Implicit and Explicit Evaluation: fMRI Correlates of Valence, Emotional Intensity, and Control in the Processing of Attitudes

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Abstract

■ Previous work suggests that explicit and implicit evaluations (good–bad) involve somewhat different neural circuits that process different dimensions such as valence, emotional intensity, and complexity. To better understand these differences, we used functional magnetic resonance imaging to identify brain regions that respond differentially to such dimensions depending on whether or not an explicit evaluation is required. Participants made either good–bad judgments (evaluative) or abstract–concrete judgments (not explicitly evaluative) about socially relevant concepts (e.g., "murder," "happiness," "abortion," "welfare"). After scanning, participants rated the concepts for goodness, badness, emotional intensity, and how much they tried to control their evaluation of the concept. Amygdala activation correlated with emotional intensity and right insula activation correlated with valence in both tasks, indicating that these aspects of stimuli were processed by these areas regardless of intention. In contrast, for the explicitly evaluative good–bad task only, activity in the anterior cingulate, frontal pole, and lateral areas of the orbital frontal cortex correlated with ratings of control, which in turn were correlated with a measure of ambivalence. These results highlight that evaluations are the consequence of complex circuits that vary depending on task demands. ■

INTRODUCTION

Sometimes, evaluation is relatively straightforward. For example, most people do not need to deliberate much before deciding whether concepts such as death, happiness, or freedom are good or bad. Other evaluations require more reflection, where multiple factors are considered and appropriately weighed. Often, these more complex attitudes about concepts such as gun control, abortion, sex education, taxes, or preemptive war can lead to heated debates with others, or even with oneself. Of course, people differ in the amount of reflection they engage in about particular concepts; some individuals have a rapid and unambiguous response to abortion, and some find disadvantages to freedom and merits even in death and taxes.

Given the strong theoretical links between attitudinal and affective processes, the brain region most clearly associated with affect, the amygdala, has been proposed to play a critical role in the evaluation of the environment, and attitudinal processes more generally. Across multiple stimulus modalities, greater amygdala activation is observed to bad than good stimuli (Phelps, O'Connor, Gatenby, et al., 2001; LeDoux, 2000; LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998; Zald, Lee, Fluegel, & Pardo, 1998; Zald & Pardo, 1997; Morris, Frith, et al., 1996). Moreover, amygdala activation has been observed when participants are consciously unaware of the stimulus being processed (Cunningham, Johnson, Raye, et al., in press; Morris, Ohman, & Dolan, 1998; Whalen et al., 1998) and when evaluative judgments are not explicitly requested (Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003), suggesting that the amygdala may be involved in automatic or unconscious forms of evaluation.

Yet, the implication that the amygdala is *the* "attitude region"—activating as a direct function of stimulus negativity—is contradicted by recent research findings. In addition to activating to negative stimuli, the amygdala activates to positive stimuli when compared with neutral stimuli (Liberzon, Phan, Decker, & Taylor, 2003; Hamann, Ely, Hoffman, & Kilts, 2002; Hamann & Mao, 2002; Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; see Zald, 2003, for a review). Such findings suggest that amygdala activation may be more a function of emotional intensity than valence. This is supported by further evidence from a patient who, despite bilateral amygdala damage, showed negative responses to Black compared to White faces on an indirect measure of race attitudes (Phelps, Cannistraci, & Cunningham, 2003).

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This finding suggests that other structures also play a role in processing valence.

In the emotion literature, emotion has been proposed to be a function of two theoretically separable concepts: valence (overall badness relative to goodness, often defined as bad minus good) and intensity (Russell, 2003). At the same time, there is evidence that negative stimuli are, on average, experienced as more intense emotionally than positive stimuli (Ito, Cacioppo, & Lang, 1998). Thus, in neuroimaging studies, it has often not been clear whether amygdala activation reflects the processing of valence or emotional intensity. Greater activation for negative than positive stimuli could simply reflect the greater average intensity of negative stimuli rather than valence per se. Support for this suggestion comes from work looking at neural processing of taste and odor, where amygdala activation is associated with intensity, and other regions are associated with valence (Anderson et al., 2003; Small et al., 2003). Moreover, a patient with bilateral amygdala damage rated valence of stimuli similar to controls, but gave quite different ratings of the emotional intensity of these stimuli (Adolphs, Russell, & Tranel, 1999).

Furthermore, in addition to intensity and valence, attitudes differ in complexity. Although some attitudes may be simple—murder is bad—others are more complex, and require reflection for evaluation. Such stimuli may be experienced as having both positive and negative aspects (i.e., we may feel ambivalent) and reflection may be necessary to arrive at an evaluative judgment. As in monitoring memories (e.g., Johnson, Hashtroudi, & Lindsay, 1993), the functional role of more reflective or controlled processes in evaluation may be to withhold responding until more information is available, integrate multiple sources or dimensions of information, and/or retrieve additional information. Also, whereas simple valence may be processed implicitly, explicit evaluation may be necessary for consideration of conflicting or additional evaluatively relevant information. People are not solely influenced by their initial response to stimuli; they can control processing to bring evaluations in line with higher-order personal values or situational constraints.

Previous research suggests two neural systems involved in evaluation (Cunningham, Johnson, Gatenby, et al., 2003). Greater activity was observed in the amygdala and right inferior prefrontal cortex (PFC) (BA 45, insula) for stimuli later rated as ''bad'' than those later rated as ''good,'' regardless of whether or not the task required an evaluative judgment, suggesting evaluative processing that occurs regardless of perceiver intent. In contrast, activity in the medial (BA 10) and ventrolateral (BA 47) PFC was greater when the task required an explicit evaluative judgment than when it did not. In addition, these areas active during explicit evaluation appeared to be involved in processing evaluative complexity: They were most active during evaluation of stimuli with competing positively and negatively valenced information. These findings suggest two systems—one sensitive to stimulus valence and another especially likely to be recruited under conditions of attitudinal complexity, where more deliberation may be necessary. Consequently, evaluations of the same stimulus can result in quite different subjective evaluative experiences and perhaps even different evaluative outcomes; for example, a positive attitude in one circumstance and a negative one in another. Consistent with this, related research shows that brain activity associated with more automatic evaluative processing that occurs when stimuli are presented too briefly for conscious report can be inhibited or modified when there is the opportunity for more conscious processing (Cunningham, Johnson, Raye, et al., in press).

An attitude system should be sensitive to valence and intensity (Eagly & Chaiken, 1998). These have not been independently assessed in neuroimaging studies of the evaluation of socially relevant stimuli; moreover, valence may have been confounded with emotional intensity in neuroimaging studies of attitudes and evaluation. In addition, an attitude system must be able to deal with a range of complexity. Here we investigated whether emotional intensity and valence are processed by different neural components, and whether the pattern of neural activity associated with intensity and valence differs for implicit and explicit evaluation. We also investigated the neural components associated with the control of attitudes, as in complex attitudes that have both positive and negative aspects.

During rapid event-related functional magnetic resonance imaging (fMRI), participants made either good–bad or abstract–concrete judgments about 144 concepts (e.g., ''murder,'' ''love,'' ''gun control,'' ''abortion''). Across trials, participants made one good–bad and one abstract–concrete judgment about each concept. Brain regions that subserve ''implicit'' evaluation should respond to evaluative aspects of the stimuli during both tasks similarly. That is, because automatic evaluation by definition occurs without intention, it should be present for both the good–bad and abstract–concrete tasks. In contrast, regions associated with ''explicit'' evaluation should show greater activity in the good–bad task compared to the abstract–concrete task. That is, these regions should be more active when participants have the intention to form an evaluation.

The items used in the study were chosen to widely sample concepts that vary on several dimensions. After scanning, participants rated each of the concepts for: badness, goodness, emotionality of their response, and the degree to which they typically seek to control their initial responses to the concept. For each participant, ''attitude valence'' for each concept was computed as the difference between the bad rating and good rating for that concept (bad − good); ''emotional intensity'' was the rating given on the emotionality scale; and "control" was the rating given on the control scale. We expected control ratings to be highest for concepts about which people felt most ambivalent (i.e., both positively and negatively).

Using these ratings, we looked for brain regions whose activity varied with each dimension for each task. If a region is associated with processing valence, we should observe increasing activation as bad–good increases; if a region is associated with processing emotional intensity, we should observe increasing activation for concepts as they are rated from less to more emotionally intense. Regions associated with control should show increasing activation as control ratings increase. Furthermore, regions that correlated with ratings on a dimension similarly for both tasks reflect implicit processing of that dimension, whereas regions that correlated with a dimension significantly more during the good–bad than the abstract–concrete task are by definition associated with explicit evaluative processing of that dimension.

RESULTS

Analysis Overview

In two hierarchical regression analyses, we examined the relationship between participants' ratings on each of our dimensions of interest (attitude valence, emotional intensity, control) with brain activity for the good–bad task and for the abstract–concrete task. Compared with bivariate correlational approaches, the regression parameters from these analyses reflect the unique relationship between the particular dimension (e.g., valence) and brain activity while controlling for the other dimensions (e.g., emotional intensity). Thus, we were able statistically to unconfound the influence of correlated predictors. First, we examined the relationship between brain activity and emotional intensity and valence (calculated as bad − good) ratings for each item. In a second analysis, we added participants' ratings of control to the regression analysis to determine additional brain regions involved in attitudinal conflict and intentional manipulation of attitudinal information. Furthermore, for each analysis, we classified activations as being involved in: (a) implicit evaluation—significant and equal correlations in both the good–bad and the abstract–concrete task, (b) explicit evaluation—significant correlation for the good–bad task only that was also greater than the correlation for the abstract–concrete task or significant correlations for both tasks, but significantly greater for the good–bad than the abstract–concrete task.

Task Effects

Activations obtained simply by subtracting one task from another are presented in Table 1. For each significant region, we additionally report the significance for the region comparing activity against a fixation baseline for each task (positive t values reflect activations and negative t values reflect deactivations relative to fixation). Replicating our previous findings, several areas were more active during the good–bad than the abstract–concrete task, including areas of the medial PFC and the ventrolateral PFC. In contrast, several areas of lateral PFC activity were greater for the abstract–concrete than for the good–bad task.

Valence and Emotional Intensity: Regression Step 1

For all analyses, valence was computed as the difference between a participant's ratings of bad and good such that larger valence scores reflected a more negative attitude. As expected and depicted in Figure 1, the emotional intensity of concepts rated as bad was higher than the emotional intensity of concepts rated as good. As goodness or badness increased, emotional intensity increased for both, but more so for the bad concepts. Thus, the regression model in which both emotional intensity and valence are entered simultaneously is necessary to separately assess the brain regions associated with these dimensions.

Emotional Intensity

Consistent with the idea that amygdala activation is associated with emotional intensity, irrespective of valence, we found a region of the left amygdala (Figure 2A) associated with rated emotional intensity [$t(19) = 4.43$, $p < .001$; MNI coordinates: −20, −4, −16], but not valence [$t(19) = .54$ $p = ns$; $t(19)_{\text{difference}} = 3.63$, $p < .001$]. Interestingly, this area of the left amygdala is the same region we previously found associated with "badness" relative to "goodness" when we were not able to differentiate between emotional intensity and valence (Cunningham, Johnson, Gatenby, et al., 2003). A large area of the orbital frontal cortex also showed more activation for more emotionally intense stimuli [$t(19) = 4.64$, $p < .001$, MNI: 12, 32, −20]. As can be seen in Figure 2A and B, the correlation between emotional intensity and neural activity for both of these regions was similar for both the good–bad and abstract–concrete tasks, suggesting that emotional intensity is processed implicitly.

In addition, consistent with the hypothesis that explicit evaluation may involve additional brain regions, several regions were correlated with emotional intensity ratings only when participants were making explicit good–bad judgments. For example, additional regions of the right orbital frontal cortex and the temporal pole were associated with rated emotional intensity only during the explicit evaluative task (Figure 2C and D).

Table 1. Significant Areas of Activation Associated with Task

Size	*Area*	*BA*	*t*	*L/R*	*x*	*y*	*z*	*A/C*	*G/B*
Good–Bad > Abstract–Concrete									
691	Orbital frontal gyrus	11	7.70	mid	0	28	−8	−7.45	*ns*
	Medial frontal gyrus	10/32	6.60	L	−8	52	20	−4.71	4.42
	Medial frontal gyrus	10	6.54	R	12	56	8	*ns*	5.04
32	Amygdala/hippocampus	na	4.90	R	16	−8	−20	4.91	5.04
86	Precuneus	23	5.95	L	−4	−56	28	*ns*	4.29
297	Inferior temporal gyrus	20/21	7.75	R	64	−12	−32	*ns*	6.08
	Middle temporal gyrus	20/21	7.71	R	64	−16	−24	*ns*	5.89
	Temporal pole	38	6.23	R	32	20	−24	*ns*	6.44
109	Middle temporal gyrus	20/21	5.22	L	−64	−8	−28	*ns*	3.89
	Temporal pole	20	4.91	L	−48	16	−44	*ns*	4.34
	Inferior temporal gyrus	20	4.25	L	−52	−24	−20	4.06	4.57
27	Superior frontal gyrus	9	4.28	R	20	36	44	4.48	5.29
90	Angular gyrus	39	6.37	L	−56	−60	24	−5.10	*ns*
	Middle temporal gyrus	37	4.13	L	−64	−60	4	*ns*	4.04
Abstract–Concrete > Good–Bad									
193	Inferior frontal gyrus	45	10.68	R	48	40	16	7.62	4.91
	Middle frontal gyrus	46	5.44	R	44	56	12	5.58	*ns*
	Inferior frontal gyrus	44	5.01	R	52	16	32	8.75	6.93
85	Middle frontal gyrus	46	5.49	L	−48	52	8	5.20	*ns*
	Middle frontal gyrus	46	5.37	L	−44	52	20	5.18	4.46
	Middle frontal gyrus	45/46	5.19	L	−52	44	16	5.88	4.43
45	Inferior temporal gyrus	37	4.62	R	56	−56	−24	6.49	6.20
	Inferior temporal gyrus	37	4.59	R	60	−60	−12	6.58	6.28
1860	Lingual gyrus	18	8.08	L	−12	−92	−8	7.24	6.48
	Calcarine gyrus	18	7.69	L	−20	−72	8	8.04	6.60
	Inferior parietal lobe	7/40	6.92	R	32	−56	40	7.98	6.78

Note: Table shows local maxima $p < .001$ with an extent threshold of 15 voxels. BA = Brodmann's area; R/L = right or left hemisphere; t = maximal t-statistic for the statistical difference; x, y, and z: the 3-D coordinates of the activation within normalized MNI space; A/C = t value for region compared to fixation for abstract–concrete trials; G/B = t value for region compared to fixation for good–bad trials. For each region, the significance for the region comparing activity against fixation baseline for each task (positive t values reflect activations and negative t values reflect deactivations relative to fixation). A/C = abstract–concrete task; G/B = good–bad task; *ns* = nonsignificant.

The full set of areas correlated with emotional intensity is presented in Table 2.

Attitude Valence

Further dissociating the processing of valence from emotional intensity, we found regions associated with valence and not emotional intensity (see Figure 3). Specifically, we found activity in an area of the right inferior frontal/insular cortex (Figure 3A) that correlated significantly with bad − good valence [$t(19) = 4.94$, $p < .001$, MNI: 32, 20, 0], but not with emotional intensity. Also, an area of anterior cingulate cortex correlated with valence [$t(19) = 4.91$, $p < .001$, MNI: 4, 20, 40]. As can be seen in Figure 3A and B, these relationships were similar for both the good–bad and abstract–concrete task, suggesting implicit processing of valence. Additionally, in the good–bad task (but not the abstract–concrete

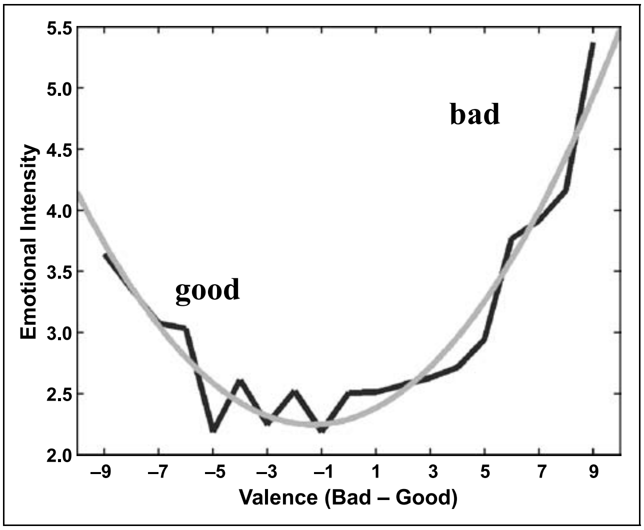

Figure 1. Relationship between valence and emotional intensity: ratings of valence (calculated as bad − good such that larger scores represent a more negative attitude) are plotted against ratings of emotional intensity in black collapsed across items and participants. Plotted in gray is the fitted relationship between the variables.

task), we found that an area of the left lateral orbital frontal cortex (BA 47) correlated with valence [$t(19) = 5.43$, $p < .001$, MNI: −44, 28, −12]. Thus, whereas left amygdala activity appears to reflect emotional intensity of the stimulus, activity in areas of the right inferior frontal/insula and anterior cingulate appears to reflect an automatic or implicit response to the valence of the concept (i.e., the degree of the difference in bad vs. good ratings).[1] The full set of areas is presented in Table 3.

Control: Regression Step 2

In many dual-process models of social cognition, the function of explicit evaluative processes is to control or manipulate attitudinal information (see Chaiken & Trope, 1999). Such reflective processing is recruited for explicit evaluation (i.e., induced by an evaluative agenda) and should be especially likely given attitudinal complexity. Examining the postscan ratings provided by participants provides information about attitudinally complex stimuli. As can seen in Figure 4A, stimuli rated as most likely to elicit control are ones for which participants indicated a roughly equal amount of positivity and negativity (resulting in a ''neutral'' attitude score when subtracting good from bad), but indicated a high emotional intensity. Further breaking down this relationship (see Figure 4B), these stimuli are the ones for which participants, as expected, indicated both strong positivity and strong negativity, that is, ambivalence (e.g., Preister & Petty, 1996; Cacioppo & Bernston, 1994).

Interestingly, all regions positively associated with control ratings ($p < .05$) for abstract–concrete trials were also qualified by an interaction with task in that partial correlations with rated control were significantly larger for the good–bad trials than for the abstract–concrete trials. This suggests that control was greater under a reflective agenda of explicit evaluation than in implicit evaluation. Specifically, we found that areas of the anterior cingulate (BA 32) [$t(19) = 5.42$, $p < .001$; MNI: −4, 24, 32; see Figure 5A] and the right anterior PFC (BA 10) [$t(19) = 6.63$, $p < .001$; MNI: 40, 56, 4; see Figure 5B]—areas frequently associated with tasks requiring cognitive control—were correlated with control ratings. Additional areas correlated with control were the bilateral lateral orbital PFC (BA 47) [left: $t(19) = 6.63$, $p < .001$; MNI: −52, 28, −8; right: $t(19) = 5.02$, $p < .001$; MNI: 48, 32, −4] and an area of the medial PFC [$t(19) = 5.54$, $p < .001$; MNI: 8, 52, 16]. Overall, the pattern of results suggests that control is especially engaged under conditions of an agenda to evaluate and when ambivalence is detected. The full set of correlations is presented in Table 4.

We also computed an index of ambivalence using the equations specified by the Gradual Threshold Model (Preister & Petty, 1996). As might be expected, these ratings were highly correlated with the ratings of control and were not found to predict any brain regions above and beyond the other ratings. It is important to note, however, that the bivariate correlation between BOLD signal and computed ambivalence identified an area of the right inferior frontal cortex consistent with our previous findings (Cunningham, Johnson, Gatenby, et al., 2003).

DISCUSSION

Evaluation is not a single process. Rather, evaluation varies in the degree to which it is implicit (relatively automatic and perhaps unconscious) or more explicit (deliberate, controlled, and conscious) (Greenwald & Banaji, 1995). Moreover, we would expect implicit and explicit processes to differentially subserve different aspects of evaluation, such as emotional intensity, valence, and the desire to modify or control an initial response. Consistent with this idea, we identified brain areas that were associated with evaluative processing of concepts regardless of the participant's task, and other areas that were active only (or more so) when participants had the reflective agenda to evaluate concepts. Furthermore, we identified regions that were correlated with participants' ratings of specific dimensions of the stimuli pointing to distributed systems for evaluative processing.

Dissociating Valence and Emotional Intensity

Social psychologists have for some time emphasized two aspects of attitudes: emotional arousal/intensity

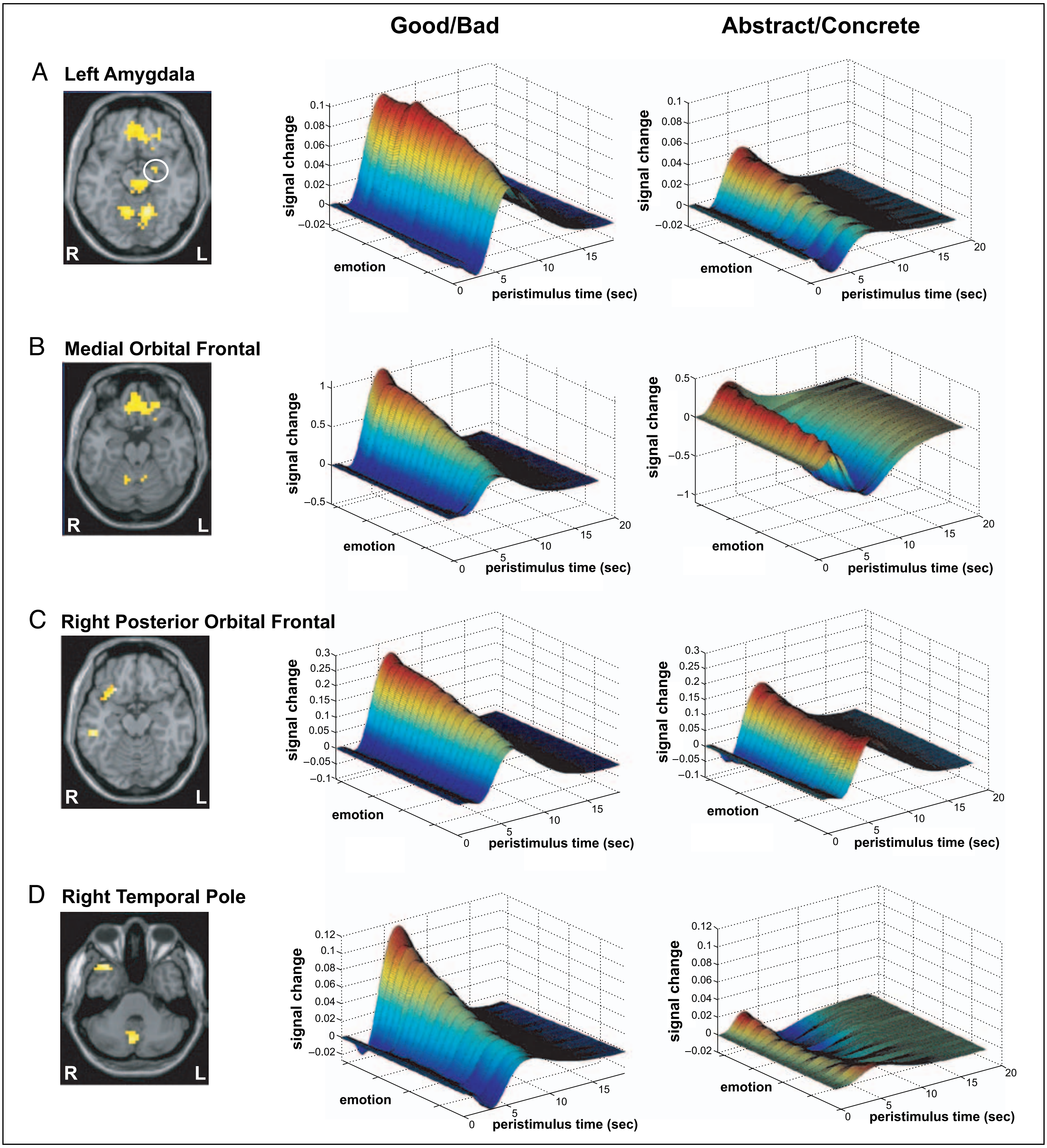

Figure 2. Correlation with emotional intensity: random effects contrasts showing partial correlations ($p < .001$) between brain activity and rated emotional intensity controlling for rated valence for (A) the left amygdala, (B) the medial orbital frontal cortex [A and B show similar correlations for the two tasks], (C) the right lateral orbital frontal cortex, and (D) the right temporal pole [C and D show significant correlations only for the good–bad task]. Parametric timelines were generated for significant voxels significant at $p < .001$ and averaged across participants separately for the good–bad and abstract–concrete trials.

and valence (Eagly & Chaiken, 1998; Osgood, Suci, & Tannenbaum, 1954). In the present study, these two aspects were dissociated during implicit evaluation. Activation in the left amygdala was correlated with the rated "emotional intensity" of concepts and an area of the right inferior frontal/insular cortex was associated with "attitude valence" scores (bad − good). That both of these relationships were observed with and without

Table 2. Areas Significantly Correlated with Rated Emotional Intensity

Size	*Area*	*BA*	*t*	*L/R*	*x*	*y*	*z*
Good–Bad = Abstract–Concrete							
50	Amygdala	na	4.43	L	−20	−4	−16
	Caudate	na	4.31	L	−4	4	−4
143	Orbital frontal gyrus	11	4.64	R	12	32	−20
29	Medial frontal gyrus	9	4.44	R	8	48	28
56	Brainstem	na	4.96	mid	0	−24	−8
18	Middle temporal gyrus	37	4.79	R	56	−72	8
45	Middle occipital gyrus	39	5.12	L	−48	−64	28
25	Middle occipital gyrus	19	4.54	L	−40	−88	32
35	Vermis	na	5.38	mid	0	−68	−40
40	Angular gyrus	39/40	4.80	R	40	−52	32
98	Precentral gyrus	6	5.22	L	−32	−8	60
19	Precentral gyrus	6	4.39	R	36	−8	52
100	Postcentral gyrus	2	5.51	L	−24	−44	56
Good–Bad > Abstract–Concrete							
27	Temporal pole	38	5.18	R	36	24	−36
135	Precuneus	23	4.95	R	12	−52	28
49	Cerebulum	18	5.86	L	−12	−56	−12
Good–Bad Only							
23	Posterior orbital frontal gyrus	11	6.68	R	24	24	−16
28	Operculum	38	4.07	L	−60	8	0
16	Inferior temporal gyrus	20	6.26	R	52	−32	−16
49	Inferior frontal gyrus	48	4.78	R	60	4	8
15	Inferior frontal gyrus	45	4.53	L	−44	36	8
16	Precuneus	23	4.78	L	−16	−60	36
65	Supramarginal gyrus	40	5.55	L	−64	−48	36

Note: Table shows local maxima $p < .001$ with an extent threshold of 15 voxels. BA = Brodmann's area; R/L = right or left hemisphere; t = maximal t-statistic for the statistical difference; x, y, and z: the 3-D coordinates of the activation within normalized MNI space.

intention to generate an evaluation provides support for the suggestion that arousal/intensity and valence are basic aspects of evaluative processing that likely occur automatically.

These results also highlight that although the amygdala may be critical in automatically processing the emotional intensity of a stimulus, it is not the only structure involved in implicit evaluation. For example, although greater amygdala activation to Black than to White faces has been associated with greater race bias on an implicit measure of race attitudes (Cunningham, Johnson, Raye, et al., in press; Phelps, O'Connor, Cunningham, et al., 2000), a patient with bilateral amygdala damage also showed race bias on this same implicit measure (Phelps, Cannistraci, et al., 2003). That a patient with bilateral amygdala damage showed an automatic race bias has been suggested to be problematic for interpreting the neuroimaging results (see Cacioppo et al., 2003). Yet, if the amygdala is only one component of an implicit evaluation system, then this may not be a puzzle. Patients with bilateral amygdala damage may have other, intact, areas that are involved in automatic evaluation such as the area of the right inferior frontal/insular cortex or orbital frontal cortex found in this study. Thus, a potentially interesting direction for future research would be to examine the qualitative differences in implicit attitudes that patients with various lesions may show.

Explicit Processing and Control

In forming evaluations of the world, we are not limited to those processes that unfold automatically and without intention. When people have a specific goal to evaluate, more controlled, reflective processes are recruited. An important function of reflection is the selection/inhibition and manipulation of activated information to achieve a desired evaluative outcome, or one that is more congruent with situational constraints. We found areas that correlated with control ratings (and not other ratings) that have typically been associated with cognitive control, such as the anterior cingulate cortex and the right PFC (Mitchell, Heatherton, Kelley, Wyland, & Macrae, 2003; Carter et al., 1998). Consistent with the idea that control is a function of more explicit processing, we found that these correlations interacted with task, such that the correlations were stronger in the good–bad task than in the abstract–concrete task. Thus, explicit processing may permit the experience of more complex attitudes than simple valence and emotional intensity.

Control processes are especially critical for evaluation when information becomes more complex and less straightforward. Examples of such complexity are instances in which both positive and negative information about an attitude object are simultaneously active—instances that are understudied in the neuroscientific

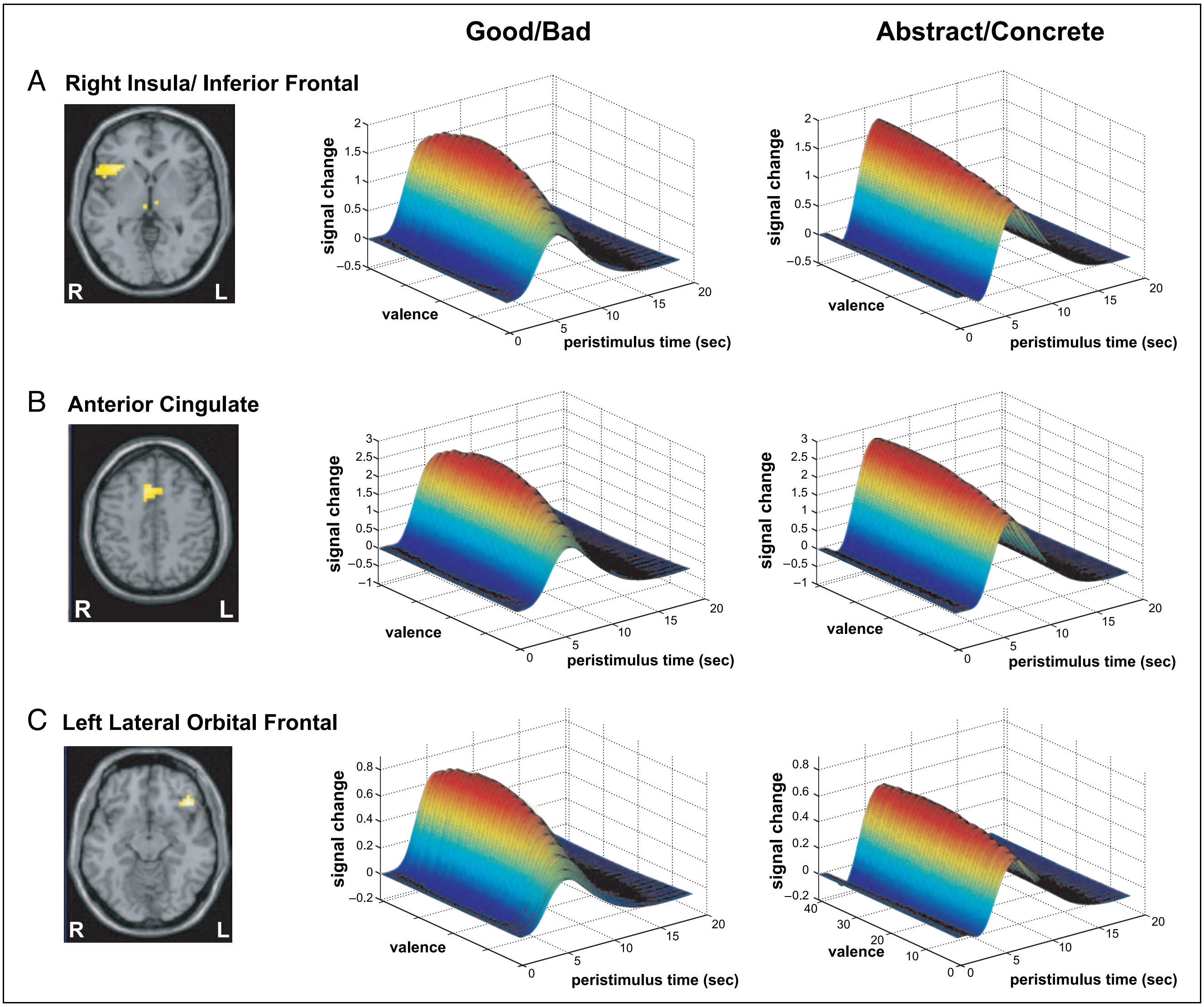

Figure 3. Correlation with valence: random effects contrasts showing partial correlations ($p < .001$) between brain activity and rated valence (bad − good) controlling for rated emotional intensity for (A) the right insular/inferior frontal cortex, (B) the anterior cingulate cortex [A and B show similar correlations for the two tasks], and (C) the left lateral orbital frontal cortex [C shows a significant correlation only for the good–bad task]. Parametric timelines were generated for significant voxels significant at $p < .001$ and averaged across participants separately for the good–bad and abstract–concrete trials.

study of affect and attitude. As depicted in Figure 4B, the concepts that participants reported trying to control the most were the ones for which they reported having both positive and negative attitudes. Further, these concepts were ones for which a calculation of valence would result in a "neutral" attitude and a high degree of emotional intensity (likely because of the coactivation of strong positive and negative responses). To deal with this complexity, different features may need to be noted, weighted, integrated, or resolved to make binary good–bad judgments required during scanning.

In our previous work, we found that regions of the ventrolateral PFC (BA 47) were active when explicitly processing information that has both positive and negative characteristics (Cunningham, Johnson, Raye, et al., in press; Cunningham, Johnson, Gatenby, et al., 2003). Similar areas have been found to be associated with semantic memory selection and perhaps inhibition of irrelevant information (e.g., Thompson-Shill, D'Esposito, Aguirre, & Farah, 1997). Activity in this region was associated with ratings of control in the present study, suggesting that attitude conflict and ambivalence may have been involved when participants sought to control their evaluative responses. This should not be surprising. At a theoretical level, control is necessary when conflicting information or desires are present. Consistent with models of affect and attitude that propose separable processing

Table 3. Areas Significantly Correlated with Rated Valence

Size	*Area*	*BA*	*t*	*L/R*	*x*	*y*	*z*
Good–Bad = Abstract–Concrete							
61	Insula (claustrum)	48	4.94	R	36	20	0
	Inferior frontal gyrus	45	4.73	R	52	20	4
33	Anterior cingulate	32	4.91	R	4	20	40
Good–Bad Only							
16	Lateral orbital frontal gyrus	47	5.43	L	−44	28	−12

Note: Table shows local maxima $p < .001$ with an extent threshold of 15 voxels. BA = Brodmann's area; R/L = right or left hemisphere; t = maximal t-statistic for the statistical difference; x, y, and z: the 3-D coordinates of the activation within normalized MNI space.

of positivity and negativity (i.e., Preister & Petty, 1996; Cacioppo & Bernston, 1994), our current and previous data suggest that sometimes positive and negative information about a stimulus can be active simultaneously.

Explicit Processing and Emotion

Explicit evaluation may allow for both more cognitively complex attitudes and more affectively complex attitudes. Simple emotions (e.g., fear, joy) can arise relatively automatically from evaluation accompanying perceptual processing of a stimulus, whereas more complex emotions (e.g., remorse, jealously, empathy) likely involve more reflective processing (e.g., Johnson & Multhaup, 1992). Similarly, attitudes may vary from relatively automatic assessments of valence and intensity, to more complex consciously constructed judgments. In this study, we found some regions that were associated with emotional intensity only when participants were making a reflective evaluation (an area of the orbital frontal cortex, temporal pole). The fact that these regions are sensitive to emotional intensity only when an agenda to evaluate is active suggests that the emotional experience resulting from explicit processing may differ from the emotional experience resulting from implicit processing alone. For example, for some people, implicit processing of the concept ''affirmative action'' may elicit relatively simple feelings of fear or anger, whereas emotions experienced during explicit evaluation of ''affirmative action'' may include guilt, jealousy, hope, and other complex emotions in different combinations across individuals.

Conclusions

In summary, many important attitude objects are not simply wholly good or wholly bad, and the potential richness of our evaluative/emotional experience cannot be realized by automatic processes alone. People actively manipulate evaluative information in light of situational constraints and circumstances, giving weight to information depending on its relevance for a current judgment. Moreover, people can engage in more controlled processes to override information and even come to final evaluations that may differ in valence from automatic evaluations (e.g., Fazio, 1990). Additionally, as more reflective component processes are engaged, the emotional experience associated with the evaluation can become qualitatively richer, and this emotional information itself can influence

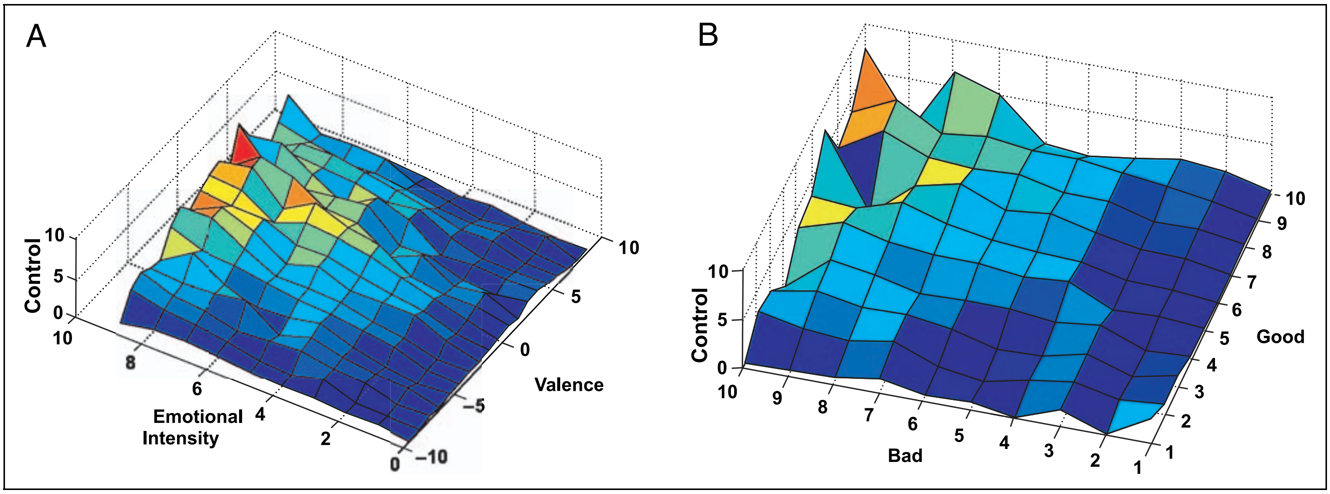

Figure 4. Relationship between valence, emotional intensity, and control. (A) Behavioral ratings of emotional intensity and computed valence are plotted against control. (B) Behavioral ratings of bad and good are plotted against control. For each plot, behavioral ratings are collapsed across items and participants. Dark blue represents the lowest control ratings and red represents the highest control ratings.

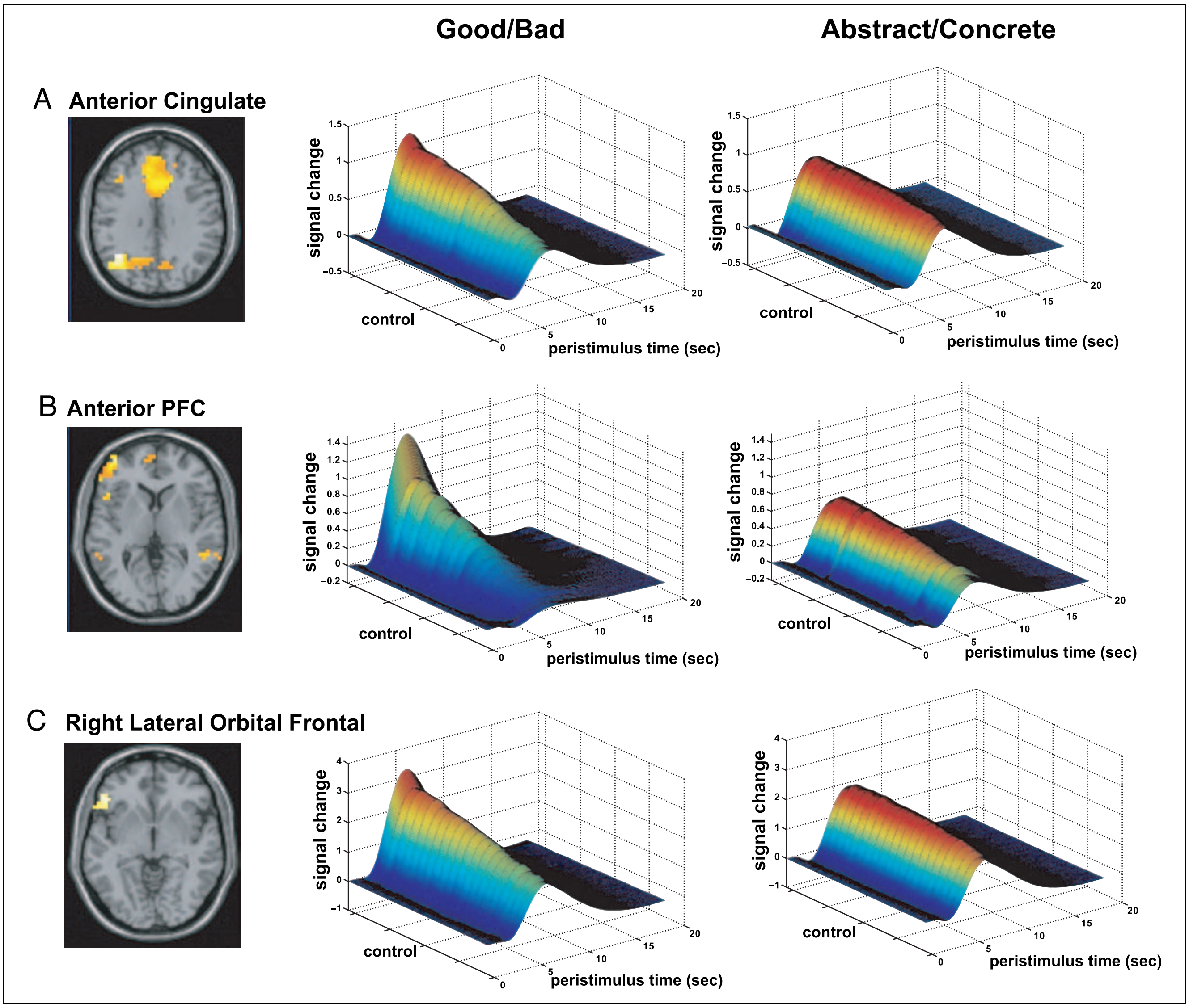

Figure 5. Correlation with control: random effects contrasts showing partial correlations ($p < .001$) between brain activity and rated control, controlling for rated emotional intensity and valence for (A) the anterior cingulate, (B) the anterior prefrontal cortex, and (C) the right lateral orbital frontal cortex. Parametric timelines were generated for significant voxels significant at $p < .001$ and averaged across participants separately for the good–bad and abstract–concrete trials.

judgments in ways that more primitive emotional responses may not.

METHODS

Participants

Twenty participants were paid for their participation. Participants reported no abnormal neurological history and had normal or corrected-to-normal vision. All participants provided informed consent.

Materials

One hundred forty-four concepts were selected for the study. These concepts varied on multiple dimensions, such as good–bad, abstract/concrete, and complexity. Examples of concepts used in the study are "murder," "love," "freedom," "multiculturalism," "technology," "recycling," "immigration," "terrorism," and "poetry."

Procedure

During fMRI, on each trial, participants categorized concepts along one of two dimensions (good–bad or abstract–concrete) and indicated their categorization by making one of two button presses with their right hand. Using E-Prime for PC, stimuli were forward projected with an LCD onto a screen at the base of the MRI bore. A prism mirror positioned over the participants' eyes allowed them to view stimuli. All

Table 4. Areas Significantly Correlated with Rated Control

Size	*Area*	*BA*	*t*	*L/R*	*x*	*y*	*z*
Good–Bad > Abstract–Concrete							
36	Anterior frontal pole	10	4.67	R	32	60	8
32	Middle frontal gyrus	9	4.74	L	−32	28	52
54	Lateral orbital frontal gyrus	47	5.02	R	48	32	−4
16	Medial frontal gyrus	8	4.56	R	16	32	60
26	Middle frontal gyrus	9	4.40	R	48	16	48
21	Inferior temporal gyrus	20	4.66	R	48	4	−44
22	Angular gyrus	39	4.74	R	48	−60	28
Good–Bad Only							
1010	Middle frontal gyrus	10/46	6.63	R	40	56	4
	Anterior cingulate	32	5.42	L	−4	24	32
	Medial frontal gyrus	10/32	5.54	R	8	52	16
	Middle frontal gyrus	9	5.05	R	40	16	52
42	Lateral orbital gyrus	47	6.80	L	−52	28	−8
21	Precuneus	31	3.44	L	−12	−60	28
67	Inferior temporal gyrus	20	6.36	R	60	−24	−16
30	Middle temporal gyrus	21	5.94	R	60	−44	−4
75	Middle temporal gyrus	21	5.27	L	−52	−40	−4
162	Angular gyrus	39	7.63	R	36	−60	28
23	Parahippicampal gyrus	35	5.53	L	−28	−24	−24
21	Precentral gyrus	6	4.49	L	−56	8	44

Note: Table shows local maxima $p < .001$ with an extent threshold of 15 voxels. BA = Brodmann's area; R/L = right or left hemisphere; t = maximal t-statistic for the statistical difference; x, y, and z: the 3-D coordinates of the activation within normalized MNI space.

stimuli were presented in black letters against a white background.

For each trial, a 500-msec cue indicated whether the trial required a good–bad or an abstract–concrete response, immediately followed by a concept presented for 2 sec. Additional null fixation trials were used to space out trials. The ratio of critical trials to null fixation trials was 4:1. Between all trials, a fixation cross remained on the screen for 2, 4, or 6 sec. To synchronize stimulus presentations with functional scanning, all functional runs were initiated by a trigger sent by the MRI scanner at the beginning of each scan. Each of six runs contained 48 of each trial type (good–bad task; abstract–concrete task, randomly intermixed). All 144 concepts were presented before any were repeated. Two lists were counterbalanced so that each concept was first rated as good–bad for half the participants and abstract–concrete for the other half.

After scanning, participants completed a questionnaire in which all concepts were rated along four dimensions. Participants indicated on a 0 to 9 scale the extent to which the target concept was good, the extent to which it was bad, the extent to which their response to the concept was emotional, and the extent to which they typically try to reflectively control or suppress initial (presumably automatic) responses that they have toward the concept.

fMRI Parameters

All imaging was conducted with a Seimens 3-T scanner at the Yale Magnetic Resonance Research Center. To get whole-brain functional coverage, 32 axial slices (slice thickness: 3.8 mm, no skip) were prescribed parallel to the AC–PC line, with the 11th slice centered on the AC–PC line. Nearly isotropic functional images were acquired from inferior to superior using a single-shot gradient echo-planar pulse sequence (TE = 25 msec, TR = 2 sec, in-plane resolution = 3.75 × 3.75 mm, matrix size = 64 × 64, and FOV = 24 × 24 cm).

Data Analysis

Data were analyzed using the general linear model as implemented by SPM2 (Friston et al., 1995). Prior to analysis, data were corrected for slice acquisition time. Motion correction was performed using the INRIAlign toolbox for SPM (Freire & Mangin, 2001). Data were then transformed to conform to the default EPI MNI brain interpolated to 4 × 4 × 4 mm. Functional data were smoothed using a 12-mm FWHM (full width half maximum) kernel. Finally, a low pass filter removed frequencies greater than 0.18 Hz, a cutoff that represents the frequency after which signals as a function of experimental effects are no longer expected.

Two hierarchical regression analyses were constructed to examine the relationship between participants' ratings on each of our dimensions of interest (attitude valence, emotional intensity, and control) separately for the good–bad task and for the abstract–concrete task. In each analysis, a series of regressors were constructed to examine BOLD brain activity to each of the trial types. Two regressors were used for each trial type: the expected BOLD signal following neural activity, and a derivative to model the onset of the neural response. For the first regression analysis, we computed the relationship between emotional intensity and valence for each trial for both the good–bad and abstract–concrete conditions. Covariation with these parametric regressors indicate brain regions that are significantly related to increases (or decreases) with the reported ratings for each participant for each of the judgment types (good–bad or abstract–concrete). In the second regression analysis, we added the third parametric regressor of control. Contrast maps were generated for each participant for each analysis of interest.

Random effects composite t-maps were generated using the individual participant contrast maps as input. Regions of activation were defined as those areas in which 15 contiguous voxels were significant at $p < .001$. This was done for all regions except for the amygdala, an a priori region of interest based on previous published work and data from our own laboratory. The criterion for amygdala activation was 5 or more voxels significant at $p < .01$. For areas to be described as involved primarily in reflective evaluation, we additionally required the correlation for the good–bad task to be significantly greater than the correlation for the abstract–concrete task, $p < .01$.

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The data reported in this experiment have been deposited in the fMRI Data Center (http://www.fmridc.org). The accession number is 2-2004-1171A.

Note

1. It is possible that the relationship between amygdala activation and emotional intensity, but not valence, could be a function of power. That is, a correlation between valence and amygdala activation might exist, but we did not have enough power to detect the relationship. Although possible, this seems unlikely given our data. Plotting the relationship between amygdala activation and valence shows a U-shaped function, with the most positive and most negative stimuli (i.e., the ones with the highest emotional intensity) showing the most activation. It should be noted, however, that the activation to the most negative stimuli was greater than to the most positive stimuli, showing evidence of the negativity bias (Ito, Cacioppo, & Lang., 1998).

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