Supplemental Materials

Grounding Emotion in Situated Conceptualization

Christine D. Wilson-Mendenhall
Lisa Feldman Barrett
W. Kyle Simmons
Lawrence W. Barsalou

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.

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 activation and the ease ratings was entered into a random effects group analysis. In each voxel, a one-sample *t*-test assessed whether the mean beta across participants differed from zero (where zero signified no correlation between ease ratings and

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

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 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-oriented 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 the 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.

References

Bohlhalter, S., Hattori, N., Wheaton, L., Fridman, E., Shamim, E.A., Garraux, G., & Hallett, M. (2009). Gesture subtype–dependent left lateralization of praxis planning: An event-related fMRI study. *Cerebral Cortex, 19*, 1256-1262.

Grahn, J.A., Parkinson, J.A., & Owen, A.M. (2008). The cognitive functions of the caudate nucleus. *Progress in Neurobiology, 86*, 141-155.

Nachev, P., Kennard, C., & Husain, M. (2008). Functional role of the supplementary and pre supplementary motor areas. *Nature Reviews Neuroscience, 9*, 856-869.

Rolls, E. T. (2005). *Emotion explained*. Oxford: Oxford University Press.

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 Tables 2-5, 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, & Barsalou, 2011), 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 information 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 processing visual details 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).

Reference

Wilson-Mendenhall, C.D., Barrett, L.F., & Barsalou, L.W. (2011). Predicting neural activation during the processing of emotional situations. *Manuscript in preparation*.

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 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.

References

Anderson, A.K., Christoff, K., Stappen, I., Panitz, D., Ghahremani, D.G., Glover, G., Gabrieli, J.D.E., & Sobel, N. (2003). Dissociated neural representations of intensity and valence in human olfaction. *Nature Neuroscience, 6*, 196-202.

Barrett, L.F., & Bar, M. (2009). See it with feeling: affective predictions during object perception. *Philosophical Transactions of the Royal Society B, 364*, 1325-1334.

Barrett, L.F. & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology, 41*, 167-218.

Binder, J.R., Rao, S.M., Hammeke, T.A., Yetkin, F.Z., Jesmanowicz, A., Bandettini, P.A., Wong, E.C., Estkowski, L.D., Goldstein, M.D., Haughton, V.M., & Hyde, J.S. (1994). Functional magnetic resonance imaging of human auditory cortex. *Annals of Neurology, 35*, 662-672.

Bohlhalter, S., Hattori, N., Wheaton, L., Fridman, E., Shamim, E.A., Garraux, G., & Hallett, M. (2009). Gesture subtype–dependent left lateralization of praxis planning: An event-related fMRI study. *Cerebral Cortex, 19*, 1256-1262.

Buxbaum L.J., Kyle K., Grossman M., & Coslett H.B. (2007). Left inferior parietal representations for skilled hand-object interactions: Evidence from stroke and corticobasal degeneration. *Cortex, 43*, 411-423.

Craig, A.D. (2002). How do you feel? Interception: the sense of the physiological condition of the body. *Nature Reviews Neuroscience, 3*, 655-666.

Gross, R.G., & Grossman, M. (2008). Update on apraxia. *Current Neurology and Neuroscience Reports, 8*, 490-496.

Kemmerer, D., Gonzalez Castillo, J., Talavage, T., Patterson, S., & Wiley, C. (2008). Neuroanatomical distribution of five semantic components of verbs: Evidence from fMRI. *Brain and Language, 107*, 16-43.

Kringelbach, M.L., O'Doherty, J., Rolls, E.T., & Andrews, C. (2003). Activation of the human orbitofrontal cortex to a liquid food stimulus is correlated with its subjective pleasantness. *Cerebral Cortex, 13*, 1064-1071.

Kringelbach, M.L., & Rolls, E.T. (2004). The functional neuroanatomy of the human orbitofrontal cortex: evidence from neuroimaging and neuropsychology. *Progress in Neurobiology, 72*, 341-372.

Miller, E.K., & Cohen, J.D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*, 167-202.

Ongur, D., & Price, J.L. (2000). The organization of networks within the orbital and medial prefrontal cortex of rats, monkeys and humans. *Cerebral Cortex, 10*, 206-219.

Rolls, E.T., Kringelbach, M.L., & de Araujo, I.E.T. (2003). Different representations of pleasant and unpleasant odours in the human brain. *European Journal of Neuroscience, 18*, 695-703.

Small, D.M., Gregory, M.D., Mak, Y.E., Gitelman, D., Mesulam, M.M., & Parrish, T. (2003). Dissociation of neural representation of intensity and affective valuation in human gustation. *Neuron, 39*, 701-711.

Thompson-Schill, S.L., Bedny, M., & Goldberg, R.F. (2005). The frontal lobes and the regulation of mental activity. *Current Opinion in Neurobiology, 15*, 219-224.

Tunik, E., Lo, O.Y., Adamovich, S.V. (2008). Transcranial magnetic stimulation to the frontal operculum and supramarginal gyrus disrupts planning of outcome-based hand–object interactions. *Journal of Neuroscience, 28,* 14422-14427.

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., in press; 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 orbitofrontal 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 orbitofrontal cortex 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 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 part of the mid-cinglulate and insula 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.

References

Barrett, L.F., & Bar, M. (2009). See it with feeling: affective predictions during object perception. *Philosophical Transactions of the Royal Society B, 364*, 1325-1334.

Barrett, L.F. & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology, 41*, 167-218.

Craig, A.D. (2002). How do you feel? Interception: the sense of the physiological condition of the body. *Nature Reviews Neuroscience, 3*, 655-666.

Kober, H., Barrett, L.F., Joseph, H., Bliss-Moreau, E., Lindquist, K., & Wager, T.D. (2008). Functional grouping and cortical-subcortical interactions in emotion: A meta-analysis of neuroimaging studies. *NeuroImage, 42*, 998-1031.

Kurth, F., Zilles, K., Fox, P. T., Laird, A. R., Eickhoff, S.B. (2010). A link between the systems: Functional differentiation and integration within the human insula revealed by meta-analysis. *Brain Structure and Function*, 214, 519-534.

Lindquist, K. A., Wager, T.D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (in press). The brain basis of emotion: A meta-analytic review. *Behavioral and Brain Sciences*.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *NeuroImage, 31*, 440-457.

Ongur, D., & Price, J.L. (2000). The organization of networks within the orbital and medial prefrontal cortex of rats, monkeys and humans. *Cerebral Cortex, 10*, 206-219.

Wager, T. D., & Barrett, L. F. (2004). From affect to control: Functional specialization of the insula in motivation and regulation. Published online at *PsycExtra*.

Wager, T. D., Barrett, L. F., Bliss-Moreau, E., Lindquist, K., Duncan, S., Kober, H., Joseph, J., Davidson, M., & Mize, J. (2008). The neuroimaging of emotion. In M. Lewis, J. M. Haviland-Jones, and L.F. Barrett (Eds.), *The handbook of emotion*, 3rd Edition (pp. 249-271). New York: Guilford.

Taylor, K.S., Seminowicz, D.A., & Davis, K.D. (2009). Two systems of resting state connectivity between the insula and cingulate cortex. *Human Brain Mapping, 30*, 2731-2745.