated conceptualizations represent emotion concepts. A key assumption of our theoretical approach is that emotion concepts, like other abstract concepts (e.g., *convince*), refer to entire situations, and thereby represent settings, agents, objects, actions, events, interoceptions, and mentalizing. In other words, an emotion concept is a relational structure that integrates multiple parts of an experienced situation.

We further assume that a specific emotion concept contains a large set of situated conceptualizations that produce emotion in many different kinds of situations, with each situated conceptualization producing a different form of the emotion. Consider one possible situated conceptualization associated with *fear*, where a runner becomes lost on a wooded trail at dusk. In this situated conceptualization, concepts for *forest, night, animals, thirst, confusion,* and many others become integrated meaningfully to represent *fear*, including the associated internal experience and potential actions. Consider another possible situated conceptualization associated with *fear,* where someone is unprepared to give an important presentation at work. In this situated conceptualization, a different set of concepts represents the situation, including *presentation, speaking, audience, supervisor,* and many others. Again, the integrated representation of diverse concepts into a situated conceptualization constitutes an instance of *fear,* including associated internal experience and action.

From this perspective, *fear* cannot be understood independently of an agent conceptualizing his- or herself in a particular situation. This is not a new insight about emotion but one that emerged in the first half of the 20th century, appearing, for example, in the writings of William James (1994/1894, p. 206). *Fear* can look and feel quite differently in different instances. When you fear a flying cockroach, you might grab a magazine and swat it; when you fear disappointing a love one, you might think of other ways to make them feel good about you; when you fear a mysterious noise late at night, you might freeze and listen; when you fear giving a presentation, you might ruminate about audience reactions or over-prepare; when you fear getting a flu shot, you might cringe anticipating the pain; when you fear hurting a friend’s feelings, you might tell a white lie. Sometimes you will approach in fear, and sometimes you will avoid.

Sometimes your heart rate will go up, and sometimes it will go down. Whatever the situation demands.

The presence of diverse situated conceptualizations for an emotion explains the Emotion Paradox (Barrett, 2006a,b; Barrett, Lindquist et al., 2007). If, as basic emotion theorists assume, an emotion like *fear* is associated with a module that always executes in the same manner to produce the same stereotyped cascade of responses, then why do the neural and bodily states associated with *fear* show tremendous variability across instances (for reviews of this variability, see Barrett, 2006b; Barrett, Lindquist et al., 2007; for a discussion see Barrett, 2009a)? Situated conceptualizations offer a natural account of this variability: If different situated conceptualizations represent the same emotion category, then differences among them across all the modalities and systems that process settings, actions, and internal states are likely to produce considerable variability in facial actions, heart rate patterns, breathing patterns, and neural activations. Furthermore, because there is not one bodily signature for each emotion, the same body state across different situations can be conceptualized as different emotions, depending on the situated conceptualization active to interpret it (cf. Dunlap, 1932).

Finally, as described earlier for concepts in general, we assume that the situated conceptualizations representing an emotion bear loose similarity relations to one another, as in a family resemblance or radial category. To the extent that abstractions exist for an emotion, they are not core properties but instead represent relevant information within particular situations, or non-defining properties used to describe the emotion across situations. The low consistency of emotion markers—facial actions, heartrate, breathing, skin conductance, action, and neural activity—across reviews and meta-analyses support the lack of core conceptual content for emotions (e.g., Barrett, 2006b; Barrett, Lindquist, et al., 2007; Kober, Barrett et al., 2008; Lindquist et al., submitted; Wager, Barrett, et al., 2008), implying that loose collections of exemplars represent emotions instead (Barrett, 2006a; Fehr & Russell, 1984; Russell, 1991; Russell & Fehr, 1994).

Composed vs. stored situated conceptualizations. So far we have focused on situated conceptualizations stored in memory that represent concepts, including emotion concepts. We further assume, however, that novel situated conceptualizations are composed online, tailored to the current situation (e.g., Hoenig, Sim, Bochev, Herrnberger, & Kiefer, 2008). Again, imagine being unprepared for a presentation at work and experiencing fear. If similar experiences have occurred previously, then a situated conceptualization that represents them might be retrieved to generate inferences about the current situation and guide behavior. If, however, the current situation is not exactly like any of these previous situations, the situated conceptualization retrieved may be adapted somewhat, incorporating important information from the situation, and retrieving further elaborative information from memory to integrate all the active information coherently. As a result, a novel situated conceptualization is composed online, different from other situated conceptualizations stored in memory for *fear*. In turn, the composed conceptualization becomes stored with *fear*, augmenting its stored collection of situated conceptualizations.

As this example illustrates, we assume that situated conceptualizations exist in two forms. On the one hand, memories of previous situated conceptualizations represent a concept in memory. On the other hand, new conceptualizations are composed online that combine a stored conceptualization with information about the current situation and other information in memory needed to integrate them. This relation between stored and composed conceptualizations will be central in drawing predictions for the experiment later and for explaining its results.

Multiple modalities and systems represent emotion concepts. Like all concepts, emotion concepts originate and operate in the context of continuous situated activity, with situations typically including a physical setting, agents, objects, and actions in the world, interoceptive sensations from the body, and mentalizing related to prospective and retrospective thought. Over the course of situated activity, numerous modalities and systems in the brain and body respond continually to represent the situation, including exteroceptive perception, interoception, core affect (valuation and salience processes that underlie experiences of pleasure/displeasure and arousal), attention, categorization, executive processing, episodic memory, action, language, reasoning, and so forth.

Meta-analyses of emotion research support the hypothesis that multiple modalities and systems are engaged during the experience and perception of emotion (Kober, Barrett et al., 2008; Lindquist et al., submitted; Wager, Barrett, et al., 2008). Furthermore, diverse studies on animals, patients with brain damage, electrical brain stimulation, and brain imaging clearly show that different emotion categories do not correspond consistently and specifically to distinct brain modules (for reviews, see Barrett, 2006b, 2009a; Barrett et al., 2007). For example, subcortical circuits involving the periaqueductal gray (PAG) underlie individual behavioral adaptations for freezing, defensive aggression, and withdrawal, respectively (Bandler, Keay, Floyd, & Price, 2000; Bandler & Shipley, 1994), and an increase in PAG activity is evident in a meta-analytic summary of neuroimaging studies on emotion (Kober et al., 2008). Notably, however, these circuits do not correspond to particular emotion categories in a one-to-one fashion (Barrett, 2009a; Barrett et al., 2007). Even rats display various combinations of freezing, defensive aggression, and withdrawal when faced with a threat assumed to produce a fear state, varying with the situational context (Bouton, 2005; Fanselow, 1994; Iwata & LeDoux, 1988; Reynolds & Berridge, 2002; Vazdarjanova & McGaugh, 1998; cf. Barrett, 2009a).

Rather than there being a unique module in sub-cortical brain areas for an emotion like fear, emotions appear to result from distributed circuitry throughout the brain that implements perception, action, interoception, core affect, attention, executive processing, memory, language, reasoning, and so forth. Indeed previous meta-analyses of brain areas active for emotion across various tasks have consistently found that distributed circuitry referred to as a "neural reference space" or a "neural work space" produces emotion (Barrett, 2009b; Barrett, Mesquita et al., 2007; Lindquist et al., submitted). Within this distributed circuitry, diverse brain states for a given emotion arise, each corresponding to a different situated conceptualization. Rather than a discrete module implementing an emotion, distributed circuitry across the emotion reference space produces an infinite number of situation-specific neural assemblies. Furthermore, the assemblies associated with the instance of one emotion category are not functionally specific, given that they can overlap considerably with assemblies for instances of other emotions.

Within the distributed neural circuitry that produces emotion, the particular processing areas critical for a specific emotion concept are typically active across multiple emotions, and also for basic cognitive processes (e.g., Duncan & Barrett, 2007; for a similar view, see Pessoa, 2008). As demonstrated by a recent meta-analysis of the neuroimaging literature (with both methodological and statistical advantages over previous meta-analyses; Wager et al., 2007), the brain areas active during both the perception and the experience of anger, disgust, happiness, sadness, and fear exhibited substantial overlap (Lindquist et al., submitted). All emotion states except the experience of fear (but including the perception of fear) were associated with significant increases in amygdala activation, consistent with the idea that the amygdala is important for representing anything with motivational relevance, particularly if uncertainty is present. Similarly, most emotions were associated with significant activation in anterior insula, likely because this part of the insula is particularly important for representing affective feelings in awareness (Craig 2002, 2009). Dorsomedial prefrontal areas were also active across emotions, because representing self and others is often important (Mitchell, 2009a; Northoff et al., 2006; Van Overwalle, 2009). Similarly, orbitofrontal cortex was active across emotions to represent affect and expected outcomes in a context-sensitive manner (Kringelbach & Rolls, 2004; Schoenbaum & Esber, 2010), as were a host of other areas typically involved in language, executive attention, and social processing (e.g., lateral prefrontal cortex, the temporal poles, and temporo-parietal junction). Of course, we are not claiming that there are no differences how the brain implements different examplars for an emotion concept. The brain state for a situated conceptualization of *fear* can be distinguished from one for *anger*, or even a different situated conceptualization for *fear*, given that each situated conceptualization reflects a different pattern across modalities. Instead, the claim is that all emotions draw on shared distributed circuitry throughout the brain, with each situated conceptualization representing a different pattern in neural space.

In general, the distributed circuitry that produces a specific instance of emotion can be viewed as the set of brain areas required for processing the information that is currently relevant. As described earlier for concepts in general, the modalities that become active to represent a concept reflect the relevant information that must be processed (e.g., Cree & McRae, 2003; Martin, 2001, 2007; Northoff et al., 2006; Van Overwalle, 2009; Simmons et al., 2010; Golland, et al., 2008). To the extent that different instances of the same emotion require the processing of different information, they should draw on different brain regions. To the extent that instances of the two different emotions require processing similar information, they should draw on similar brain regions.

Conceptual acts produce emotion during situated activity. Because emotions occur in the context of situated activity, multiple systems in the brain and body represent this activity continually, including systems that underlie perception, action, attention, executive control, core affect, interoception, episodic memory, language, and mentalizing. As these systems respond continually to represent and control situated activity, conceptual acts occur periodically that classify certain patterns of multimodal activity as emotions.

Initially, a stored situated conceptualization for an emotion concept classifies a complex distributed pattern of activity as an instance, which is then elaborated with situationally-relevant information to compose an online conceptualization. Within milliseconds, via pattern completion mechanisms, the resulting situated conceptualization has the potential to change core affect and other bodily responses associated with the emotion, along with relevant actions and perceptual construals. Most importantly, the situated conceptualization determines the emotion experienced—what we mean by a *conceptual act*. Because the conceptualization is grounded in modalities for perception, action, and internal states, and because it controls these modalities, emotion emerges from its activation—the conceptualization does not merely describe the emotion symbolically. Importantly, we assume that these conceptual acts are typically *not* conscious deliberate events, but are often unconscious and relatively automatic, analogous to how perception, action, and cognition often proceed unconsciously (Barrett, 2006a; Barrett et al. 2010), although they are likely not free from the influences of executive attention (Barrett et al., 2004; Lindquist & Barrett, 2008).[4]

Initiation and control of bodily states, action, and perceptual construal. As a situated conceptualization for an emotion concept is composed online, it produces a variety of responses via pattern completion inferences. Although a person is always in some state of core affect (pleasure or displeasure with some degree of arousal; Barrett, 2006a; Barrett & Bliss-Moreau, 2009; Russell & Barrett, 1999), a situated conceptualization has the capacity to shift core affect toward a state typically experienced during emotion episodes for a particular kind of situation. Along with core affect, the situated conceptualization produces related changes in bodily states, such as muscle tension and visceral activity. Additionally, the situated conceptualization may initiate relevant actions that are typically associated with the emotion in this situation, with core affect and bodily states often motivating and energizing these actions. Finally, the situated conceptualization may produce perceptual construals of the current situation, biasing and distorting perception toward typical experiences associated with the respective type of situation. Importantly, because many situated conceptualizations can represent a particular emotion concept, each is likely to produce different pattern completion inferences across bodily states, action, and perceptual construal, leading to a wide variety of emotional responses.

Again consider situated conceptualizations for *fear*. If someone experiences becoming lost in the woods at night, a relevant situated conceptualization for *fear* becomes active. As a result, core affect might shift into feelings of strong negative valence, which initially encourage freezing behavior but that then increase arousal significantly, thereby energizing subsequent actions, such as searching memory and the environment for the correct route. During this evolving process, noises in the forest may be construed perceptually as ominous and threatening. Analogously, as someone stumbles through a work presentation unprepared, a situated conceptualization for *fear* in this situation becomes active. As a result, core affect might shift info feelings of negative valence, suggesting that a problem has just arisen, and it might increase arousal, thereby energizing the executive system to generate a compensatory strategy. The situated conceptualization may further engage the attentional system to focus on the supervisor, and to inhibit the motor system from performing further actions unless absolutely necessary. At the same time, the supervisor's facial actions may be construed perceptually as conveying intense disappointment. As these examples illustrate, when a situated conceptualization stored with an emotion concept becomes active, it has multiple concrete effects on perception, action, and internal states. It produces the emotion.

Overview and Predictions

We present a neuroimaging experiment that tests the core hypotheses about emotion concepts in the Conceptual Act Theory of Emotion. Specifically, the experiment assessed Conceptual Act Theory's hypotheses that different situated conceptualizations represent the same emotion when it is experienced in different situations, and that the composition of a situated conceptualization reflects contributions from diverse sources of information in the distributed neural circuitry that produces emotion.

Experiment overview. In an initial training phase, participants became familiar with two situation types. Importantly, these situations were constructed so that a participant could experience either anger or fear within the context created. One situation type was associated with physical danger brought on by one's own carelessness. On becoming lost during a spontaneous run in the woods at dusk, for example, one could fear bodily harm (e.g., starvation or animal predators) or experience anger directed toward oneself (e.g., for running at night or not being familiar with the route). The other situation type was associated with social evaluation in unfair circumstances. For example, on being unprepared for a work presentation because others on the team did not contribute, one could fear critical judgment (e.g., from a supervisor) or experience anger directed towards others (e.g., at co-workers). Table 1 presents additional examples of these two situation types. On two separate days before the critical scans, participants listened to situations of each type and rated each situation for familiarity, imagery, and their ability to "be there" (i.e., immerse oneself in the situation). As participants listened to a situation, they were instructed to immerse themselves in it as deeply as possible. Descriptions of the situations were written from the first person perspective and contained various details designed to induce immersion.[5]

Insert Table 1 about here

The training versions of the situations were longer in duration than was optimal for use in a scanner. For this reason, shorter core versions were written that captured the central components of the longer full versions. Table 1 presents examples. During training, participants were told about the relation between the full and core version of each situation, and practiced generating the full version while listening to the core version. This ensured that participants were prepared to imagine the full version of each situation as they listened to the core version later in the scanner.

On critical trials during scanning, participants first listened to one of 30 physical danger or to one of 30 social evaluation core situations mixed randomly together. Following the situation, participants heard the word for one of four concepts, again mixed randomly: *anger, fear, observe*, or *plan*. Participants' task on hearing the concept word was to rate how easily they experienced the concept in the given situation. This method was designed so that participants would first immerse themselves in the situation, and then later conceptualize this situated activity as an instance of *anger*, *fear*, *observe*, or *plan*. Of primary interest was to examine if, as the theory predicts, different patterns of brain activity occurred when an emotion (*fear* or *anger)* was conceptualized in two different types of situations. Again, all situations were developed so that any of the concepts could be experienced in the context of the situation, especially *fear* and *anger*. The two non-emotion abstract concepts were included for comparison purposes (*observe* and *plan)*.[6]

Each of the four concepts was presented after each of the 30 physical danger situations and each of the 30 social evaluation situations. To test our hypotheses, it was essential to separate activation during the period when participants processed the concept from the preceding period when participants processed the situation. Because each concept immediately followed a situation after a short non-varying interval, we used a catch trial methodology to separate activations for the situation and concept (Ollinger, Corbetta, & Shulman, 2001; Ollinger, Shulman, & Corbetta, 2001). Thus, the experiment contained eight critical types of events: *anger, fear, observe*, or *plan* experienced in physical danger situations and *anger, fear, observe*, or *plan* experienced in social evaluation situations.[7]

Predictions. The brain activations that occurred as participants processed the concepts, with activations for the preceding situations removed, were submitted to a Situation Type (physical or social) X Concept (*anger, fear, observe, plan*) group ANOVA. Taking a factorial ANOVA approach here allowed us to address two general issues. First, it allowed us to establish the different brain regions that composed the situated conceptualizations for an emotion. Second, it allowed us to assess similarities and differences in situated conceptualizations for the same emotion across physical danger and social evaluation situations.[8]

More specifically, taking a factorial ANOVA approach allowed us to establish how three sources of information composed the two situated conceptualizations for a given emotion. First, concept main effects represented contributions from an emotion concept to a situated conceptualization (where concept main effects were brain areas active for a concept consistently across *both* types of situations; e.g., activations associated with *fear*). It is essential to note that concept main effects are units of analysis, not theoretical constructs. A concept main effect is *not* the activation of a core concept for an emotion, but is simply information active for a concept across physical and social situations. Following our earlier discussion, we assume that the content of a concept main effect is the activation of one or more stored situated conceptualizations that are contributing to the composition of an online situated conceptualization. From hereon, when we use "concept main effect," we simply mean the unit of analysis that captures the brain activations common across both situation types for a concept, nothing more.

Second, situation main effects represented contributions from situation knowledge to a situated conceptualization (where situation main effects were brain areas active for a situation type consistently across *all* four concepts; e.g., activations associated with physical danger situations). Again, a situation main effect is *not* a theoretical construct implying core knowledge about a situation, but simply a unit of analysis that establishes common activations across concepts within a situation.

Third, concept X situation interactions represented information in a situated conceptualization that reflected experiencing a particular concept in a specific situation (where interactions were brain areas more active for one or more situation-concept combinations than for others; e.g., activations for *fear* in physical danger situations). Again, interaction effects are simply units of analysis that capture activations reflecting both the concept and situation.

Establishing these three units of analysis allowed us to assess how information from emotion concepts and situated knowledge compose different situated conceptualizations for the same emotion. We begin with a preliminary hypothesis that motivates our two critical hypotheses:

Preliminary hypothesis. The brain areas active for a situated conceptualization that produces an emotion should reflect the neural systems required for processing relevant information in the situation. If mental states are relevant, regions of medial prefrontal cortex should become active. If interoceptive or evaluative information is relevant, regions of insula and orbitral frontal cortex should become active. If visual or auditory information is relevant, regions of visual and auditory cortex should become active. In general, when two situated conceptualizations require processing similar information, they should recruit similar neural systems; when they require processing different information, they should recruit different neural systems. Two more specific hypotheses follow from the preliminary hypothesis.

Hypothesis 1. Different situated conceptualizations should produce different forms of a given emotion in different situations. Another way of stating this prediction is that constant, relatively unique modules should not produce the same emotion in different situations. Specifically, we predicted that experiencing emotions in physical danger situations—where harm to the body could occur—would recruit brain regions that process the environment (e.g., parahippocampal gyrus), action in the environment (e.g., motor and parietal regions), and bodily states (e.g., insula). Conversely, we predicted that experiencing emotions in social evaluation situations where negative evaluations could occur would recruit brain regions that evaluate social situations (e.g., medial prefrontal and orbitofrontal cortices) and that represent relevant social information about individuals (e.g., temporal poles).

Hypothesis 2. Our second hypothesis was that that the composition of a situated conceptualization for an emotion would draw on contributions from different sources of information in the distributed neural circuitry that produces emotion. Specifically, we predicted that a situated conceptualization would be composed of information stored with the emotion concept (concept main effects), information stored with knowledge about the situation (situation main effects), and information specific to experiencing the emotion concept in the situation (interaction effects). We further predicted that these different compositional elements of situated conceptualizations would generally draw on common neural circuitry distributed throughout the brain that produces emotions dynamically (following the meta-analyses in Barrett, 2009b; Barrett, Mesquita et al., 2007; Lindquist et al., submitted). Specifically, we predicted that *fear* and *anger* would draw on areas associated with mentalizing and interoception (e.g., medial prefrontal and orbital frontal cortices, insula). Similarly, if an emotion required action in the world, such as retaliation during social *anger* or avoidance during physical *fear*, areas that process action and space would become active (e.g., motor and parietal areas). We similarly predicted that areas relevant to processing the non-affective abstract concepts of *observe* and *plan* would draw on brain areas that process relevant information. Specifically, we predicted that *observe* would draw on perceptual systems that monitor the environment (e.g., visual and auditory cortices), whereas *plan* would draw on the executive system (e.g., inferior frontal gyrus, lateral prefrontal cortex). We further predicted that *plan*, even though it is a non-affective concept, would also draw on regions involved in mentalizing, similar to *anger* and *fear,* because mentalizing is central for planning intentional actions.

Method

Design and Participants

The experiment contained two training sessions and an fMRI scanning session. The first training session occurred 24 to 48 hours before the second training session, followed immediately by the scan. In the scanning session, participants received 240 complete trials that each contained a physical danger situation or a social evaluation situation followed immediately by one of the four concepts. Participants also received 120 catch trials containing only a situation, which enabled separation of the situation and concepts in the complete trials (Ollinger et al., 2001; Ollinger et al., 2001). The catch trials constituted 33% of the total trials, a proportion in the recommended range for an effective catch trial design (Ollinger et al., 2001). The 360 complete and catch trials were randomly intermixed in an event-related design, with random ISIs intervening that ranged from 0 to 12 sec in increments of 3 sec (obtained from optseq2[9]).

Two variables—situation type and concept—were implemented in a complete repeated-measures design. The 60 situations that participants received in the critical scanning session described either a physical danger or social evaluation situation (30 each). The concepts that participants received included two emotion concepts (*anger* and *fear*) and two non-emotion concepts (*observe* and *plan*). Each situation was followed once by each concept, for a total of 240 complete trials (60 situations followed by 4 concepts). Each of the 60 situations also occurred twice as a catch trial, for a total of 120 catch trials.

Twenty right-handed, native-English speakers from the Emory community, ranging in age from 20 to 33 (10 female), participated in the experiment. Six additional participants were dropped due to problems with audio equipment (3 participants) or excessive head motion in the scanner. Participants received $100 in compensation, along with anatomical images of their brain.

Materials

The 66 situations developed for the experiment described 33 physical danger situations and 33 social evaluation situations. The critical training and scanning sessions used 30 situations of each type; the practice session just before the scan used 3 other situations of each type. Each situation was designed so that each of the four concepts could be plausibly experienced in it (i.e., *anger, fear, observe, plan*).

A full and core form of each situation was constructed, the latter being a subset of the former. The full form served to provide a rich, detailed, and affectively compelling description of a situation. The core form served to minimize presentation time in the scanner, so that the number of necessary trials could be completed in the time available. As described shortly, participants practiced reinstating the full form of a situation when receiving its core form during the training sessions, so that they would be prepared to also reinstate the full forms during the scanning session when they received the core forms. Table 1 presented earlier provides examples of the full and core situations.

Each full and core situation described an emotional situation from first-person perspective, such that the participant could immerse him- or herself in it. In all physical danger situations, the immersed participant was the only person present, and was responsible for creating the threat of bodily harm, such that anger was directed toward the self and fear involved imminent physical danger. In all social evaluation situations, other people were present, and one of them was responsible for putting the immersed participant in a risky or difficult social situation, such that anger was directed toward someone else and fear involved the threat of being critically (and negatively) evaluated by another. Templates that were used to construct the full and core situations are described in the *Supplemental Materials*.

CD quality audio recordings were created for the full and core versions of each situation, spoken by an adult woman with a slight northeastern accent. The prosody in the recordings expressed slight emotion, so that the situations did not seem strangely neutral.[10] The four concepts were recorded similarly. Each core situation lasted about 8 sec or slightly less.

Procedure

In the first training session, participants provided informed consent and were screened for any potential problems that could arise during an MRI scan. Participants had no history of psychiatric illness and were not currently taking any psychotropic medication. Participants then received an overview of the experiment and of the first day's training session, using an additional example of a physical danger situation not used in the practice or critical trials. The relation of the full to the core situations was described, and participants were encouraged to reinstate the full situations whenever they heard the core situations. Participants were also encouraged to immerse themselves in all situations from the first-person perspective, to construct mental imagery of the situation as if it were actually happening, and to experience it in as much vivid detail as possible.

Participants then listened over computer headphones to the full versions of the 66 situations that they would later receive on the practice trials and in the critical scan 24-48 hours later, with the physical danger and social evaluation situation types randomly intermixed.[11] After hearing each full situation, participants provided three judgments about familiarity and prior experiences, prompted by questions and response scales on the screen. After taking a break, participants listened to the 66 core versions of the situations, again over computer headphones and randomly intermixed. While listening to each core situation, participants were instructed to reinstate the full version that they had heard earlier, immersing themselves fully into the respective situation as it became enriched and developed from memory. One example of a physical situation that did not appear in the later practice and critical trials was again used to instruct the participant. After hearing each core situation over the headphones, participants rated the vividness of the imagery that they experienced immersed in the situation. This task encouraged the participants to develop rich imagery from the core version. For details on the ratings provided during the training, see the *Supplemental Materials*.

As the first training session ended, participants received an overview of the next training session, and of the critical scanning session. Besides being told what to expect in the scanner, participants were instructed to remain still during the scan, emphasizing that even minor movements could prevent using their data. Overall, the initial training session lasted about 2 hours.

In the second training session, participants first listened to the 66 full situations to be used in the practice and critical scans, and then rated how much they were able to immerse themselves in each situation, again hearing the situations over computer headphones and in a random order (see *Supplemental Materials* for details). The full situations were presented again at this point to ensure that participants were reacquainted with all the details before hearing the core versions later in the scanner. This first phase of the second training session lasted about 1 hour.

Participants were then instructed on the task that they would perform in the scanner and performed a run of practice trials. On each complete trial, participants were told that they would hear the core version of a situation, receive one of four words for a concept (*anger, fear, observe, plan*), and judge how easy it was to experience the concept in the context of the situation. The core situation was presented auditorily at the onset of a 9 sec period, lasting no more than 8 sec. The concept was then presented auditorily at the onset of a 3 sec period, and participants responded as soon as ready, indicating how easy it was to experience the concept in the context of the situation. To make their judgments, participants pressed one of three buttons on a button box for not easy, somewhat easy, and very easy. Participants were also told that there would be catch trials containing situations and no concepts, and that they were not to respond on these trials. During the practice trials, participants used an E-Prime button box to practice making responses. In the scanner, participants used a Current Designs fiber optic button box designed for high magnetic field environments. To make responses, participants held the response box in their right hand and used their thumb to press the three response buttons.

At the beginning of the practice trials, participants heard the same short instruction that they would hear before every run in the scanner: "Please close your eyes. Listen to each situation and experience being there vividly. If a word follows, rate how easy it was to have that experience in the situation." Participants performed a practice run equal in length to the runs that they would perform in the scanner (for further details see the *Supplemental Materials*). Following the practice run, the experimenter and the participant walked 5 min across campus to the scanner. Once settled safely and comfortably in the scanner, an initial anatomical scan was performed, followed by the 10 critical functional runs, and finally a second anatomical scan. Prior to beginning each functional run, participants heard the same short instruction from the practice run over noise-muffling headphones.

In each of the 10 functional runs, participants received 24 complete trials and 12 catch trials. Both types of trials (complete and catch) were randomly inter-mixed. On a given trial, participants could not predict whether a complete or catch trial was coming, a necessary condition for an effective catch trial design (Ollinger et al., 2001). Participants also could not predict the type of situation or the concept that would appear. Random ISI occurred between trials, as in the critical experiment, ranging from 0 to 12 sec (in increments of 3 sec), with an average ISI of 4.5 sec. Across trials, physical danger and social evaluation situation types each occurred 18 times, and each of the 4 concepts (*anger, fear, observe, plan*) occurred 6 times, equally often with physical danger and social evaluation situations. Across complete trials, the 8 combinations defined by situation type (2) X concept (4) design occurred 3 times each. Across catch trials, each situation type occurred 6 times. A given situation was never repeated with a run; the 6 presentations of the same situation were distributed randomly across the 10 runs. Participants took a short break between each of the 8 min 3 sec runs. Total time in the scanner was a little over 1.5 hours.

Image Acquisition

The neuroimaging data were collected in the Biomedical Imaging Technology Center at Emory University on a research-dedicated 3T Siemens Trio scanner. In each functional run, 163 T2*-weighted echo planar image volumes depicting BOLD contrast were collected using a Siemens 12-channel head coil and parallel imaging with an iPAT acceleration factor of 2. Each volume was collected using a scan sequence that had the following parameters: 56 contiguous 2 mm slices in the axial plane, interleaved slice acquisition, TR = 3000 ms, TE = 30 ms, flip angle = 90°, bandwidth = 2442 Hz/Px, FOV = 220 mm, matrix

= 64, voxel size = 3.44 mm × 3.44 mm × 2 mm. This scanning sequence was selected after testing a variety of sequences for susceptibility artifacts in orbitofrontal cortex, amygdala, and the temporal poles. We selected this sequence not only because it minimized susceptibility artifacts by using thin slices and parallel imaging, but also because using 3.44 mm in the X-Y dimensions yielded a voxel volume large enough to produce a satisfactory temporal signal-to-noise ratio.

In each of the two anatomical runs, 176 T1-weighted volumes were collected using a high resolution MPRAGE scan sequence that had the following parameters: 192 contiguous slices in the sagittal plane, single-shot acquisition, TR = 2300 ms, TE = 4 ms, flip angle = 8°, FOV = 256 mm, matrix = 256, bandwidth = 130 Hz/Px, voxel size = 1 mm × 1 mm × 1 mm.

Image Preprocessing and Analysis

Image preprocessing and statistical analysis were conducted in AFNI.[12] The first anatomical scan was registered to the second, and the average of the two scans computed to create a single high-quality anatomical scan. Initial preprocessing steps of the functional data included slice time correction and motion correction in which all volumes were registered spatially to a volume within the last functional run. A volume in the last run was selected as the registration base because it was collected closest in time to the second anatomical scan, which facilitated later alignment of the functional and anatomical data.[13] The functional data were smoothed using an isotropic 6 mm full-width half-maximum Gaussian kernel. Voxels outside the brain were removed from further analysis, as were high-variability low-intensity voxels likely to be shifting in and out of the brain due to minor head motion. Finally, the signal intensities in each volume were divided by the mean signal value for the respective run and multiplied by 100 to produce percent signal change from the run mean. All later analyses were performed on these percent signal change data.

The averaged anatomical scan was corrected for non-uniformity in image intensity, skull-stripped, and then aligned with the functional data. The resulting aligned anatomical dataset was warped to Talairach space using an automated procedure employing the TT_N27 template.

Regression analysis was performed at the individual level using a canonical, fixed-shape Gamma function to model the hemodynamic response. To assess the effect of the situation manipulation on the same concept, two conditions were constructed for the concept, one when it was preceded by physical situations, and one when it was preceded by social situations. Thus betas were calculated from event onsets for 10 conditions: 2 types of situation conditions (physical, social) and 8 concept conditions (physical-anger, social-anger, physical-fear, social-fear, physical-observe, social-observe, physical-plan, social-plan).[14] Because the situation presentations were 9 sec in length (3 TRs), the Gamma function was convolved with a boxcar function for the entire duration. In contrast, the 3 sec concept periods were modeled as events. Six regressors obtained from volume registration during preprocessing were included to remove any residual signal changes correlated with movement (translation in the X, Y, and Z planes; rotation around the X, Y, and Z axes). Scanner drift was removed by finding the best-fitting polynomial function correlated with time in the preprocessed time course data.

As described earlier, the catch trial design used allowed us to separate activations for the situations from activations for the subsequent concepts that followed immediately without random jitter. The two situation conditions were modeled by creating regressors that included situation blocks from both complete trials and from catch trials. Including situations blocks from both trial types in one regressor made it possible to mathematically separate each situation from the subsequent concept conditions. Thus, activations from the preceding situation blocks were *not* included in the activations for the eight concept conditions, having been removed by separating out the two situation conditions.

The betas for the 8 concept conditions from each participant's regression were warped to Talairach space in preparation for group analyses. Each participant's betas for the concept conditions were then submitted to a repeated-measures ANOVA at the group level with the fully-crossed factors of situation type (physical, social) and concept (*anger, fear, observe, plan*). A voxel-wise significance level of $p < .005$ with a spatial extent threshold of 971 mm^3 (41 functional voxels) was used to threshold the resulting main effect and interaction F maps, yielding a whole-brain threshold of $p < .05$ corrected for multiple comparisons. The spatial extent threshold was established using Alphasim in AFNI, which runs Monte Carlo simulations to estimate extent thresholds needed to exceed cluster sizes of false positives at a given voxel-wise threshold. Further aspects of the analysis procedures will be described as relevant results are presented.

Results

As described earlier, we used a factorial ANOVA to establish contributions to the situated conceptualizations constructed when the participant experienced a concept (*anger*, *fear*, *observe*, or *plan*) in the context of situation type (physical danger or social evaluation). Initially, we report activations from the ANOVA for the two main effects and their interaction. We then integrate activations across the main effects and interaction to establish the situated conceptualizations for each concept in physical danger and social evaluation situations. Reorganizing the results this way allowed us to examine in detail the overlap vs. differences between the two situated conceptualizations for a given concept. The behavioral data and their relation to the BOLD data had minimal relation to the critical ANOVA results, and are thus reported in the *Supplemental Materials*.

Results from the Concept X Situation ANOVA

Four types of effects from the ANOVA are reported next: (1) clusters that only exhibited a concept main effect, (2) clusters that only exhibited a situation main effect, (3) clusters that exhibited both a concept and a situation main effect, and (4) clusters that exhibited an interaction between a concept and a situation. Overlap in effect types was addressed in the following manner. First, any cluster exhibiting a main effect and interaction is reported as an interaction cluster only, not as a main effect cluster, because an interaction best describes the pattern of activations across conditions.[15] Second, as stated above, any cluster in which both main effects occurred is reported as a combined main effect cluster. Thus, each cluster reported for the ANOVA is exclusively one of the four effect types listed above, with no cluster repeating across multiple types. Although clusters exhibiting different effect types sometimes occurred adjacent to one another in the same general brain region, the clusters reported do not overlap spatially. The masking procedures used to isolate the four effect types are described in the *Supplemental Materials*.

Because an *F* was associated each cluster that showed a significant effect type, this statistic did not indicate which conditions were differentially active to produce the effect (main effect or interaction). To characterize the differences driving an effect type, we extracted mean percent signal change for the relevant conditions, and then assessed pairwise differences between them.

Several original clusters observed in the main effect and interaction maps were very large, extending across many anatomical regions that serve diverse functions. These clusters are shown in Figure 1. To interpret mean signal change for a large cluster meaningfully, we divided it into smaller sub-clusters, thereby making it possible to contrast conditions in functionally meaningful brain regions. To define meaningful sub-clusters within a large original cluster, we used Brodmann Area (BA) masks from the AFNI Talairach Atlas. The complete procedure used to determine regional sub-clusters within the original large clusters is described in the *Supplemental Materials*. Whenever a sub-cluster was extracted using a BA mask for an effect type, its BA number is bolded in Tables 2-5. In some cases, it was more appropriate to use a defined anatomical region as a mask instead of a BA (e.g., for the insula, parahippocampal gyrus). Whenever a sub-cluster was extracted using an anatomically defined region, the word 'tal' is bolded instead of the BA number in the respective table. In the tables to follow, sub-clusters extracted from the same large cluster are shown adjacently, grouped by a contiguous gray or a white background.

Insert Figure 1 about here

Concept main effects. Essentially, a concept main effect indicated whether different brain areas were systematically associated with each concept (*anger, fear, observe, plan*), across the two types of situations assessed here (physical, social). Any cluster that exhibited greater activity for one concept over another exhibited this dominance across both situation types, statistically speaking. If, for example, a cluster showed a main effect for *anger* relative to the other three concepts, it tended to show this dominance across both physical danger and social evaluation situations. If this dominance did not hold systematically across situations, then the cluster instead exhibited an interaction effect, as described later. Figure 1A illustrates concept main effect clusters.

As described earlier, a concept main effect is a unit of analysis, *not* a theoretical construct. Again, we do not assume that concept main effects reflect conceptual cores common across situations. Instead, we assume that a diverse collection of situated conceptualizations represents a concept, together with minimal abstractions. From this perspective, a concept main effect simply indicates that some of this diverse content was retrieved across both physical and social situations in this experiment. It does not follow at all the content of a concept main effect reflects core content for a concept, or that any core content exists.

Because an *F* was associated with each cluster that showed a significant concept effect, this statistic did not indicate which specific concepts were more active than others. To make this determination, the betas for individual subjects within each cluster were extracted for each concept, and the cluster was associated with any concept(s) significantly more active than the least active concept ($p < .05$). These classifications exhibited a variety of patterns across clusters. If, for example, *anger* was more active in a cluster than *fear, observe,* and *plan* (which did not differ), then the cluster was classified as an *anger* cluster. Alternatively, if *anger*, *fear,* and *plan* were all more active in a cluster than *observe*, then the cluster was classified as an *anger*, *fear,* and *plan* cluster. The right-most columns of Table 2 use a plus sign (+) to indicate any concept that was more active than the least active concept.

In addition, when activity in a cluster was significantly greater for one concept than for all others, it was assigned a larger plus sign (**+**) to indicate that it could be distinguished statistically as significantly more active than all other concepts (see Table 2). If, for example, *anger*, *fear* and *plan* were more active in a cluster than *observe*, but *anger* was also more active than *fear* and *plan*, then a larger plus sign indicated that *anger* was more active than the other three concepts.

Insert Table 2 about here

As Table 2 illustrates, three main types of patterns emerged for clusters that exhibited a concept main effect: (1) clusters active during *anger*, *fear,* and *plan*, (2) clusters active during *observe* and *plan*, (3) clusters active during *observe* alone. Clusters in lateral and medial orbitofrontal cortex, medial prefrontal cortex extending up into the supplementary motor area,[16] and dorsal anterior cingulate were active during *anger*, *fear,* and *plan*. The temporal poles were also active during *anger*, *fear*, and *plan* bilaterally. Among these clusters, only the medial orbitofrontal and adjacent ventromedial prefrontal regions showed a profile in which one of the emotion concepts, *anger*, was significantly greater than all the other concepts. In these two clusters, *fear* and *plan* showed greater activity than *observe*, and *anger* showed greater activity than *fear*, *plan*, and *observe*.

Clusters active during *observe* and *plan* were primarily located in more posterior, left-lateralized motor and visual areas. Specifically, left premotor cortex, mid-cingulate, left middle temporal gyrus, left inferior temporal gyrus, left parahippocampal gyrus, left extrastriate visual areas, and left precuneus[17] were more active during *observe* and *plan*. Bilateral superior temporal regions, bilateral posterior regions of the insula, and right inferior parietal cortex were also more active during *observe* and *plan*. Right middle temporal gyrus showed a unique pattern, active during *observe* and *plan*, as well as during *anger*.

Clusters only active during *observe* tended to occur in right-lateralized visual areas. Specifically, right extrastriate occipital regions, right precuneus, right middle and inferior temporal gyrus, and left fusiform gyrus were only active during *observe*. Activations also occurred during *observe* in angular gyrus/temporal-parietal junction bilaterally and left inferior parietal cortex.

Situation main effects. A situation main effect indicated that an activation during *anger*, *fear*, *plan*, and *observe* was systematically associated the situation type preceding it (physical danger or social evaluation). Because activations from the situations themselves were removed using the catch trial procedure described earlier, these activations reflect situational influences on the subsequent concept events. Figure 1B illustrates these clusters. Importantly, any cluster that exhibited greater activity for one situation type in a situation main effect exhibited this dominance across all four concepts, statistically speaking. If, for example, a cluster showed a main effect in the physical danger situation type relative to social evaluation situation type, it tended to show this dominance across all four concepts (*anger, fear, observe, plan*). If this dominance did not hold systematically across all concepts, then the cluster instead exhibited an interaction effect, as described later. Because an *F* was associated with each cluster that showed a significant situation effect, this statistic did not indicate whether the cluster was more active for all concepts following physical danger or social evaluation situation types. To make this determination, the betas for individual subjects within each significant cluster were extracted to determine if they were significantly more active in physical danger or social evaluation situations ($p < .05$). If, for example, a cluster showed significantly higher activation during physical danger situations than during social evaluation situations, it was classified as a physical danger cluster, meaning that the respective brain area was more active when experiencing all concepts in the context of the physical danger situations. The right-most columns of Table 3 use a plus sign (+) to indicate these classifications.

Insert Table 3 about here

As Table 3 illustrates, bilateral parahippocampal gyrus and mid-cingulate, extending up into the paracentral lobule, were active for all concepts following physical danger situations, significantly more so than when the same concepts followed social evaluation situations. In contrast, significantly more activation was observed in ventromedial prefrontal cortex and early visual areas when the concepts were experienced following social evaluation situations than following physical danger situations.

In the *Supplemental Materials*, we describe situation effects in parahippocampal gyrus and visual cortex that only occurred during the concept period, not during the situation period. These situation effects demonstrate that the compositional process producing emotional states is dynamical in the sense that situation effects *not* present initially during the situations can emerge later during the concepts.

Overlapping concept and situation main effects. Table 4 shows the clusters in which additive main effects were observed for both a concept and a situation. Figure 1C illustrates these clusters. One cluster in dorsomedial prefrontal cortex was more active during all concepts in social evaluation situations relative to physical danger situations, and was also more active during *anger, fear,* and *plan* than *observe* (across situation types). The other region active in both a situation and a concept main effect was located in right superior temporal gyrus. This region was more active during all concepts in physical danger than social evaluation situations, and was also more active during *plan* and *observe* (across situation types).

Insert Table 4 about here

Interaction effects. Whenever the eight concept conditions—physical-*anger*, social-*anger*, physical-*fear*, social-*fear*, physical-*observe*, social-*observe*, physical-*plan*, social-*plan*—differed significantly from one another in some way that did not constitute a main effect, an interaction resulted. Figure 1D shows these clusters. Because an *F* was associated with every cluster that exhibited an interaction, the betas for individual subjects within each significant cluster were extracted for each of the eight situation-concept conditions, and the cluster was associated with any situation-concept condition(s) significantly more active than the least active condition ($p < .05$). These classifications exhibited many different patterns across clusters, as shown by the plus sign (+) indicators in Table 5. In these interaction clusters, no one condition was ever significantly more active than all the others.

Insert Table 5 about here

As Table 5 illustrates, interaction clusters were located primarily in lateral regions of left prefrontal cortex and bilateral temporal and parietal cortex. In the left hemisphere, dorsolateral prefrontal cortex, inferior frontal gyrus, orbitofrontal cortex, posterior insula, temporal pole, superior temporal gyrus, and inferior parietal cortex showed significant interaction effects. In the right hemisphere, interaction effects were observed in posterior insula, superior temporal gyrus, and inferior parietal cortex. The only more medial activation was a cluster in the precuneus, with all other clusters being relatively lateral.

Establishing the Composition of Situated Conceptualizations

In the previous section, Tables 2, 3, 4, and 5 presented activations observed in situation main effects, concept main effects, both main effects, and interaction effects. In this section, we reorganize these same results to achieve two additional goals: (1) Compile all the active clusters for a particular concept across effect types, (2) Assess the extent to which these clusters occurred in one or both situations types. Tables 6 and 7 reorganize the earler results for *fear* and *anger*. Supplemental Tables 2 and 3 reogranize them for *plan* and *observe*. Each table establishes the situated conceptualizations for a concept in physical danger and social evaluation situations. As will be seen, each situated conceptualization contains clusters exhibiting concept main effects, situation main effects, both main effects, and interaction effects. As will also be seen, some of the clusters in each situated conceptualization are common to both situations, whereas other clusters are unique to one situation.

In the right-most column of each table, a plus sign (+) indicates whether a cluster was active in physical situations, social situations, or both. As each table for a concept illustrates, clusters exhibiting a concept main effect indicate that a brain region was active in both situated conceptualizations. In contrast, clusters exhibiting a situation main effect indicate that a brain region was active in only one of the situated conceptualizations. Interaction clusters, on the other hand, could exhibit patterns in which a brain region was active in both situated conceptualizations or only in one situated conceptualization (because the interaction was computed across all situation-concept conditions). Finally, clusters exhibiting both main effects took one of two forms. For some clusters, the concept exhibited both a situation effect in one situation (indicated by **+**) and was simultaneously more active than at least one other concept across both situations (indicated by + in the other situation). For other clusters, the concept only exhibited a situation main effect (indicated by +), and was *not* more significant than the least active concept (indicated by a blank in the other situation), with *another* concept being responsible for the simultaneous concept effect.

Table 6 compiles clusters across effect types that were active during *anger* in physical situations, social situations, or both situations. As Table 6 illustrates, roughly half the clusters occurred for both situation types, whereas half occurred only for physical danger situations or only for social evaluation situations. Table 7 compiles clusters across effect types that were active during *fear* in physical danger situations, social evaluation situations, or both situations. As can be seen, roughly one third of these clusters occurred for both situation types, whereas the large majority occurred only for physical danger situations or for social evaluation situations.

Insert Tables 6 and 7 about here

Supplemental Tables 2 and 3 in the *Supplemental Materials* compile the effect types for *observe* and *plan*, respectively. The situationally unique activations for these abstract concepts were not as extensive as those for the emotion concepts. Nevertheless, there were several regions exhibiting situation main effects and interactions that were unique in the situated conceptualizations for these concepts.

Table 8 provides a final summary of the contributions to the situated conceptualizations in Tables 6 and 7 for *anger* and *fear* and in Supplemental Tables 2 and 3 for *observe* and *plan*. Specifically, Table 8 presents the proportions of voxels for each concept in each situation type as a function of effect type and whether voxels were associated with one or both situations. The procedures used to calculate these proportions are described in the *Supplemental Materials*. Essentially, Table 8 summarizes the composition of each situated conceptualization.

Insert Table 8 about here

As Table 8 illustrates, the percentage of voxels unique to the situations varied across the four concepts, with the situated conceptualizations for the emotion concepts containing the most situationally unique voxels, and the non-emotion abstract concepts containing the least. Specifically, f*ear* had the lowest percentage of shared voxels across both situations. For *fear* in physical danger situations, only 47% of voxels were shared with the social evaluation situation, indicating that more voxels were situationally unique (53%). For *fear* in the social evaluation situation, 60% of voxels were shared across situations, and 40% were unique. Thus, the situation that preceded the construction of a *fear* experience significantly affected how the emotion was represented and experienced. As Table 8 further illustrates, the situated conceptualizations for *anger* similarly contained large proportions of situationally unique voxels, although not as large as *fear*. Across physical danger and social evaluation situations, respectively, 68% and 73% of the voxels for *anger* were shared, whereas 32% and 27% were unique.

Plan and *observe* showed less variation in their representations across situations. Across physical danger and social evaluation situations, respectively, 79% to 89% of the voxels for *plan* and *observe* were shared, whereas 21% to 11% were unique. It is not surprising that the non-emotion abstract concepts showed smaller situation effects than the emotion concepts, given that the physical danger and social evaluation situations were designed to manipulate elements of *anger* and *fear*. The presence of significant situation effects for *plan* and *observe* under these conditions speaks to their strength. We suspect that larger situation effects could be obtained for these concepts with other manipulations.

Discussion

The results support our preliminary hypothesis that a situated conceptualization draws on neural systems that process relevant information. In the discussion that follows, we review extensive supporting evidence for this hypothesis. The results further support the two critical hypotheses that follow from the preliminary hypothesis. First, as Conceptual Act Theory predicts, different situated conceptualizations represented the same emotion in different situations. Inconsistent with basic emotion theories, constant relatively unique modules did not represent the same emotion across different situations. Second, situated conceptualizations were composed of information that represents concepts, situations, and their interaction, drawn from a common neural circuitry distributed throughout the brain. The following two sections examine the implications of our results for each hypothesis in turn, while simultaneously addressing the preliminary hypothesis.

Situated Conceptualizations for Emotion Concepts

The results in Tables 6, 7, and 8 offer strong support for Hypothesis 1 that an emotion is constructed differently depending on the situation. As Tables 6 and 7 show, *anger* and *fear* were represented differently when experienced in a physical danger vs. a social evaluation situation. Although some brain areas were common across both situation types for the same emotion, many other brain areas were only active in one situation type or the other. Furthermore, the overall percentage of voxels unique for an emotion concept in a particular situation was typically large, ranging from 27% to 53% across situated conceptualizations for the emotion concepts (Table 8). Thus, the situation in which an emotion concept was experienced shaped how the emotion was instantiated in the brain. We next present a brief overview of the shared and unique activations observed in the situated conceptualizations for each emotion concept. The brain regions and general functions summarized in this overview receive more detailed treatment in later sections. Thus, we do not integrate these initial summaries with previous literature here, but do so in the next section when addressing the neural circuitry associated with Hypothesis 2.

Situated conceptualizations of anger. Approximately two-thirds of the voxels in the situated conceptualizations for *anger* were shared across the two situations, originating in concept main effects and interactions (Tables 6 and 8). Lateral and medial orbitofrontal cortex, dorsal anterior cingulate, medial prefrontal cortex, the temporal poles, supplementary motor area, right middle temporal gyrus, left inferior frontal gyrus, and bilateral posterior superior temporal gyrus were active in both situated conceptualizations. Based on this activation profile, we suggest that representations of *anger* in both situations involved facets of socio-emotional processing, including integration of internal and external sensory states (lateral orbitofrontal cortex), visceromotor control (medial orbitofrontal cortex), mentalizing (medial prefrontal cortex), action planning (supplementary motor area), and language (inferior frontal gyrus, middle and superior temporal gyrus).

Numerous situationally unique activations were also observed in the situated conceptualizations for *anger*, originating in situation main effects and interactions. Approximately one-third of the active voxels occurred in only one of the situations (Tables 6 and 8). In physical danger situations, *anger* was directed towards the self because one had acted carelessly. Bilateral posterior insula, bilateral superior temporal gyrus, bilateral parahippocampal gyrus, mid-cingulate gyrus, and left dorsolateral prefrontal cortex were more active during *anger* in this context. We propose that these activations reflect cognitive control and inner speech (dorolateral prefrontal cortex, superior temporal gyrus), as well as interoceptive processing (insula) and orienting of the body (mid-cingulate, parahippocampal cortex), relevant to experiencing anger directed inward towards oneself. In social evaluation situations, *anger* was directed towards an unfair other. Ventromedial prefrontal cortex, bilateral inferior parietal cortex, and posterior occipital regions were more active during *anger* in this context. We propose that these activations reflect the evaluation of oneself and others (ventromedial prefrontal cortex), as well as the visualizing of details (occipital) and assessing extra-personal space for action (inferior parietal cortex), specific to experiencing anger directed outward towards another.

Situated conceptualizations of fear. Similar to *anger*, situated conceptualizations of *fear* across the physical danger and social evaluation situation types shared common processing areas, originating exclusively in concept main effects. Notably, however, the extent of these common processing areas was lower than for any other concept, given that only about half of the voxels were shared across situations (Tables 7 and 8). The shared activations for *fear* included a subset of the regions observed for *anger*. Specifically, lateral and medial orbitofrontal cortex, dorsal anterior cingulate, medial prefrontal cortex, supplementary motor area, and the temporal poles were active in both situated conceptualizations for *fear*. Like *anger*, the situated conceptualizations for *fear* in both situations included facets of socio-emotional processing. Unlike *anger*, however, shared activations for *fear* did not involve brain regions typically involved in auditory processing and language (e.g., left inferior frontal gyrus, bilateral superior temporal gyrus), suggesting that spoken language was more central for *anger*.

Fear exhibited considerable specificity to the situation, given that approximately half of the active voxels were situationally unique. Again, activations unique to one situation originated in situation main effects and interactions. In physical danger situations, the f*ear* experienced was related to bodily harm. Mid-cingulate, as well as bilateral posterior insula, parahippocampal cortex, inferior parietal cortex, and superior temporal gyrus were more active during *fear* in this context. This profile of activation was the most sensory-motor oriented of the situated conceptualizations for the emotion concepts. We propose that these activations reflect action planning in the visuo-spatial environment (inferior parietal cortex, parahippocampal cortex), and also the interoceptive (insula) and auditory (superior temporal gyrus) processing specific to experiencing fear of physical harm. In social evaluation situations, the *fear* experienced was related to being judged negatively by another. Specifically, ventromedial prefrontal cortex, left posterior orbitofrontal cortex, left inferior frontal gyrus, left dorsolateral prefrontal cortex, left temporal pole, and posterior occipital cortex were more active during *fear* in this context. We propose that these activations reflect the evaluation of oneself and others (orbitofrontal cortex, ventromedial prefrontal cortex), access of social knowledge about individuals (temporal pole), cognitive control (dorsolateral prefrontal cortex; inferior frontal gyrus), and visualizing details (posterior occipital) specific to experiencing fear of social judgment (instead of physical harm).

Anger vs. fear. Judging by Tables 6, 7, and 8, one might be tempted to conclude that *anger* generally exibits less variability across situations than does *fear*. An important possibility, however, is that the situational elements that were manipulated in the two situation types were stronger for *fear* (bodily harm vs. social evaluation) than for *anger* (directed towards self vs. directed towards another). Future research is required to distinguish these possibilities. We strongly suspect that the magnitude of situation effects is likely to vary widely depending on the particular situation manipulations implemented.

Implications for theories of basic emotion. According to basic emotion theories, emotions are natural kinds, each produced by a unique circuit stable across instances of the emotion (Ekman, 2003; Izard, 2007; Panksepp, 2000). From this perspective, an emotion such as *fear* should activate one or more brain regions significantly more than should any other emotion, and should also show stability in the areas activated across its instances. Clearly, our results did not display consistency within instances, as shown by the different activation patterns for the two situated conceptualizations of each emotion (Tables 6, 7).

To examine whether one or more regions were activated significantly more during *anger* or *fear* than for all other concepts, we further examined the concept main effects. Whenever one concept (across both situation types) was more active than the other three concepts (across both situation types) in a cluster, a large bolded **+** exists for that concept in the concept main effects table (Table 2). As can be seen, *observe* showed the most selective pattern of neural activity according to this criterion, followed by *plan* and then *anger*. To rule out the possibility that only one of the situation-concept conditions reflected the "true" basic emotion (e.g., *fear* during physical danger), we also looked for this profile of activation in the interaction effects. No single situation-concept condition (e.g., physical-*fear*) was ever significantly more active than all other conditions in an interaction cluster.

The experience of *fear* in our study did not selectively activate any region more than the other three concepts. Because our paradigm oriented participants towards experiencing *fear* (not towards detecting it in ambiguous contexts), our findings are consistent with meta-analyses that distinguish emotion perception from emotion experience. Whereas the perception of *fear* (along with other emotions) consistently activates the amygdala, the experience of *fear* does not (Lindquist et al., 2010; Wager et al., 2008). Although other meta-analyses have found the amygdala to be consistently (but not specifically) active for *fear*, these analyses did not distinguish between perception vs. experience (Murphy et al., 2003; Phan et al., 2002; Vytal & Hamann, in press). Recent evidence further indicates that the amygdala is not selective for *fear* per se, but that it responds to motivationally salient events that require attention and learning (Barrett, 2009a,b; Whalen et al., 2009; Winston, O'Doherty, & Dolan, 2003; Winston et al., 2005).

Medial orbitofrontal cortex was more active during *anger* than during all other concepts. Importantly, though, *fear* and *plan* showed more activity in this region than *observe*, but less activity than *anger*. Thus, *anger* did not selectively activate this region in an absolute manner, given that it was also active during *fear* and *plan*, but to a lesser degree. Furthermore, the orbitofrontal cluster we observed is more medial than those reported for *anger* in recent meta-analyses (Murphy et al., 2003; Vytal & Hamann, in press; but see Lindquist et al., 2010). In contrast to lateral orbitofrontal cortex, medial areas are highly connected with visceromotor structures in the hypothalamus and brainstem (Ongur & Price, 2000). Thus, the medial activation observed here suggests that *anger* was associated with viceromotor processing, more so than the other concepts. It is clear, however, that activity in this region constituted only one part of a distributed set of processing areas for *anger* in a particular situation—there was much more to *anger* than this specific process. And again, this region was more active during *fear* and *plan* than during *observe*, demonstrating that *anger* is not completely selective in utilizing its processing resources.

To summarize, the lack of selective responses for *anger* and *fear* is consistent with our conclusion that situated conceptualizations represented these emotions. Constant, relatively unique circuits did not represent the same emotion in different situations, as basic emotion theories predict.

The Composition of Situated Conceptualizations for Emotion

According to Hypothesis 2, the composition of a situated conceptualization should reflect contributions from different compositional elements in shared neural circuitry for emotion distributed across the brain. As Tables 2, 3, 4, and 5 illustrate, the representation of an emotion in a given situation was composed of information from emotion concepts (concept main effects), the situations in which emotions were experienced (situation main effects), information common to emotion concepts and related situations (overlapping concept and situation main effects), and information specific to experiencing an emotion concept in a specific situation (interaction effects). These compositional elements of emotion representation combined to form the situated conceptualizations in Tables 6 and 7 (summarized in Table 8).

In the following sub-sections, we first explore each compositional element that contributed to the representation of situated conceptualizations. We then address the related prediction that these compositional elements are generally drawn from shared neural circuitry distributed throughout the brain that produces situated conceptualizations of emotions dynamically. Figure 2 illustrates each effect type from the factorial ANOVA in a different color, and illustrates the close proximity of different effect types to one another in various brain regions.

Insert Figure 2 about here

Contributions from concepts (concept main effects). As Tables 2 and 8 specify, and as Figures 1 and 2 illustrate for concept main effects, information from concepts contributed significantly to the composition of situated conceptualizations for emotion. Specifically, certain information was active for the same emotion in different situations, suggesting that it was drawn from conceptual knowledge about the emotion common across situations.

As proposed earlier, we do not assume that emotions have conceptual cores. Instead, we assume that emotion concepts, like other concepts, are dynamical systems whose collections of situated conceptualizations and partial abstractions change constantly over time, producing representations that vary widely across situations (e.g., Barsalou, 1987, 1989, 1993, 2003b). From this perspective, any information active for an emotion across both situations simply reflects conceptual information that happened to be relevant in both situations.

Notably, many brain regions active during experiences of *fear* were also active during experiences of *anger*, and also *plan*. Regions in medial prefrontal cortex played a primary role in contributing information across situations to all three concepts, along with regions of medial orbitofrontal cortex and dorsal anterior cingulate. These regions are generally associated with emotion perception, emotion experience, mentalizing, attitudes, evaluation, self-concepts, and understanding the minds of others (for reviews see Amodio & Frith, 2006; Mitchell, 2009b; Van Overwalle, 2009). Medial prefrontal cortex has also been highlighted as a critical part of the "core" (Buckner & Carroll, 2007) or "default" network (Gusnard & Raichle, 2001), often hypothesized to be a global system for inner-oriented processing (Golland et al., 2008), self-related processing (Buckner & Carroll, 2007), contextual processing (Bar, 2004), and processing that involves bringing prior experience to bear on constructing the present psychological moment (Barrett, 2009a). The medial prefrontal activations extended up into the supplementary motor area, suggesting that planning internally generated action was also central to *anger*, *fear*, and *plan* (Nachev, Kennard, & Husain, 2008; Picard & Strick, 1996). Left lateral orbitofrontal cortex and the temporal poles also showed a similar profile, active across these three concepts. Increasing evidence indicates that lateral orbitofrontal cortex integrates external and internal sensory information (Ongur & Price, 2000), and is sensitive to the affective properties of stimuli (Kringelback & Rolls, 2004; Wager et al., 2008). Increasing evidence suggests that the temporal poles represents individuals in social contexts (Damasio et al., 2004; Drane et al., 2008; Simmons & Martin, 2009; Tranel, 2006).

Notably, however, the large majority of activations for the concept main effects occurred in posterior sensory-motor regions for the two non-affective abstract concepts, *observe* and *plan*. Consistent with our proposal that distributed patterns of activity across relevant modalities represent concepts, visual, auditory, and motor areas were all activated more active for these concepts than for the emotion concepts. Because visual, auditory, and motor processing are all central to observing the world and planning action in it, the activation of relevant neural systems for representing *observe* and *plan* is not surprising. Additionally, clusters in bilateral posterior insula were also more active for *observe* and *plan* than for the emotion concepts, suggesting that interoception was especially important for observing and planning (Craig, 2002). Although this might seem surprising, we will see that an adjacent cluster in posterior insula was active for the emotion concepts as well, but only in physical danger situations (present in an interaction effect).

As predicted, the profiles of stable activations across situations during *fear* and *anger* reflected processes associated with mentalizing, such as internally evaluating the current situation, projecting future outcomes, accessing person knowledge, and planning actions. This pattern contrasted with very different predicted profiles across situations for *observe* and *plan*. For *observe,* neural systems became active that perform externally-oriented visual, auditory, motor, and spatial processing, as well as internally-oriented interoception associated with monitoring. For *plan*, these posterior perceptual regions were again active, together with medial prefrontal areas associated with mentalizing, suggesting that planning requires integrating or shifting between mentalizing and operating in the environment.

Contributions from situations (situation main effects). As Tables 3 and 8 specify, and as Figures 1 and 2 illustrate, representations of situations contributed significantly to the composition of situated conceptualizations for emotion. Specifically, certain information was active for the same situation across different concepts, suggesting that it was drawn from conceptual knowledge about the situation. As a situated conceptualization became active to represent an emotion in a particular situation, it drew on knowledge about the situation, as well as on knowledge about the emotion. These two types of compositional elements were then integrated to represent the emotion in a situated manner, along with information found for joint main effects and interaction effects.

When the concepts were experienced in physical danger situations, mid-cingulate and bilateral parahipocampal gyrus were significantly more active than during social evaluation situations. Much evidence suggests that mid-cingulate integrates evaluation of the present situation with skeletomotor control and orientation (Rolls, 2005), and further implicates this region in nociception (Vogt, 2005; Vogt, Berger, & Derbyshire, 2003). In contrast to anterior cingulate, mid-cingulate cortex contains motor areas that project to the motor cortices and that play roles in response selection (Morecraft & Van Hoesen, 1992; Vogt, 2005). This main effect suggests that orienting and/or controlling movement in response to physical discomfort is relevant to experiencing *fear*, *anger*, *observe*, and *plan* in physical danger situations. Bilateral parahippocampal gyrus was also active during these situations, suggesting that large-scale visuo-spatial settings were being simulated (Bar, 2004; Epstein, 2005). Taken together, these mid-cingulate and parahippocampal activations suggest that orienting the body in a large-scale visuo-spatial scene was a common element in physical danger situations across concepts, consistent with our initial predictions.

Following social evaluation situations, ventromedial prefrontal cortex was significantly more active across concepts than following physical harm situations. This region is often associated with monitoring the value of possible outcomes (Amodio & Frith, 2006), self-referential processing (Mitchell, Heatherton, & Macrae, 2002; Northoff et al., 2006), and visceromotor control (Ongur & Price, 2000). A posterior occipital cluster (BA 17/18) was also active following social evaluation situations. Activation in early occiptial regions during visual imagery has been observed when tasks involve high-resolution details and shapes rather than spatial orientation (Kosslyn & Thompson, 2003), suggesting that the processing of visual detail was important, perhaps for faces. As predicted, social evaluation situations involved self-related, evaluative processing instead of pressing bodily concerns, as for physical harm situations. Interestingly, social evaluation situations also recruited the processing of fine-grained visual details instead of large-scale visuo-spatial scenes.

Because the regions for the situation main effects were active across all four concepts, one might assume that they were peripheral to each concept's representation. We propose, however, that these effects were just as central to representing each concept as were the other effect types. For example, representing visuo-spatial scenes and responses to pain are both central for experiencing *fear* in physical danger situations. Analogously, representing psychological attributes of oneself and the facial detail of others are central for experiencing *fear* in social evaluation situations. Without the presence of this critical information in the respective situation, it does not seem possible to experience the relevant form of *fear*.

Overlapping contributions from concepts and situations (both main effects). As Tables 4 and 8 specify, and as Figures 1 and 2 illustrate, some information used to compose situated conceptualizations for emotions existed both in an emotion concept and in situation knowledge. In these cases, information typically relevant for a concept across situations was also often relevant in a particular type of situation across concepts. Such activations further indicate that concepts are situated, given this situational information in their representation. Interestingly, however, some situated information in a concept appears to be broadly represented across many concepts.

A region in dorsomedial prefrontal cortex was active during all concepts in social evaluation situations, and also active during *anger*, *fear*, and *plan*. One interpretation is that this cluster reflected the importance of person knowledge and theory of mind across all four concepts in social situations relative to physical situations, but more so for *anger*, *fear*, and *plan* than for *observe*. A very different profile occurred for a region in superior temporal gyrus, being more active for physical situations than for social situations, and being more active for *plan* and *observe* than for *anger* and *fear*. This pattern may reflect the importance of auditory processing across all four concepts in physical situations, but more so during *plan* and *observe*, which generally involved more external sensory processing.

Contributions from concept-situation interactions (interaction effects). As Tables 5 and 8 specify, and as Figures 1 and 2 illustrate, many neural activations were specific to experiencing an emotion concept in specific situations. One possibility is that these activations reflect information stored in a concept that only becomes active in particular situations, not all (e.g., Barsalou, 1982). Another possibility is that these activations reflect information constructed on-line to integrate a concept into a situation, with this information later being stored with the concept (e.g., Barsalou, 1983). We suspect that both mechanisms could underlie the interaction effects observed here (e.g., Barsalou, 1987, 1989, 1993, 2003b).

Interestingly, instead of one or two dominant patterns emerging as for the main effects, these clusters exhibited many unique patterns of activation across conditions. All clusters but one (precuneus) contained at least one significantly active emotion condition. Thus, it was not the case that the non-emotion concepts drove the interaction effects, as basic emotion theories might predict. Instead, the emotion concepts exhibited strong variability across situation types. For detailed discussion of these interaction effects and their relations to relevant literature, see the *Supplemental Materials*. Here we summarize that discussion. It is important to note that we did not attempt to generate detailed predictions about interaction effects initially. Thus, our interpretations of the interaction effects are informed by other findings in the literature.

Interaction clusters were located primarily in lateral prefrontal, temporal, parietal, and insular cortices. A cluster in left lateral orbotifrontal cortex was active for *fear* in social situations and for *anger* in both situations, suggesting that *fear* in physical situations, relative to the other emotion conditions, may have involved less attention to subjective feelings of unpleasantness, perhaps because attention was focused more on actions taken to avoid a physical threat. Clusters in bilateral posterior insula were active for *fear* and *anger* in physical but not social situations, suggesting that the monitoring of interoceptive states was especially important when physical harm was anticipated. Clusters in left dorsolateral prefrontal cortex and inferior frontal gyrus were more active when *fear* was experienced in social situations than when *fear* was experienced in physical situations, suggesting that executive control was especially important for coping with threatening evaluations in social situations. Conversely, clusters in temporal auditory areas showed the opposite pattern, suggesting that monitoring environmental sounds and inner speech were especially important for coping with possible bodily harm in physical situations. Finally, bilateral inferior parietal cortex was active for *fear* in social situations but for *anger* in physical situations, suggesting that *fear* in physical situations involves acting on threats in the environment, whereas *anger* in social evaluation situations involves initiating retribution towards another person.

Constructing Emotion Instantiates Distributed Neural Circuitry

As described earlier, Hypothesis 2 predicts that the different compositional elements of situated conceptualizations should generally be drawn from common neural circuitry distributed throughout the brain that produces situated representations of emotions dynamically. In other words, certain brain regions should consistently play central roles in representing the same emotion in different situations, and in representing different emotions. The results reported here strongly confirm this prediction.

First, it is important to note that many of the brain regions observed are not, strictly speaking, functionally specific to emotion per se. These regions are also frequently involved in representing other abstract concepts—as illustrated by their roles in representing *plan* and *observe*. This pattern supports Conceptual Act Theory, which proposes that an instance of emotion (i.e., a situated conceptualization) is a compositional representation constructed from basic psychological components not specific to emotion (Barrett, 2009a b; Gendron & Barrett, 2009). Such findings are also broadly consistent with meta-analyses of the neuroimaging literature which show that brain regions typically referred to as “affective,” “cognitive, and “perceptual” are all consistently active during emotion (Lindquist et al., 2010; Kober et al., 2008; Pessoa, 2008; Wager et al., 2008).

In our results, we observed activations during *fear* and *anger* in five of the six functional networks established in the Kober et al. meta-analysis. Interestingly, many of the activations during *plan* and *observe*—our two non-emotion concepts—also occurred in regions that this meta-analysis identified (especially in temporal and occipital cortices). Because these concepts were embedded in emotional situations, it is perhaps not surprising that they activated brain regions reported in meta-analyses of emotion. As described above, though, it is likely that these processing areas enter into the processing of many concepts. Because this article focuses on emotion, however, our discussion only addresses these processing areas with respect to the emotion concepts. For detailed discussion of these processing areas and their connection to relevant literature, see the *Supplemental Materials*. Here we summarize that discussion.

Three regions often central for emotion in the literature were also central in our experiment: medial prefrontal cortex, lateral prefrontal cortex, and insular cortex. As Figure 2 illustrates, multiple effect types from the factorial ANOVA lay adjacent to one another in these regions, reflecting functional heterogeneity in a given region.

Much of medial prefrontal cortex was active in either concept main effects, situation main effects, or in both main effects, including medial orbitofrontal cortex, ventromedial prefrontal cortex, dorso-medial prefrontal cortex, and supplemental motor area. Interestingly, these areas did not contain any interaction effects. Instead, these areas contained concept effects for *anger, fear,* and *plan*, along with situation effects for social situations, implicating the importance of social evaluation, self-referential processing, and action planning in these three concepts and in knowledge about social situations.

In lateral prefrontal cortex, a concept main effect in left orbitofrontal cortex adjoined an interaction effect in dorsal regions of left orbitofrontal cortex that extended up the inferior lateral surface. For the concept main effect, a left lateralized cluster in orbitofrontal cortex was more active for *anger, fear,* and *plan* than for *observe* across both situations. As suggested earlier, this cluster may reflect the general importance of evaluation and mentalizing for these three concepts. An adjoining interaction effect in lateral orbifrontal cortex was active for *anger* in both situations and for *fear* only in social situations. Additional interaction effects showing the same pattern as for *fear* occurred more dorsally in inferior frontral gyrus and lateral prefrontal cortex. One interpretation of all these interaction effects is that they reflect the importance of intereceptive information in controlling attention when processing individuals (other people for *fear* and *anger* in social evaluations situations, and oneself for *anger* in physical harm situations). Conversely, these areas do not become active for *fear* in physical harm situations, because responding rapidly to external physical threats is more important.

Finally, concept main effect and interaction clusters occurred adjacently to one another in posterior insula. In the concept effect cluster, insula activity during *plan* and *observe* was greater than during *fear* and *anger*. In the interaction cluster, insula activity was greater during *plan* and *observe* in both situations, and also during *fear* and *anger* in physical danger situations. A somewhat similar profile was observed in mid-cingulate, where adjacent clusters exhibited a concept main effect for *plan* and *observe* and a situation main effect for physical danger situations. One interpretation of these activations is that for *observe* and *plan* across situations, and for all concepts in physical situations, the insula represents salient interoceptive information that initiates motor processing in mid-cingulate.

In summary, different effect types lay adjacent to one another in three cortical regions central to emotion experience (medial prefrontal, lateral prefrontal, and insular cortices). These results further support the proposal that emotions instantiate distributed neural circuitry that composes situated conceptualizations dynamically. More speculatively, we propose that the different effect types represented in a common brain region may play slightly different roles in emotion experience, with the precise functions of these individual areas remaining to be established in future work.

Conclusion

Our results support the Conceptual Act Theory of Emotion. Consistent with this theory, different situated conceptualizations represent the same emotion concept in different situations. Furthermore, situated conceptualizations of emotion instantiate common neural circuity distributed across the brain that is not specific to emotion per se. Specific instances of emotion are constructed dynamically within this circuitry to represent an emotion in a particular situation.

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Author Notes

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Table 1. Examples of physical danger and social evaluation situations used in the experiment.

Examples of Physical Danger Situations

Full Version

(P1) You're driving home after staying out drinking all night. (S1) The long stretch of road in front of you seems to go on forever. (P2A) You close your eyes for a moment. (P2C) The car begins to skid. (S2) You jerk awake. (S3) You feel the steering wheel slip in your hands.

Core Version

(P1) You're driving home after staying out drinking all night.
(P2) You close your eyes for a moment, and the car begins to skid.

Full Version

(P1) You're standing by a very shallow swimming pool. (S1) Because you can see that bottom is so close to the surface of the water, you realize that diving in could be dangerous. (P2A) You dive in anyway. (P2C) Your head bangs hard on concrete bottom. (S2) You put out your hands to push away. (S3) You feel yourself swallowing water.

Core Version

(P1) You're standing by a very shallow swimming pool.
(P2) You dive in anyway, and your head bangs hard on the concrete bottom.

Examples of Social Evaluation Situations

Full Version

(P1) You're at a dinner party with friends. (S1) A debate about a contentious issue arises that gets everyone at the table talking. (P2A) You alone bravely defend the unpopular view. (P2C) Your comments are met with sudden uncomfortable silence. (S2) Your friends are looking down at their plates, avoiding eye contact with you. (S3) Your feel you chest tighten.

Core Version

(P1) You're at a dinner party with friends.
(P2) You alone bravely defend the unpopular view, and your comments are met with sudden uncomfortable silence.

Full Version

(P1) You're checking e-mail during your morning routine. (S1) You hear a familiar ping, indicating that a new e-mail has arrived. (P2A) A friend has posted a blatantly false message about you on Facebook. (P2C) It's about your love life. (S2) The lower right corner of the website shows 1,000 hits already. (S3) You feel yourself finally exhale after holding in a breath.

Core Version

(P1) You're checking e-mail during your morning routine.
(P2) A friend has posted a blatantly false message on Facebook about your love life.

Note. On complete trials in the scanner, each situation was followed once by each of the four concepts (*anger, fear, observe, plan*). On catch trials, each situation appeared alone. The label preceding each sentence (e.g., P1) designates its role in the situation, as described in the *Supplemental Materials*.

Table 2. Brain areas active for concept main effects in the Concept X Situation ANOVA on concept activations (not active for situation main effects or for interaction effects).

Brain Region	**Brodmann Area**	**Spatial Extent**	**Peak**			**Mean F**	**Main Effect**			
			x	**y**	**z**		**Anger**	**Fear**	**Observe**	**Plan**
mOFC	**11**	16	3	35	-12	7.23	**+**	+		+
vmPFC	**10**	35	-2	49	-9	6.23	**+**	+		+
dmPFC	**9**	126	-2	46	32	10.92	+	+		+
ACC	**32**	12	-10	37	21	6.44	+	+		+
dmPFC/FEF	**8**	73	-4	51	38	9.45	+	+		+
dmPFC/SMA	**6**	42	-2	47	33	8.77	+	+		+
Mid-Cingulate	23/31	86	0	-38	39	6.06			+	+
L Premotor	6	43	-24	1	56	6.83			+	+
L OFC	**47**	29	-30	17	-12	7.72	+	+		+
L Temporal Pole	**38**	53	-47	12	-23	7.16	+	+		+
L STG	**41**	12	-33	-26	13	6.84			+	
L STG	**42**	9	-59	-10	11	7.60			+	+
L STG	**22**	86	-56	-45	2	7.32			+	+
L Insula	**tal**	41	-34	-26	15	6.57			+	+
L PHG	**tal**	37	-32	-31	-16	6.87			**+**	+
L ITG	**20**	32	-56	-43	-10	7.76			+	+
L Fusiform	**37**	69	-56	-50	-6	7.89			**+**	
L MTG	**21**	79	-57	-50	-1	7.40			+	**+**
L Angular g/TPJ	**39**	12	-35	-73	28	5.77			**+**	
L Precuneus	**7**	6	-30	-74	43	5.78			+	+
L Occipital	**19**	33	-34	-73	26	5.94			**+**	+
L Inf Parietal	40	45	-37	-44	37	5.84			**+**	
R Temporal Pole	**38**	54	49	16	-26	7.18	+	+		+
R STG	**41**	22	56	-25	13	7.67			+	+
R STG	**42**	20	61	-30	6	8.90			+	+
R STG	**22**	81	62	-3	-2	8.86			+	+
R Insula	**tal**	24	45	-19	4	6.12			+	+
R MTG	**21**	86	61	-4	-3	8.33	+		+	**+**
R ITG/MTG	37	158	56	-48	-9	6.78			**+**	
R Angular g/TPJ	**39**	12	36	-72	30	6.29			**+**	
R Inf Parietal	**40**	30	57	-24	14	5.74			**+**	+
R Precuneus	**7**	62	31	-72	46	5.91			**+**	
R Occipital	**19**	41	30	-73	33	6.39			**+**	
R Occipital	**18**	7	3	-77	30	5.65			**+**	

Note. None of these clusters is the same as any other cluster reported in Tables 2, 4, and 5 for other effect types. The blocks of regions indicated within a contiguous white or gray background are all areas extracted from a large cluster of activation in the initial *F* maps. L is left hemisphere, R is right hemisphere, Inf is inferior, and g is gyrus. mOFC is medial orbitofrontal cortex, vmPFC and dmPFC are ventromedial and dorsomedial prefrontal cortex, FEF is frontal eye fields, ACC is anterior cingulate cortex, SMA is supplementary motor area, STG MTG and ITG are superior/middle/inferior temporal gyrus, PHG is parahippocampal gyrus, TPJ is temporal-parietal junction. Bolded Brodmann Areas were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that the corresponding Talairach atlas region was used as a mask instead of a Brodmann Area. Spatial extent is in functional voxels, where 1 functional voxel is approximately 23.67 voxels in mm^3 units. Main effects in bold indicate that the activation for the respective concept was significantly greater than all other concepts. Cluster peaks are given in Talairach coordinates.

Table 3. Brain areas active for situation main effects in the Concept X Situation ANOVA on concept activations (and not active for concept main effects or for interaction effects).

Brain Region	Brodmann Area	Spatial Extent	Peak x	Peak y	Peak z	Mean F	Main Effect Physical	Main Effect Social
vmPFC	10	57	6	53	-6	14.70		+
Mid-Cingulate	**31**	25	-7	-27	39	13.76	+	
Paracentral Lobule	**5**	30	5	-41	60	14.22	+	
L PHG/Fusiform	35/36	46	-28	-37	-16	17.04	+	
R PHG	35/36	82	31	-30	-13	18.40	+	
L Occipital	17/18	84	-5	-97	9	14.60		+

Note. None of these clusters is the same as any other cluster reported in Tables 3, 4, and 5 for another effect type. The blocks of regions indicated within a contiguous white or gray background are all areas extracted from a large cluster of activation in the initial *F* maps. L is left hemisphere, R is right hemisphere, vmPFC is ventromedial prefrontal cortex, PHG is parahippocampal gyrus. Bolded Brodmann Areas were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that the corresponding Talairach atlas region was used as a mask instead of a Brodmann Area. Spatial extent is in functional voxels, where 1 functional voxel is approximately 23.67 voxels in mm^3 units. Cluster peaks are given in Talairach coordinates.

Table 4. Overlapping brain areas active for both concept and situation main effects in the Concept X Situation ANOVA on concept activations.

			Situation				**Concept**				**Main Effect**					
			Peak				**Peak**				**Situation**		**Concept**			
Brain Region	**Brodmann Area**	**Spatial Extent**	**x**	**y**	**z**	**Mean F**	**x**	**y**	**z**	**Mean F**	**Physical**	**Social**	**Anger**	**Fear**	**Observe**	**Plan**
dmPFC	9	76	-1	50	30	16.40	-3	51	31	17.70		+	**+**	+		+
R STG	**41**	5	40	-25	14	15.51	38	-26	11	7.64	+				+	+
R STG	**22**	8	47	-15	-1	17.21	66	-18	2	7.36	+				+	+

Note. None of these clusters is the same as any other cluster reported in Tables 2, 3, and 5 for another effect type. The blocks of regions indicated within a contiguous white or gray background are all areas extracted from a large cluster of activation in the initial *F* maps. The overlapping clusters in this table are *not* repetitions of clusters in Tables 2 and 3 but are unique clusters that occurred in *both* situation and concept main effects (see the text for further details). The blocks of regions indicated within a contiguous white or gray background are all areas extracted from a large cluster of activation in the initial *F* maps. R is right hemisphere, dmPFC is dorsomedial prefrontal cortex, STG is superior temporal gyrus. Bolded Brodmann Areas were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that the corresponding Talairach atlas region was used as a mask instead of a Brodmann Area. Spatial extent is in functional voxels, where 1 functional voxel is approximately 23.67 voxels in mm^3 units. Main effects in bold indicate that the activation for the respective concept was significantly greater than all other concepts. Cluster peaks are given in Talairach coordinates.

Table 5. Brain areas that interacted for situations and concepts in the Concept X Situation ANOVA on concept activations.

Brain Region	Brodmann Area	Spatial Extent	Peak			Mean F	Interacting Conditions: Anger		Fear		Observe		Plan	
			x	y	z		Phys	Soc	Phys	Soc	Phys	Soc	Phys	Soc
L OFC	**47**	31	-47	23	-1	6.94	+	+		+		+	+	
L IFG	**44**	26	-52	15	8	6.44				+		+	+	
L IFG	**45**	37	-49	26	10	7.04	+	+		+			+	
L dlPFC	**46**	11	-52	27	12	6.83	+			+			+	
L dlPFC	**9**	11	-58	14	28	5.95				+				
L Temporal Pole	**38**	8	-44	14	-18	6.09	+	+		+			+	+
L STG	**41**	52	-43	-22	10	10.13	+		+		+	+	+	+
L STG	**42**	21	-55	-15	10	7.54	+	+	+		+	+	+	+
L STG	**22**	50	-56	-7	7	9.34	+	+	+		+	+	+	+
L Insula	**tal**	69	-43	-20	11	7.74	+		+		+	+	+	+
L Inf Parietal	**40**	63	-54	-40	38	6.94		+	+		+	+	+	
R STG	**41**	26	57	-18	8	9.92	+		+		+	+	+	+
R STG	**42**	21	60	-22	10	8.68	+		+		+	+	+	+
R STG	**22**	63	50	-16	6	9.06	+	+	+		+	+	+	+
R Insula	**tal**	12	47	-15	7	7.01	+		+		+	+	+	+
R Inf Parietal	**40**	20	58	-50	30	5.61		+	+		+	+	+	+
Precuneus	7	43	-8	-65	50	6.50						+	+	

Note. None of these clusters is the same as any other cluster reported in Tables 2, 3, and 4 for another effect type. The blocks of regions indicated within a contiguous white or gray background are all areas extracted from a large cluster of activation in the initial *F* maps. L is left hemisphere, R is right hemisphere, Inf is inferior, OFC is orbitofrontal cortex, IFG is inferior frontal gyrus, dlPFC is dorsolateral prefrontal cortex, STG is superior temporal gyrus. Bolded Brodmann Areass were originally part of a larger cluster broken out using a mask for the respective area (all areas in this table). tal indicates that the corresponding Talairach atlas region was used as a mask instead of a Brodmann Area. Spatial extent is in functional voxels, where 1 functional voxel is approximately 23.67 voxels in mm^3 units. Cluster peaks are given in Talairach coordinates.

Table 6. Brain areas active for *anger* from Tables 2-5, broken out by whether they were active in both physical danger and social evaluation situations, or were only active in one.

Brain Region	Brodmann Area	Effect Type	Spatial Extent	Anger	
				Physical	Social
dmPFC/FEF/SMA	**6,8,9**	Concept Main Effect	241	+	+
dmPFC	9	Both Main Effects	76	+	**+**
ACC	**32**	Concept Main Effect	12	+	+
vmPFC	**10**	Concept Main Effect	35	+	+
mOFC	**11**	Concept Main Effect	16	+	+
L OFC	**47**	Concept Main Effect	29	+	+
L OFC	**47**	Interaction	31	+	+
L IFG	**45**	Interaction	37	+	+
L Temporal Pole	**38**	Concept Main Effect	53	+	+
L Temporal Pole	**38**	Interaction	8	+	+
L STG	**42,22**	Interaction	71	+	+
R Temporal Pole	**38**	Concept Main Effect	54	+	+
R STG	**22**	Interaction	63	+	+
R MTG	**21**	Concept Main Effect	86	+	+
L dlPFC	**46**	Interaction	11	+	
L STG	**41**	Interaction	52	+	
L Insula	**tal**	Interaction	69	+	
L PHG	35/36	Situation Main Effect	46	+	
R STG	**41,22**	Both Main Effects	13	+	
R STG	**41,42**	Interaction	47	+	
R Insula	**tal**	Interaction	12	+	
R PHG	35/36	Situation Main Effect	82	+	
Mid-Cingulate	**31**	Situation Main Effect	25	+	
Paracentral Lobule	**5**	Situation Main Effect	30	+	
vmPFC	10	Situation Main Effect	57		+
L Inf Parietal	**40**	Interaction	63		+
R Inf Parietal	**40**	Interaction	20		+
L Occipital	17/18	Situation Main Effect	84		+

Note. Cluster details can be found in Tables 2-5 for the respective effect type. L is left hemisphere, R is right hemisphere, Inf is inferior, SMA is supplementary motor area, dmPFC and vmPFC are dorsomedial and ventromedial prefrontal cortex, FEF is frontal eye fields, ACC is anterior cingulate cortex, mOFC is medial orbitofrontal cortex, IFG is inferior frontal gyrus, STG and MTG are superior/middle temporal gyrus, dlPFC is dorsolateral prefrontal cortex, PHG is parahippocampal gyrus. Brodmann areas in bold were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that the corresponding Talairach atlas region was used as a mask instead of a Brodmann Area. Spatial extent is in functional voxels. A large **+** indicates that an overlapping situation and concept main effect exhibited a situation effect for *one* situation, while simultaneously exhibiting a concept main effect across *both* situations, which is why the effect is also indicated for the other situation with a regular +. When an overlapping main effect did not exhibit a concept effect for *this* concept, it received a regular + indicating the relevant situation effect.

Table 7. Brain areas active for *fear* from Tables 2-5, broken out by whether they were active in both physical danger and social evaluation situations, or were only active in one.

Brain Region	**Brodmann Area**	**Effect Type**	**Spatial Extent**	**Fear**	
				Physical	**Social**
dmPFC/FEF/SMA	**6,8,9**	Concept Main Effect	241	+	+
dmPFC	9	Both Main Effects	76	+	**+**
ACC	**32**	Concept Main Effect	12	+	+
vmPFC	**10**	Concept Main Effect	35	+	+
mOFC	**11**	Concept Main Effect	16	+	+
L OFC	**47**	Concept Main Effect	29	+	+
L Temporal Pole	**38**	Concept Main Effect	53	+	+
R Temporal Pole	**38**	Concept Main Effect	54	+	+
L STG	**41,42,22**	Interaction	123	+	
L Insula	**tal**	Interaction	69	+	
L Inf Parietal	**40**	Interaction	63	+	
L PHG	35/36	Situation Main Effect	46	+	
R STG	**22,41**	Both Main Effects	13	+	
R STG	**41,42,22**	Interaction	110	+	
R Insula	**tal**	Interaction	12	+	
R Inf Parietal	**40**	Interaction	20	+	
R PHG	35/36	Situation Main Effect	82	+	
Mid-Cingulate	**31**	Situation Main Effect	25	+	
Paracentral Lobule	**5**	Situation Main Effect	30	+	
vmPFC	10	Situation Main Effect	57		+
L Occipital	17/18	Situation Main Effect	84		+
L OFC	**47**	Interaction	31		+
L IFG	**44,45**	Interaction	63		+
L dlPFC	**46,9**	Interaction	22		+
L Temporal Pole	**38**	Interaction	8		+

Note. Cluster details can be found in Tables 2-5 for the respective effect type. L is left hemisphere, R is right hemisphere, Inf is inferior, SMA is supplementary motor area, dmPFC and vmPFC are dorsomedial and ventromedial prefrontal cortex, FEF is frontal eye fields, ACC is anterior cingulate cortex, mOFC is medial orbitofrontal cortex, IFG is inferior frontal gyrus, STG is superior temporal gyrus, dlPFC is dorsolateral prefrontal cortex, PHG is parahippocampal gyrus. Brodmann areas in bold were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that Talairach coordinates are more informative than Brodmann areas. Spatial extent is in functional voxels. A large **+** indicates that an overlapping situation and concept main effect exhibited a situation effect for *one* situation, while simultaneously exhibiting a concept main effect across *both* situations, which is why the effect is also indicated for the other situation with a regular +. When an overlapping main effect did not exhibit a concept effect for *this* concept, it received a regular + indicating the relevant situation effect.

Table 8. Proportions of voxels for each concept as a function of situation and effect type, and whether the effect occurred for one or both situations.

	Conditions								
	Anger		Fear		Observe		Plan		
Effect Type	**Phys**	**Soc**	**Phys**	**Soc**	**Phys**	**Soc**	**Phys**	**Soc**	**Average**
Situation Main Effect									
One Situation Only	.15	.13	.17	.16	.11	.08	.09	.08	.12
Concept Main Effect									
Both Situations	.44	.47	.40	.51	.65	.61	.57	.63	.54
Both Main Effects									
One Situation Only	.01	.07	.01	.09	.01	.04	.01	.04	.03
Both Situations	.06	.07	.07	.09	.01	.01	.05	.05	.05
Interactions									
One Situation Only	.16	.07	.35	.14	.00	.05	.11	.00	.11
Both Situations	.18	.19	.00	.00	.23	.21	.17	.19	.15
Totals									
Situationally Shared	.68	.73	.47	.60	.89	.83	.79	.88	.73
Situationally Unique	.32	.27	.53	.40	.11	.17	.21	.12	.27

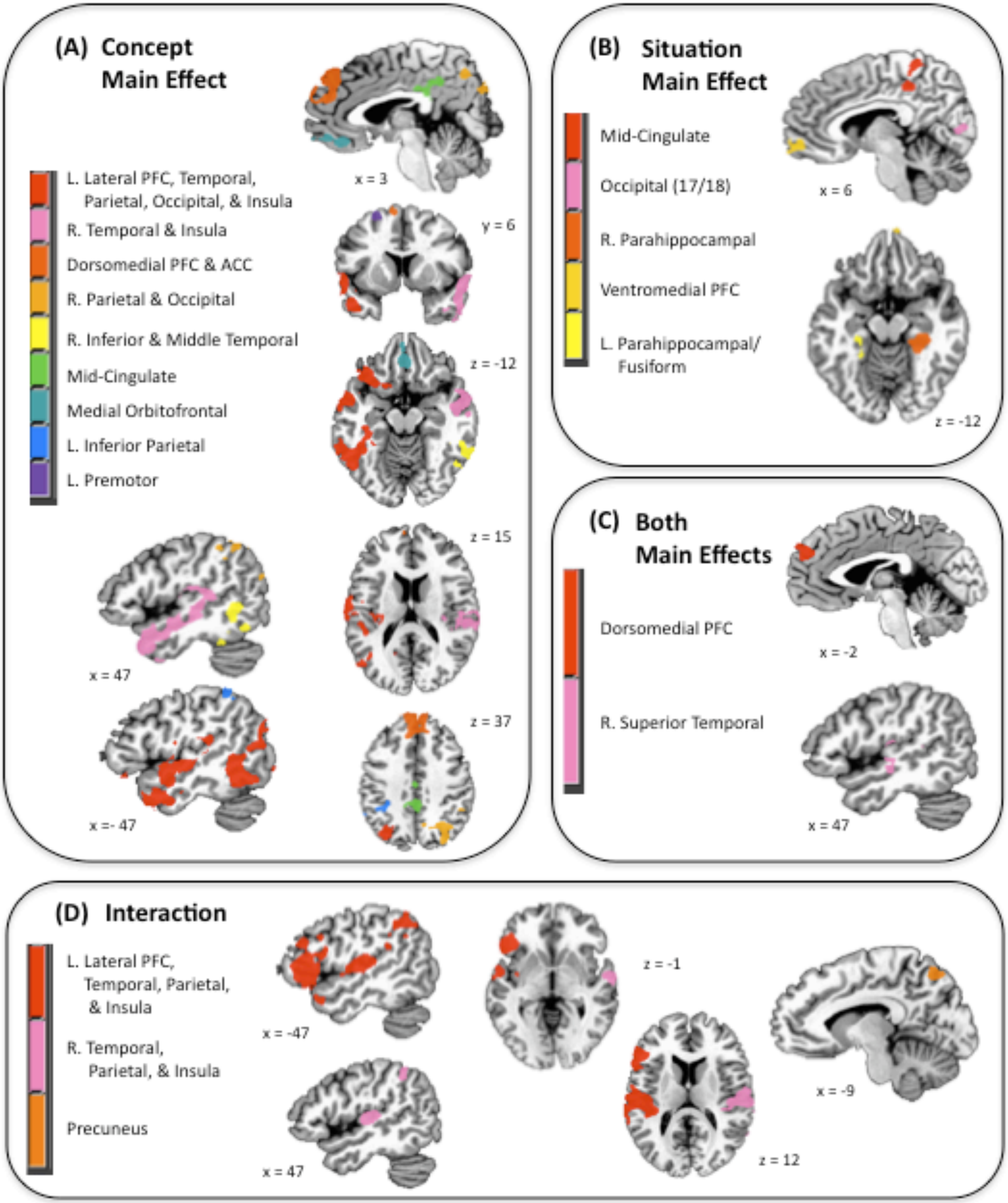
Note. Phys and Soc refer to the concept following Physical or Social situations, respectively. The proportions in each column sum to 1. Voxels for Both Main Effects were counted twice if the voxels were simultaneously significant for the target concept (contributing to Both Situations), and again if they were significant for one situation type (contributing to One Situation Only). When voxels for Both Main Effects were only significant for a situation but not for the target concept (i.e., they were significant for some other concepts), they were only counted once for the situation (contributing to One Situation Only). For Totals, Situationally Shared voxels include voxels from Concept Main Effects, Both Main effects in Both Situations, and Interactions in Both Situations. Situationally Unique voxels include voxels from Situation Main Effects, Both Main Effects in One Situation Only, and Interactions in One Situation Only.

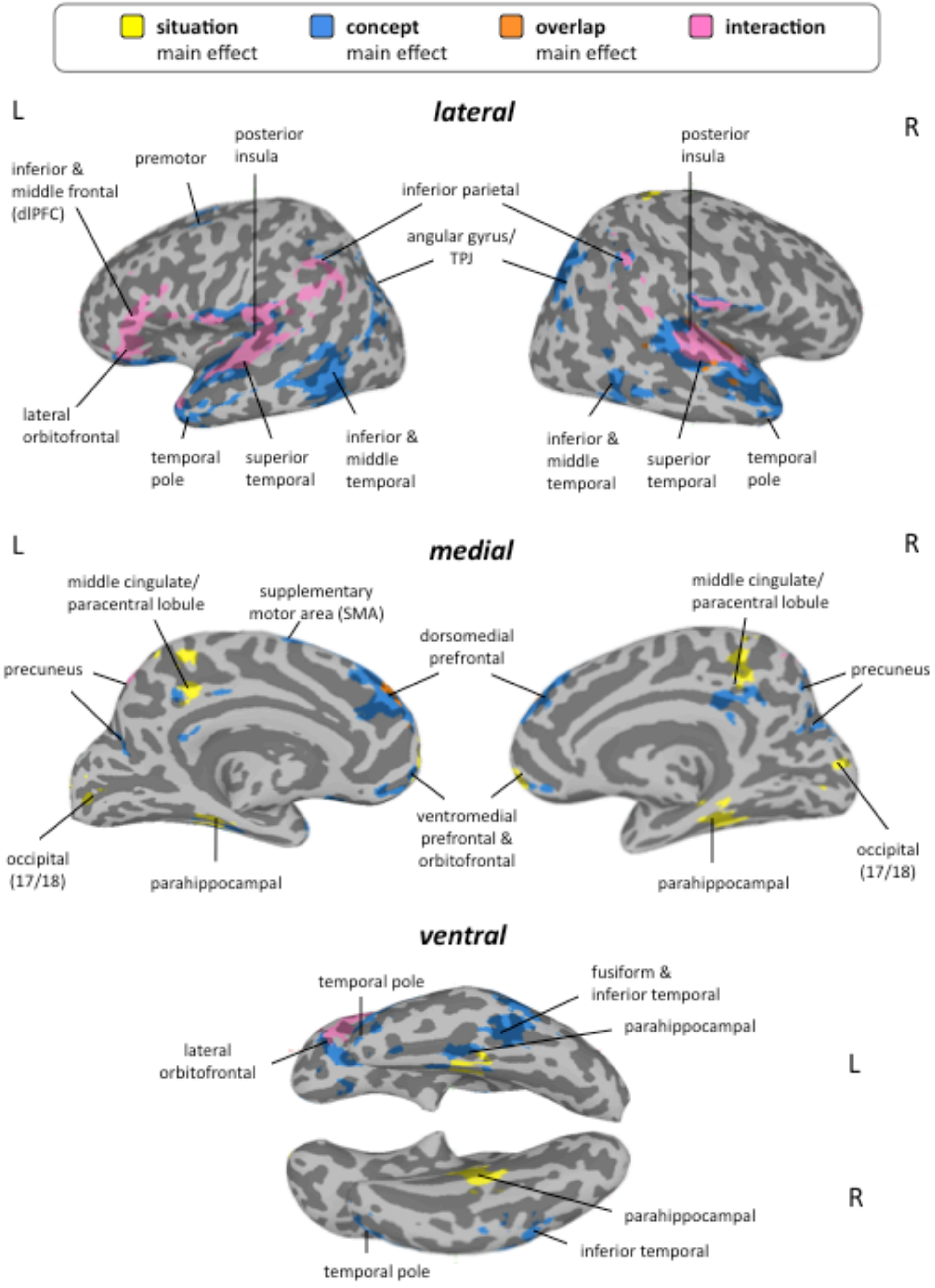
Figure Captions

(figures have been uploaded in separate files)

Figure 1. Clusters for each effect type before being broken out into sub-clusters. For a given effect type, each cluster is displayed in a different color. Warmer colors at the top of the color bar indicate larger clusters.

Figure 2. Whole-brain activations for each effect type displayed on an inflated surface. The inflated surface is only used for display purposes; analyses were not computed in this space. L is left and R is right.


(A) Concept Main Effect
L. Lateral PFC, Temporal, Parietal, Occipital, & Insula
R. Temporal & Insula
Dorsomedial PFC & ACC
R. Parietal & Occipital
R. Inferior & Middle Temporal
Mid-Cingulate
Medial Orbitofrontal
L. Inferior Parietal
L. Premotor
x = 3
y = 6
z = -12
z = 15
z = 37
x = 47
x =- 47
(B) Situation Main Effect
Mid-Cingulate
Occipital (17/18)
R. Parahippocampal
Ventromedial PFC
L. Parahippocampal/ Fusiform
x = 6
z = -12
(C) Both Main Effects
Dorsomedial PFC
R. Superior Temporal
x = -2
x = 47
(D) Interaction
L. Lateral PFC, Temporal, Parietal, & Insula
R. Temporal, Parietal, & Insula
Precuneus
x = -47
x = 47
z = -1
z = 12
x = -9


situation main effect
concept main effect
overlap main effect
interaction
lateral
L
R
inferior & middle frontal (dlPFC)
premotor
posterior insula
inferior parietal
angular gyrus/ TPJ
posterior insula
lateral orbitofrontal
temporal pole
superior temporal
inferior & middle temporal
inferior & middle temporal
superior temporal
temporal pole
medial
L
R
middle cingulate/ paracentral lobule
supplementary motor area (SMA)
dorsomedial prefrontal
middle cingulate/ paracentral lobule
precuneus
precuneus
occipital (17/18)
parahippocampal
ventromedial prefrontal & orbitofrontal
parahippocampal
occipital (17/18)
ventral
temporal pole
fusiform & inferior temporal
parahippocampal
lateral orbitofrontal
L
R
parahippocampal
inferior temporal
temporal pole

Footnotes

[1] Throughout this article, "internal states" will include interoceptions (e.g., affective valuence, arousal, hunger, pain, visceral activity, muscle tension) and mentalizing (e.g., self-related thoughts, evaluations, representing the thoughts of others, representing how one is perceived by others).

[2] Throughout this article, we use italics to indicate a concept (e.g., *car*) and quotes to indicate the word or phrase associated with it (e.g., "car").

[3] In a family resemblance, a given exemplar is similar to some exemplars of a category but not to all, with each exemplar being similar to a different subset, such that exemplars bear a resemblance to one another, with no properties shared across all category exemplars. In a radial category, multiple chains of related exemplars develop that are one or more transformations away from an initial category member, with no properties common across chains.

[4] It is perhaps interesting to note that grounding a conceptual theory of emotion in the modalities and in the body makes it much more feasible to explain the non-cognitive aspects of emotion relative to non-grounded conceptual theories of emotion (e.g., Fehr & Russell, 1984; Russell, 1991; Russell & Fehr, 1994). Because non-grounded theories stress the symbolic representation of emotion with amodal symbols in either prototype or classical form, it is not clear how they can explain the bodily, motor, and perceptual aspects of emotion. A grounded conceptual theory resolves this issue by assuming that simulations of bodily states, actions, and perceptual construals represent emotion concepts and control emotion. Whereas non-grounded theories describe emotion, grounded theories implement it.

[5] From here on, we use the word "situation" in two different ways that will always be clear from context. First, we will use "situation" when referring to the theoretical construct of a situation in situated conceptualizations. Second, we will use "situation" when referring to the description of a situation presented auditorally to participants during the experiment, both in training and on critical trials in the scanner. To avoid extensive clutter throughout the text, we will not use complete phrases such as "situation description." Instead, the intended sense will always be clear from the surrounding text.

[6] Analogous to the use of "situation" as described in Footnote 5, we will use "concept" in two different ways

that will again be clear from context. First, we will use “concept” in a theoretical sense, namely, as the cognitive representation of a category (e.g., Murphy, 2002). Importantly, however, this theoretical sense will *not* imply that a single static representation underlies a concept, such as a prototype. Instead, we assume that a concept is a dynamical system that constantly adapts to experience and that dynamically produces an infinite number of conceptual representations each tailored to the current situation (e.g., Barsalou, 1987, 1989, 1993, 2003b; Barsalou et al., 2007). Second, we will use “concept” when referring to a concept word presented auditorally to participants during the experiment, both in training and in critical scanner trials. To avoid extensive clutter throughout the text, we will not use complete phrases such as “concept word.” Instead, the intended sense will always be clear from the surrounding text.

[7] Results for the situations will be presented in another article (Wilson-Mendenhall, Barrett, & Barsalou, 2010).

[8] Factorial ANOVA approaches have been used effectively in previous neuroimaging research on emotion (e.g., Moriguchi, Negreira, Weierich, Dautoff, Dickerson, Wright, & Barrett, in press; Weierich, Wright, Negreira, Dickerson, & Barrett, 2010; Wright, Negreira, Gold, Britton, Williams, & Barrett, 2008).

[9] http://surfer.nmr.mgh.harvard.edu/optseq/

[10] The specific recording parameters were 44.1 khz sample rate, 32 bits, recorded in wav format and converted to mp3 MP3 format at a quality level of 128 kbps.

[11] E-Prime software controlled all phases of the experiment, both during the training sessions and during the scan session.

[12] http://afni.nimh.nih.gov/afni/

[13] For one participant, the second anatomical was registered to the first anatomical due to some movement towards the end of the functional scans. In another participant, the second anatomical was not acquired so only the first anatomical was used. The volume used for motion correction in both of these cases was from the first functional run not the last function run.

[14] One participant became anxious during scanning. The participant was easily calmed and finished the scan

without a problem and very little head motion. As a precaution we discarded the run just before the participant indicated feeling anxious, so this individual's dataset consists of 9 runs instead of 10.

[15] Although a concept main effect was present, the situations modulated it signficantly, such that the concept main effect was not constant across situations but instead interacted. For this reason, classifying the respective cluster as an interaction effect was more appropriate than classifying it as a concept main effect.

[16] The betas extracted for the medial prefrontal/SMA sub-cluster were obtained using the BA 6 mask. BA 6 also covered a separate cluster in left premotor cortex that was active in the concept main effect (see Table 3). The medial prefrontal/SMA activation profile shown in Table 3 resulted from averaging *only* voxels in the medial prefrontal/SMA region within the BA 6 mask. This profile was clearly different from the pattern in left premotor cortex, which was not masked with a BA because it was not part of a large activation cluster initially.

[17] Precuneus activations in the concept main effect were separate sub-clusters in the left and right hemisphere, and are thus referred to as left precuneus and right precuneus. The precuneus activation in an interaction effect was more medial, a continuous cluster of activation across both hemispheres. In this case, no hemisphere is specified to indicate the medial nature of the activation.

Supplemental Materials

Situation Templates

Each template for the full situations specified a sequence of six sentences: three primary sentences (P_i) also used in the related core situation, and three secondary sentences (S_i) not used in the core situation that provided additional relevant detail. The two sentences in each core situation were created by using P_1 as the first sentence and a conjunction of P_{2A} and P_{2C} as the second sentence (see Table 1 for examples).

For the physical situations, the template specified the following six sentences in order: P_1 described a setting and activity performed by the immersed participant in the setting, along with relevant personal attributes; S_1 provided visual detail about the setting; P_{2A} described an action (A) of the immersed participant; P_{2C} described the consequence (C) of that action; S_2 described the participant's action in response to the consequence; S_3 described the participant's resulting external somatosensory experience (on the body surface).

The templates for the social situations were similar, except that S_1 provided auditory detail about the setting (instead of visual detail), S_2 described another person's action in response to the consequence (not action by the immersed participant), and S_3 described the participant's resulting internal bodily experience (not on the body surface). Different secondary sentences were used for the physical and social threat situations to assess issues addressed in another paper on activations during the situations.

A broad range of real-world situations served as the content of the experimental situations. The physical situations were drawn from situations that involved vehicles, pedestrians, water, eating, wildlife, fire, power tools, and theft. The social situations were drawn from situations that involved friends, family, neighbors, love, work, classes, public events, and service.

Training

In the first training task with the full situations (during session one), participants were asked to make three ratings for each imagined situation. First, participants were asked, “How familiar are you with this type of situation, where your familiarity could come, not only from experiencing the situation, but from reading about it, seeing it on TV, hearing someone else talk about it, and so forth.” Participants responded using the keyboard, using a 1 to 7 scale for familiarity, where 1 indicated no familiarity, 4 indicated average familiarity, and 7 indicated high familiarity. Second, participants were asked, “Have you ever experienced this type of situation yourself or been present when someone else experienced it?” responding yes or no. Third, participants were asked, “When was the last time that you experienced this type of situation either yourself or with someone else?,” responding within the past month (5), within the past year (4), within the past five years (3), any other earlier time (2), or never (1). Because another article assesses the relation of the training data to the BOLD data, none of the training data are addressed further here.

In the second training task with the core versions of the situations, participants rated the vividness of the imagery they experienced on four modalities (always in the same fixed order): vision, audition, body, and thought (affect was not mentioned explicitly for thought). For each modality, participants entered a rating on the keyboard using a 1 to 7 scale, where 1 meant no imagery at all, 4 meant moderate imagery, and 7 meant highly vivid imagery.

In the third training task during session two, participants rated how much they experienced being immersed in the imagined situation. After listening to each full situation, the computer screen presented the question, “How much did you experience ‘being there’ in the situation?” Participants responded on the computer keyboard, using a 1 to 7 scale, where 1 meant not experiencing being in the situation at all, 4 meant experiencing being there a moderate amount, and 7 meant experiencing very much as if actually being there.

Scanner Task Practice

Six situations from the training (three physical, three social) were used that were not used later during critical trials in the scanner. At this point, participants had trained on both the full and core versions of these situations, so that both versions and the relation between them were familiar. Participants received 6 situations a total of 6 times each, for a total of 36 trials. Each situation occurred on 4 complete trials, once with each of the 4 concepts (*anger, fear, observe, plan*), and occurred on 2 catch trials by itself. Although situations repeated in the practice run, no situation ever repeated within a critical scanner run. Because situations required considerable effort to develop, we repeated situations during the practice run. Each of the 10 functional run was identical in design and procedure to the practice run. The only difference, as just described, was that a situation never repeated within a run. Instead, the 6 presentations of the same situation were distributed randomly across the 10 runs.

Behavioral Ratings and their Relation to the BOLD Data

The behavioral ratings were coded so that 1 indicated a response of "not easy," 2 indicated a response of "somewhat easy," and 3 indicated a response of "very easy." On average, participants responded on 96% of the trials. The mean and standard error for each Concept x Situation condition are shown in Supplemental Table 1. Condition means for each participant's behavioral data were submitted to a 4 (concept) x 2 (situation) repeated measures ANOVA. The ANOVA revealed a significant concept main effect ($F(3,57) = 7.42, p < .05$) qualified by a significant concept x situation interaction ($F(3,57) = 91.85, p < .05$). The situation main effect was not significant. The interaction was largely driven by different effects of the situation manipulation on the two emotion conditions. Physical-fear ($M = 2.74$) was rated as significantly easier to experience than social-fear ($M = 1.94$); $t(19) = 9.17, p < .05$. Conversely, social-anger ($M = 2.57$) was rated as significantly easier to experience than physical-anger ($M = 1.71$); $t(19) = 11.27, p <.05$. Whereas participants found it easier to experience fear of physical harm in physical situations than fear of social evaluation in social situations, they found it easier to experience anger at others in social situations than anger at themselves in physical situations.

Supplemental Table 1. Mean and standard error of the behavioral ratings for concepts as a function of situation type.

	Mean		Standard error	
Concept	Physical	Social	Physical	Social
anger	1.71	2.57	0.11	0.09
fear	2.74	1.94	0.05	0.10
observe	2.29	2.32	0.13	0.11
plan	1.85	1.77	0.11	0.11

To determine whether differences in perceived ease of experience influenced the imaging results, we performed an amplitude modulated regression in AFNI that allowed us assess whether ease ratings correlated with BOLD activity in any brain regions. For each participant, the event onsets for three conditions were specified: the 9-sec physical danger situation period, the 9-sec social evaluation situation period, and the 3-sec concept period. The concept period was not differentiated into the eight situation-concept conditions because we wanted to identify regions correlating with the experience of subjective ease across situation-concept conditions. The ease rating (1, 2, or 3) was also specified for every trial of the concept condition. Trials with missing responses were replaced with the participant's mean rating. Two participants had more than 10% missing ease responses (12.5% and 17.5% respectively). The results reported below for the group analysis, however, did not change when the data for these participants were removed.

Event onset times and ease ratings were used to create two regressors for the concept condition, each modeled with a gamma variate function. The two regressors for the combined concept condition detected: (1) voxels whose BOLD activation was correlated with the ease ratings (also known as a parametric regressor); (2) voxels whose BOLD activation was only associated with the condition but not correlated with the ease ratings. The 9-sec physical and social situation conditions were modeled in the same way as in the main analysis, in which a boxcar function for the 9-sec blocks was convolved with a gamma function.

At the group level, each participant's beta for the parametric regressor that detected correlations between BOLD and ease ratings activation was entered into a random effects group analysis. For each voxel in a situation-concept condition, a one-sample *t*-test assessed whether the mean beta across participants differed from zero (where zero signified no correlation between ease ratings and BOLD activity in the voxel). The results were thresholded using a voxel-wise threshold of $p < .005$ and extent threshold of 971 mm^3, yielding a corrected threshold of $p < .05$, as computed by Alphasim in AFNI.

Mid-cingulate cortex (peak -4 -42 55), left inferior parietal cortex (peak -43 -61 37), and bilateral caudate nucleus (peak -5 14 5) all exhibited significant positive correlations (i.e., BOLD activity increased as it became easier to experience a concept). These regions are thought to play roles in goal-directed action planning and selection (Bohlhalter et al., 2009; Grahn, Parkinson, & Owen, 2008; Rolls, 2005). A rating of very easy would be consistent with successful achievement of the participant's goal to experience the concept in the situation. When the participant was able to easily experience the concept, these areas became highly active because the anticipated goal was achieved. When the participant had difficulty experiencing the concept in the situation, these areas were less active, reflecting less successful goal pursuit.

Supplementary motor area (peak 11 15 52), on the other hand, showed a different pattern in which BOLD activity increased as it became more difficult to experience a concept. One interpretation of this activation is that when experiencing a concept in a situation was difficult, effort was required for shifting action goals or increasing the monitoring of possible responses (Nachev, Kennard, & Husain, 2008).

Most importantly, nearly all brain areas active in the critical ANOVA did not correlate with ratings of ease. This overall finding suggests that the differences just reported for the behavioral analysis of ease ratings were not responsible for most of the activations in the BOLD results. Only two BOLD activations from the ANOVA exhibited some relation to the ease ratings: the mid-cingulate activation in the situation main effect, and the left inferior parietal activation in the interaction effect. Each of these two activations is addressed in turn.

The peak and center of the mid-cingulate cluster that correlated with ease ratings fell within the mid-cingulate cluster for the situation main effect in the ANOVA, where activity was higher for all concepts in physical situations relative to social situations. Because, the ease ratings did not significantly differ across the two situation types, however, we suggest that the ANOVA effect was not driven by subjective ease of experience. If it had been, ease ratings should have been higher in physical situations than in social situations, and they were not (Supplemental Table 1). Instead, we propose that the function of this mid-cingulate area, which is thought play a role in response selection (Rolls, 2005), had two functions in our experiment. First, mid-cingulate played a central role in planning motor actions, which were more central in physical situations than in social situations (the situation main effect). Second, mid-cingulate simultaneously played a second role in selecting goal-orient task responses, being more active when the anticipated goal was achieved (the positive correlation between ease ratings and the BOLD response). Because these two activations in mid-cingulate were not identical, it appears that different circuits in mid-cingulate contributed to these two different functions.

The same argument applies to inferior parietal cluster that exhibited a significant interaction effect in the ANOVA. Because the ease ratings did not differ significantly between the five conditions significantly active in the interaction relative to the other three conditions (Supplemental Table 1), it does not appear that ease ratings drove the interaction. As for mid-cingulate, it appears that left inferior parietal cortex played two roles in our experiment. In the interaction effect, it reflected greater preparation for action in five situation-concept conditions relative to three others. In the correlation between BOLD activity and ease ratings, it reflected successful goal achievement, as described earlier. Again, because the activations were not identical, it appears that different circuits contributed to these two functions.

In summary, nearly all brain areas active in the critical ANOVA did not correlate with ratings of ease, suggesting that differences in ease ratings were not responsible for most of the critical BOLD activations. For each BOLD activation in the ANOVA that was related to ease, the specific pattern of ease ratings was inconsistent with the conclusion that ease produced the ANOVA effect.

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Separating ANOVA Effect Types

Because we wanted to first identify clusters that *only* exhibited a concept effect and that did not also exhibit any other effect type, we omitted clusters that exhibited a concept main effect *and* an interaction by removing the significant interaction clusters. We designated any cluster showing this overlap as exhibiting an interaction effect because interpretation of the interaction pattern is most appropriate for these clusters (these clusters are presented in Table 5). Although a concept main effect is present, situations modulate it sufficiently that the concept main effect is not constant across situations but instead interacts. A mask of significant clusters in the interaction *F* map was used to remove this effect type from the concept main effect *F* map. With interaction clusters removed, some of the remaining clusters exhibited a concept main effect *and* a situation main effect. This pattern occurred whenever the eight situation-concept conditions exhibited additive (non-interacting) effects of situation and concept. The following procedure was used to remove clusters that exhibited both main effects (these clusters are presented later in Table 4). First, a mask was constructed that contained all significant clusters in the situation main effect *F* map. This mask was then used to remove situation main effect clusters from the modified concept main effect *F* map that had been constructed by first removing interaction clusters. By exclusively masking out significant interaction clusters and significant situation main effect clusters, we were left with a map that contained clusters exhibiting only concept main effects and no other effect type.

Similarly, some clusters that exhibited a situation main effect also exhibited an interaction or concept main effect. Areas exhibiting these overlapping effects were masked out using the same procedure described above for the concept main effects. Interaction clusters were excluded first, followed by concept main effect clusters. Finally, some clusters exhibited both concept and situation main effects when these effects were additive (non-interacting) across the eight concept conditions. To identify these clusters, we performed a conjunction analysis of the concept and situation main effect maps to identify clusters where the effects overlapped.

Extracting Meaningful Anatomical Sub-Clusters from Large Original Clusters

Originally, some clusters were quite large, spanning many brain regions known to be functionally heterogeneous. Interpreting mean signal change extracted from all voxels in these larger clusters was not optimal given the many diverse functional regions that they contained. To characterize the specific regions driving each *F* effect type, we used the AFNI Talairach atlas to identify more specific anatomical regions within large clusters. We then extracted the signal change from activations in each nested anatomical region using masks. Thus, this procedure allowed us to examine average differences among conditions across voxels in distinct regions known to differ in function (instead of examining averages across voxels spanning many regions in the initial large clusters).

We chose to primarily use Talairach-defined Brodmann Area (BA) masks instead of Talairach-defined regions to gain more anatomical precision in large gyri (e.g., superior temporal gyrus, inferior frontal gyrus). Whenever a sub-cluster was extracted using a BA mask, its BA number is bolded in the respective table. In some cases, it was more appropriate, however, to use a defined anatomical region as a mask instead of a BA (e.g., insula, parahippocampal gyrus). Whenever a sub-cluster was extracted using an anatomically defined region, the word 'tal' is bolded instead of the BA number in the respective table.

During the extraction process, some voxels from the large initial clusters were lost if they resided outside the Talairach-defined BA mask. These significantly active voxels generally appeared to lie outside grey matter on the template, a result of averaging, warping, and smoothing. Thus, the total number of voxels summed across extracted clusters was smaller than the total number of voxels in the original large, undifferentiated cluster. Although some voxels dropped out with use of the Talairach masks, this procedure allowed us to sample the patterns of activation across the concept conditions in distinct, well-defined regions of a large cluster. As we will see, the activation patterns differed for the extracted sub-clusters across conditions, suggesting that this approach was necessary. In the tables to follow, sub-clusters extracted from the same large cluster are shown adjacently, grouped by a contiguous gray or a white background. The original large clusters are also presented in Figure 1.

Situation Effects During the Concepts that Did Not Occur During the Situations

In this article, we focus on activations during the concept period. In a related article (Wilson-Mendenhall, Barrett, et al., 2010), we report activations during the situation period. Of interest in this section are situation effects that only occurred during the concepts, not during the situations. Interestingly, the compositional process that produced emotions drew on situational information not active during the situations. From our perspective, these activations reflect the dynamic character of the process that constructs online situated conceptualizations to represent concepts. The composition of a situated conceptualization is not a simple linear combination of information active first for the situation and then for the concept. Instead, additional sources of information emerge, as emotional states develop.

The following two clusters demonstrate the emergence of new situational for the concepts. First, right parahippocampal gyrus was more active when all *concepts* were processed following physical danger situations relative to being processed following social evaluation situations). Interestingly, this brain region was *not* differentially active during the preceding physical danger and social evaluation *situations*. One interpretation of this cluster is that the processing of scenes was equally important for physical and social situations during the situation periods, but became more important for the physical situations during the concept period (and/or less important for the social situations).

Second, early visual cortex was more active when all *concepts* were processed following social evaluation situations relative to being processed following physical danger situations. Conversely, this region was *not* differentially active during the preceding physical danger and social evaluation *situations*. One interpretation of this cluster is that visual scene information was equally important for physical and social situations during the situation periods, but became more important for the social situations during the concept period (and/or less important for the physical situations).

Computing the Proportion of Voxels in each Situated Conceptualization

To construct these proportions, the total number of voxels for a given concept in a particular situation was summed across all clusters for all effect types. For each concept-situation combination, the number of voxels was then summed across all clusters within each effect type and divided by the total voxels for the combination to produce the proportion of voxels associated with the effect type. By definition, voxels in situation main effects were active in one situation only, whereas voxels in concept effects were active in both situations. Voxels active in both main effects were counted once for each effect, first for the situation in which they were significant, and second for both situations reflecting the concept effect. Thus, each of these voxels was counted twice, once for one situation only and again for both situations (this was taken into account when computing the total voxels for each concept-situation combination). When voxels active in an interaction were only significant for one situation, they were included in the row for One Situation Only; when they were active in both situations, they were included instead in the row for Both Situations. The final two rows of Table 8 sum the voxels that were shared vs. unique across situations to summarize how much shared vs. unique processing occurred for a given concept in physical and social situations.

Situated Conceptualizations for *Observe* and *Plan*

Supplemental Table 2. Brain areas active for *observe* from Tables 2-5, broken out by whether they were active in both physical danger and social evaluation situations, or were only active in one.

Brain Region	Brodmann Area	Effect Type	Spatial Extent	Observe	
				Physical	Social
Mid-Cingulate	23/31	Concept Main Effect	86	+	+
L Premotor	6	Concept Main Effect	43	+	+
L STG	**41,42,22**	Concept Main Effect	107	+	+
L STG	**41,42,22**	Interaction	123	+	+
L Insula	**tal**	Concept Main Effect	41	+	+
L Insula	**tal**	Interaction	69	+	+
L ITG	**20**	Concept Main Effect	32	+	+
L MTG	**21**	Concept Main Effect	79	+	+
L Fusiform	**37**	Concept Main Effect	69	+	+
L PHG	**tal**	Concept Main Effect	37	+	+
L Angular g/TPJ	**39**	Concept Main Effect	12	+	+
L Inf Parietal	40	Concept Main Effect	45	+	+
L Inf Parietal	**40**	Interaction	63	+	+
L Precuneus	**7**	Concept Main Effect	6	+	+
L Occipital	**19**	Concept Main Effect	33	+	+
R STG	**41,42,22**	Concept Main Effect	123	+	+
R STG	**41,22**	Both Main Effects	13	**+**	+
R STG	**41,42,22**	Interaction	110	+	+
R Insula	**tal**	Concept Main Effect	24	+	+
R Insula	**tal**	Interaction	12	+	+
R MTG	**21**	Concept Main Effect	86	+	+
R ITG/MTG	37	Concept Main Effect	158	+	+
R Angular g/TPJ	**39**	Concept Main Effect	12	+	+
R Inf Parietal	**40**	Concept Main Effect	30	+	+
R Inf Parietal	**40**	Interaction	20	+	+
R Precuneus	**7**	Concept Main Effect	62	+	+
R Occipital	**19,18**	Concept Main Effect	48	+	+
L PHG	35/36	Situation Main Effect	46	+	
R PHG	35/36	Situation Main Effect	82	+	
Mid-Cingulate	**31**	Situation Main Effect	25	+	
Paracentral Lobule	**5**	Situation Main Effect	30	+	
dmPFC	9	Both Main Effects	76		+
vmPFC	10	Situation Main Effect	57		+
L OFC	**47**	Interaction	31		+
L IFG	**44**	Interaction	26		+
Precuneus	7	Interaction	43		+
L Occipital	17/18	Situation Main Effect	84		+

Note. Cluster details can be found in Tables 2-5 for the respective effect type. L is left hemisphere, R is right hemisphere, Inf is inferior and g is gyrus. STG MTG and IFG are superior/middle/inferior temporal gyrus, PHG is parahippocampal gyrus, TPJ is temporal-parietal junction, dmPFC and vmPFC are dorsomedial and ventromedial prefrontal cortex, OFC is orbitofrontal cortex, IFG is inferior frontal gyrus. Brodmann areas in bold were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that Talairach coordinates are more informative than Brodmann areas. Spatial extent is in functional voxels. A large **+** indicates that an overlapping situation and concept main effect exhibited a situation effect for *one* situation, while simultaneously exhibiting a concept main effect across *both* situations, which is why the effect is also indicated for the other situation with a regular +. When an overlapping main effect did not exhibit a concept effect for *this* concept, it received a regular + indicating the relevant situation effect.

Supplemental Table 3. Brain areas active for *plan* from Tables 2-5, broken out by whether they were active in both physical danger and social evaluation situations, or were only active in one.

Brain Region	**Brodmann Area**	**Effect Type**	**Spatial Extent**	**Plan**	
				Physical	**Social**
dmPFC/FEF/SMA	**9,8,6**	Concept Main Effect	241	+	+
dmPFC	9	Both Main Effects	76	+	**+**
ACC	**32**	Concept Main Effect	12	+	+
vmPFC	**10**	Concept Main Effect	35	+	+
mOFC	**11**	Concept Main Effect	16	+	+
L OFC	**47**	Concept Main Effect	29	+	+
L Premotor	6	Concept Main Effect	43	+	+
Mid-Cingulate	23/31	Concept Main Effect	86	+	+
L Temporal Pole	**38**	Concept Main Effect	53	+	+
L Temporal Pole	**38**	Interaction	8	+	+
L STG	**41,42,22**	Interaction	123	+	+
L STG	**42,22**	Concept Main Effect	95	+	+
L Insula	**tal**	Concept Main Effect	41	+	+
L Insula	**tal**	Interaction	69	+	+
L ITG	**20**	Concept Main Effect	32	+	+
L MTG	**21**	Concept Main Effect	79	+	+
L PHG	**tal**	Concept Main Effect	37	+	+
L Precuneus	**7**	Concept Main Effect	6	+	+
L Occipital	**19**	Concept Main Effect	33	+	+
R Temporal Pole	**38**	Concept Main Effect	54	+	+
R STG	**41,42,22**	Concept Main Effect	123	+	+
R STG	**41,22**	Both Main Effects	13	**+**	+
R STG	**41,42,22**	Interaction	110	+	+
R MTG	**21**	Concept Main Effect	86	+	+
R Insula	**tal**	Concept Main Effect	24	+	+
R Insula	**tal**	Interaction	12	+	+
R Inf Parietal	**40**	Concept Main Effect	30	+	+
R Inf Parietal	**40**	Interaction	20	+	+
L OFC	**47**	Interaction	31	+	
L IFG	**44,45**	Interaction	63	+	
L dlPFC	**46**	Interaction	11	+	
L PHG	35/36	Situation Main Effect	46	+	
L Inf Parietal	**40**	Interaction	63	+	
R PHG	35/36	Situation Main Effect	82	+	
Mid-Cingulate	**31**	Situation Main Effect	25	+	
Paracentral Lobule	**5**	Situation Main Effect	30	+	
Precuneus	7	Interaction	43	+	
vmPFC	10	Situation Main Effect	57		+
L Occipital	17/18	Situation Main Effect	84		+

Note. Cluster details can be found in Tables 2-5 for the respective effect type. L is left hemisphere, R is right hemisphere, Inf is inferior, SMA is supplementary motor area, dmPFC and vmPFC are dorsomedial and ventromedial prefrontal cortex, FEF is frontal eye fields, ACC is anterior cingulate cortex, mOFC is medial orbitofrontal cortex, STG MTG and IFG are superior/middle/inferior temporal gyrus, PHG is parahippocampal gyrus, IFG is inferior frontal gyrus, dlPFC is dorsolateral prefrontal gyrus. Brodmann areas in bold were originally part of a larger cluster broken out using a mask for the respective area. tal indicates that Talairach coordinates are more informative than Brodmann areas. Spatial extent is in functional voxels. A large **+** indicates that an overlapping situation and concept main effect exhibited a situation effect for *one* situation, while simultaneously exhibiting a concept main effect across *both* situations, which is why the effect is also indicated for the other situation with a regular +.

Interaction Effects for Emotion Concepts: Relations to Previous Literature

Here we provide a detailed discussion of the interaction effects and their connection to relevant literature. Because this article focuses on emotion, this discussion only addresses interaction patterns for the emotion concepts. Interaction clusters dependent on both the concept and the situation were primarily located in orbitofrontal, lateral prefrontal, temporal, parietal, and insular cortex.

A posterior region of left lateral orbitofrontal cortex was more active when *fear* was experienced in social evaluation situations than when *fear* was experienced in physical danger situations. The same cluster was active during *anger* in both situations. This region of caudolateral orbitofrontal cortex is part of a proposed lateral orbital network thought to integrate external sensory information with internal somato-visceral states to represent the value of experience (Barrett & Bliss-Moreau, 2009; Barrett & Bar, 2009; Ongur & Price, 2000). In general, caudolateral orbitofrontal cortex is consistently implicated in the affective, valuative component of sensory experiences (taste, smell, touch), especially unpleasantness (Anderson et al., 2003; Kringelbach, O'Doherty, Rolls, & Andrews, 2003; Kringelback & Rolls, 2004; Rolls, Kringelbach, & de Araujo, 2003; Small et al., 2003). Thus, one interpretation of this interaction is that the experience of *fear* in physical danger situations, relative to the other emotion conditions, involved less attention on the subjective feeling of unpleasantness, and more attention on the action needed to deal with the physical threat.

In bilateral posterior insula, significantly more activity was observed during *fear* and *anger* when these emotions were experienced in physical danger situations as compared to social evaluation situations. Given that the body is so central in physical danger situations, it is not surprising that this region, which is known to play a role in interoception (Craig, 2002), showed situation-specific activation for the emotions. This result also suggests that *fear* and *anger* during the social evaluation situations involved less interoception of the body's current state than the other conditions.

Within both posterior insula and left orbitofrontal cortex, the interaction effects just described resided adjacent to other effect types. We discuss what this arrangement might mean in the final section of the paper, which focuses on how different effect types reside adjacently in a particular neural areas associated with producing emotion.

Another group of clusters in left dorsolateral prefrontal cortex and inferior frontal gyrus were more active when *fear* was experienced in social evaluation situations than when *fear* was experienced in physical danger situations. These regions are thought to be central to cognitive control and working memory (Miller & Cohen, 2001; Thompson-Schill, Bedny, & Goldberg, 2005). Perhaps the *fear* experienced when being negatively judged by others involves more cognitive control and working memory operations to resolve and deal with complicated social situations. On the other hand, *fear* in physical danger situations seems more likely to initiate action quickly and automatically.

In contrast to these frontal regions, *fear* showed the opposite pattern in lateral temporal cortex. Bilateral superior temporal gyrus showed more activation during *fear* and *anger* in physical danger situations than in social evaluation situations. Because superior temporal gyrus is critical to auditory and language processing (Binder et al., 1994), it seems likely that experiencing *fear* and *anger* in physical danger situations involved an external focus on the environment, including the monitoring of sounds. Consistent with this idea is the finding that these same regions were active during *observe* and *plan* in both situations. Another possibility is that activity in these regions reflected inner speech, especially in posterior Wernicke's area (BA 22). In these more posterior regions, significant activity during *anger* in social evaluation was also observed (in addition to the activity observed during *fear* and *anger* in physical danger situations), suggesting that this result may in part involve linguistic processing.

Another posterior region showing an interesting interaction pattern was bilateral inferior parietal cortex, which has been associated with processing the spatial structure of an observed situation in relation to potential action (e.g., Bohlhalter et al., 2009; Buxbaum, Kyle, Grossman, & Coslett, 2007; Gross & Grossman, 2008; Kemmerer et al., 2008; Tunik, Lo, Adamovich, 2008). This area was significantly more active during *fear* in physical danger situations than during *fear* in social evaluation situations. *Anger*, however, showed the opposite profile; namely, more activity was observed during *anger* directed towards others in social evaluation situations than *anger* directed towards the self in physical danger situations. Whereas *fear* in physical danger situations may involve assessing the environment in preparation to act more so than *fear* in social evaluation situations, *anger* directed outward towards someone else in social evaluation situations may be more likely to initiate preparing to act in space than *anger* directed inwards towards the self in physical danger situations. This particular interaction effect is a good illustration of how properties of the concept can interact with features of the situation.

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Adjacent Activations for Multiple Effect Types: Relations to Previous Literature

This discussion focuses on three processing regions important for emotion in emotion meta-analyses (Lindquist et al., submitted; Kober et al., 2008; Wager et al., 2008): medial prefrontal, lateral prefrontal, and insular cortices. In these regions, we observed multiple effect types from the factorial ANOVA lying adjacent to one another, implicating functional heterogeneity in a given region.

Much of medial prefrontal cortex was active in concept main effects (for concepts across situation type), in situation main effects (for a situation type across concepts), and in both main effects (for concepts and situations). Ventral activations in medial orbitofrontal cortex (BA 11) were observed in the concept main effect, with more activity during *anger*, *fear*, and *plan* than during *observe*. This effect extended up into ventromedial prefrontal cortex (BA 10), lying adjacent to another cluster in BA 10 showing a situation main effect, in which all the concepts were more active when experienced in social evaluation situations than in physical danger situations. Why is the pattern of activation different in these adjacent clusters? One possibility is that the part of this region showing a situation main effect is performing a different function, such that activity during *observe* becomes similar to the other concepts (eliminating a concept main effect), but only in social evaluation situations. Because this region is often more active for tasks that involve self-referential processing, one hypothesis is that it may represent information from one's "bodily" self as belonging to one's "conceptual" self (Northoff et al., 2006). Perhaps this basic self-referential process was fundamental to experiencing all the concepts in the social evaluation situation, even *observe*.

Another interesting transition occurred in dorsomedial prefrontal cortex (BA 9), where the main effects overlapped. Greater activity was seen during *anger*, *fear*, and *plan* than *observe*, and, in addition, this activity was greater when all concepts were experienced in social evaluation than physical danger situations. In this region of overlap, person knowledge and theory of mind processing may have been important in social situations, but not as important for *observe* as for the other concepts, thereby producing a concept main effect as well. In general, experiencing *observe* appeared to be associated with less activity in regions of medial prefrontal cortex involved in interpretation and evaluation, which is why the ventromedial cluster described above is so interesting (i.e., where *observe* did not differ from the other concepts in social situations). Moving even more dorsally in medial prefrontal cortex to regions associated with action monitoring and planning, these areas again only showed a concept main effect for *anger*, *fear*, and *plan*. Motor planning appeared important in both situations, but again, not for *observe*, which was grounded more in vision, audition, and interoception.

Multiple effect types were also observed in lateral prefrontal cortex. In lateral orbito-frontal cortex, a concept effect adjoined an interaction effect. This region is perfectly situated to integrate information from the external world with the internal landscape of the body, and has thus been suggested to be constantly monitoring and altering bodily reactions to external stimuli (Ongur & Price, 2000). Integration of external and internal states creates value, which can then be used to guide behavior (Barrett & Bliss-Moreau, 2009; Barrett & Bar, 2009). For the concept effect, a left lateralized cluster in orbitofrontal cortex was more active for *anger, fear,* and *plan* than for *observe* across both situations. As suggested earlier, this cluster may reflect the general importance of interoceptive information for these three concepts. The adjoining interaction cluster was active for *anger* in both situations and for *fear* only in social situations. As proposed earlier, one explanation of this cluster is that subjective feelings of unpleasantness or pain were dampened by the need to act quickly in physical danger situations.

Interestingly, the interaction effect in lateral orbito-frontal cortext extended up into inferior frontal and dorsolateral prefrontal cortex, with all of these clusters also showing significantly more activation for social-*fear* than for physical-*fear* (*anger* showed varied effects in these clusters). A dorsal-ventral distinction was similarly found in a recent meta-analysis of nearby anterior insula (Kurth et al., 2010; see also Wager & Barrett, 2004). Specifically, dorsal anterior insula was more active in working memory and attentional shifting tasks than ventral anterior insula, leading the authors to suggest that the dorsal region may update attentional demands and reallocation by monitoring internal states. Perhaps a similar distinction exists in posterior orbitofrontal cortex, with more dorsal regions communicating with attention systems located in dorsolateral prefrontal cortex.

If so, the dorsal orbitofrontal interaction cluster here may signify that experiencing social-*fear* involved more updating of attention systems based on interoceptive states than physical-*fear*. Again, this fits with the idea that *fear* of physical harm to the body quickly initiated responding, accompanied by decreased awareness or processing of internal states.

Concept main effect and interaction clusters were also observed adjacent to one another in posterior insula, a region thought to receive and integrate continuous information concerning the state of the body, including pain and temperature (Craig, 2002). In the concept main effect cluster, insula activity during *plan* and *observe* was greater than during the emotions. In the interaction cluster, insula activity was greater during *fear* and *anger* in physical danger situations, and also during *plan* and *observe* in both situations. A somewhat similar profile was observed in mid-cingulate. Adjacent clusters exhibited a concept main effect in which *plan* and *observe* were greater than *fear* and *anger*, and a situation main effect for the physical danger situations (different from the interaction effect above where *observe* and *plan* were not active in both situations). It has been proposed recently that posterior insula and mid-cingulate form part of a general salience and action network (Taylor, Seminowicz, & Davis, 2009). The question remains why all the concepts activated one of these mid-cinglulate areas in physical danger situations, whereas only the non-emotion abstract concepts activated an adjacent area. One possibility is that the cluster active across all concepts is specialized for pain and nociception in physical situations, whereas the adjacent cluster is specialized for detecting salience during *planning* and *observing* across situations.

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