

## Attention and emotion: Does rating emotion alter neural responses to amusing and sad films?

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Functional neuroimaging of affective systems often includes subjective self-report of the affective response. Although self-report provides valuable information regarding participants' affective responses, prior studies have raised the concern that the attentional demands of reporting on affective experience may obscure neural activations reflecting more natural affective responses. In the present study, we used potent emotion-eliciting amusing and sad films, employed a novel method of continuous self-reported rating of emotion experience, and compared the impact of rating with passive viewing of amusing and sad films. Subjective rating of ongoing emotional responses did *not* decrease either self-reported experience of emotion or neural activations relative to passive viewing in any brain regions. Rating, relative to passive viewing, produced increased activity in anterior cingulate, insula, and several other areas associated with introspection of emotion. These results support the use of continuous emotion measures and emotionally engaging films to study the dynamics of emotional responding and suggest that there may be some contexts in which the attention to emotion induced by reporting emotion experience does not disrupt emotional responding either behaviorally or neurally.

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### Introduction

One of the thorniest problems in the field of affective science is determining whether and to what extent the methods we use to assess emotional responding influence the unfolding emotional response itself. Does the emotion-focused attention evoked by eliciting ratings of emotional experience change the response itself? This question has proved difficult to address in the past, because the mapping between emotional responding and traditional measures such as autonomic nervous system activity or expressive

behavior remains unclear (e.g., Cacioppo et al., 1993). Thus, one way researchers have begun to examine the impact of attention on emotional responding is to take advantage of recent developments in the ability to image neural activity associated with emotion using PET and fMRI. In particular, by combining self-reports of emotion experience with neuroimaging methodology, it has been possible to explore the impact of introspecting about one's emotional response on the response itself.

Within this literature, a consensus is beginning to emerge, suggesting that two regions—rostral anterior cingulate (ACC) and dorsomedial prefrontal cortex (DMPFC)—are involved in introspecting on emotion experience (Hariri et al., 2000; Lane et al., 1997, 1998; Northoff et al., 2004; Ochsner et al., 2004a; Taylor et al., 2003). These regions, particularly medial prefrontal cortex, appear to be consistently more active during tasks that require participants to attend to their emotions than during tasks that require participants to attend to other aspects, such as visual properties. This evidence has led some to postulate a role for ACC and DMPFC in the representation of somatic and emotional states (Lambie and Marcel, 2000; Lane, 2000). However, some researchers have also observed these regions to be involved in the regulation of emotional responding (Beauregard et al., 2001; Ochsner et al., 2002, 2004b), suggesting that attention to emotion may activate modulatory processes that could lead to changes in activation in regions generating the emotional response. At present, the extent and nature of the influence of attention on emotional responding remain unclear.

Three competing hypotheses can be derived regarding the impact of attention on neural responses in emotion-generative circuits. First, attending to how something feels may amplify activation in regions involved in representing aspects of the emotional response (e.g., amygdala or orbitofrontal cortex). This hypothesis is consistent with studies of visual perception, which suggest that focusing attention on specific aspects of a percept, which increases their subjective salience, activates regions thought to specialize in processing the attended features (e.g., O'Craven et al., 1999). It is also consistent with social psychological studies

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indicating that self-directed attention correlates with more intense reports of emotional arousal (Scheier and Carver, 1977), and the fact that some affective disorders, such as social anxiety, have been linked to a heightened attention to somatic states and greater emotional arousal (Mansell et al., 2003).

Alternatively, attending to how one feels might decrease one's emotional response. This hypothesis derives largely from behavioral research on emotion, which suggests that self-directed attention or introspection about the causes of feelings or preferences can significantly disrupt the emotional response (Silvia, 2002; Wilson et al., 1993). Greater focus on feelings may also lead to a more differentiated representation of emotional states, which Barrett et al. (2001) have proposed enables better emotional regulation and leads to decreases in negative emotional states. Deliberative processes engaged by introspection have also been postulated to interrupt emotion-related processing (Drevets and Raichle, 1998; Lieberman, 2003).

A third hypothesis posits no interaction between attention and activation in areas involved in generating the emotional response. On this view, the regions involved in attending to emotion may be separate from those involved in generating the emotional response, and their activities do not influence one another.

How have these hypotheses fared empirically? Consistent with the hypothesis that attention to emotion should increase activation in regions associated with the emotional response, some researchers have reported that tasks directing attention to emotion increase activation in areas such as the amygdala (e.g., Gorno-Tempini et al., 2001; Keightley et al., 2003; Liberzon et al., 2000). However, consistent with the second hypothesis, others have found that activations observed in limbic regions like the amygdala decrease when attending to emotion (e.g., Critchley et al., 2000; Hariri et al., 2000; Taylor et al., 2003). Although there is some suggestion in the literature that the type of stimulus used to evoke an emotional response may be an important contextual factor to consider in understanding the influence of attention on the neural response to emotional stimuli (Keightley et al., 2003), conflicting reports of attention's influence have been reported using both facial expressions (Critchley et al., 2000; Gorno-Tempini et al., 2001; Hariri et al., 2000) and evocative slides (Keightley et al., 2003; Northoff et al., 2004; Taylor et al., 2003; for review see Ochsner and Gross, 2005).

Inconsistent reports in the literature may be due to several limitations in the methods used to evoke emotions. First, it is not always clear in these studies whether robust emotional responses are actually being elicited. If little or no real emotion is evoked when a participant attends to the emotion expressed in a face, for example, the implication of any modulatory effects on neural response is ambiguous with respect to the question of how attention impacts emotional experience or behavior in general (Ochsner and Gross, 2005). Studies manipulating attention to facial expressions have frequently shown decreased responding in the amygdala (Critchley et al., 2000; Hariri et al., 2000) and hippocampus (Lange et al., 2003) when attention is directed to the emotional features of the face, although this effect may depend on the type of emotional expression (Anderson et al., 2002; Gorno-Tempini et al., 2001). Importantly, attentional manipulation in this context may be conceptualized best not as attention to one's internal feeling state but rather as attention to external perceptual features indicative of emotion.

A second, related limitation is that studies that manipulate attention to emotion often fail to elicit activation during baseline

viewing of emotional photos in areas implicated in emotion generation, such as the amygdala (e.g., Gusnard et al., 2001; Lane et al., 1997; Northoff et al., 2004; Ochsner et al., 2004a). Although typically these studies have aggregated across responses to positive and negative emotional stimuli or have averaged across blocks of intermixed neutral and emotional slides—which may account for weak activations during baseline—it is also possible that slides elicit only moderately intense affective responses. If a given study fails to fully activate strong emotional responses, it may be difficult to observe any differences in emotional responding under different attentional conditions.

Previous research has also been limited because most studies have not provided sufficient experimental control to rule out the possibility that some control conditions require respondents to inhibit their emotional response. For example, most studies to date have contrasted attending to emotion with attending to another stimulus dimension, such as the locale of the scene (Gusnard et al., 2001; Lane et al., 1997; Ochsner et al., 2004a), the orientation of the picture (Northoff et al., 2004), or another's emotion (Ochsner et al., 2004a). Although requiring participants to attend to another dimension ensures equal attentional demands across conditions, it may be problematic to the extent that it results in actively *inhibiting* emotional responses that may be incidental or distracting to the task at hand. Rather than using comparisons in which emotion may be actively suppressed, we might better understand the relationship between emotion-directed attention and emotional responding by comparing it to more passively experienced emotion elicitation.

To date, only a single study has compared attending to emotion with a passive viewing condition (i.e., a condition in which participants were not required to attend *away* from their emotions; Taylor et al., 2003). In this PET study, the researchers noted amygdala activation during baseline passive viewing, consistent with research pointing to the critical importance of this region in emotional responding (Aggleton, 1992). In contrast, the researchers observed that attending to and reporting emotion *decreased* the intensity of the response in a region extending into both the amygdala and the insula, but increased activity in the anterior cingulate and medial prefrontal cortex. Attention also decreased self-reported experience of sadness, but not other emotions. This evidence supports the hypothesis that attending to one's experience *decreases* activation in emotion-related regions. However, important and interesting as this study is, like others, it relied upon static stimuli to evoke emotion, and does not permit us to assess separately the consequences for the neural response of attending to different emotions. The finding of a selective decrease in self-reported sadness is difficult to reconcile with the more general neural deactivation, and the study did not include positive stimuli for comparison. In addition, it is not clear whether participants in this study were attending to and rating their own emotions or whether they were making judgments regarding the emotional content of the stimuli. Although related, these different kinds of judgments may recruit distinct mechanisms or differentially impact emotional responding. It thus remains unclear whether attention to ongoing emotional responses has divergent consequences for different types of emotions.

The goal of the present study was to examine the impact of attending to one's own ongoing emotions on ratings of emotion experience and associated brain responses in the context of powerful emotion-inducing films. Because one key dimension along which emotions vary is valence, we selected film stimuli to

elicit either pleasant (amusing), unpleasant (sad), or neutral emotional states. These stimuli were used to identify separately brain regions activated while experiencing different discrete types of emotion. This allows us to extend investigation to regions other than the amygdala, which research has indicated is neither necessary for the subjective experience of all emotions (Anderson and Phelps, 2002) nor unique in participating in emotional responding (e.g., ventral striatum: Knutson et al., 2001; Mobbs et al., 2003; temporal and medial prefrontal cortex: Goel and Dolan, 2001; orbitofrontal cortex: Kringelbach and Rolls, 2004).

To explore the three alternative hypotheses discussed above, we used emotionally evocative films and employed a rating manipulation to elicit conscious introspection on emotional experience, and compared it to passive viewing, a condition in which the emotion was allowed to unfold as naturally as possible. Because even subtle cues have been shown to impact the focus of attention and subsequent emotional responding (e.g., presence or absence of a mirror: Silvia, 2002), we wished to avoid any contamination of natural, passive viewing because of previously encountered or anticipated task instructions. Thus, we employed both between- and within-group manipulations of rating of emotion. This mixed design has the important advantage that any overlap in results observed in the two comparisons gives us greater confidence in the replicability of findings.

## Method

### Participants

Twenty-eight women (age range: 18–21 years) were recruited from the Stanford University community. All participants were right-handed, had normal visual acuity, and were screened for history of any psychiatric or medical disorders. Only women were enrolled to limit potential gender differences in emotional responding (e.g., Wager et al., 2003). Participants provided informed consent in accordance with guidelines set forth by the Medical Human Subjects Committee of Stanford University and were paid US\$50 for their participation.

### Materials and measures

Studies have found that emotion-eliciting films are an effective means of eliciting specific discrete target emotions (Gross and Levenson, 1995; Hagemann et al., 1999). Compared to other methods of emotion induction, films have the advantage that they generate prolonged, intense, and temporally varying emotion responses that are comparable across subjects. In the present study, participants viewed a series of nine 2-min color film clips. Two amusing and two sad film clips were drawn from a set of previously validated film stimuli (Gross and Levenson, 1995). These included amusing film clips of comedic routines performed by Robin Williams and Bill Cosby, and sad film clips from the *Champ* and *Stepmom*. The amusing film clips involved a single actor conducting a comedic routine. The sad film clips both displayed an adult and a child in a very sad interaction. We selected five neutral film clips that were matched to the emotional film clips in terms of duration, number of actors, and social interaction. The neutral film clips consisted of a single actor demonstrating cooking skills or two actors demonstrating home repair, sewing, or commercial sales. Amusing, neutral, and sad

film clips were presented to participants in one of two counter-balanced versions.

### Procedure

Participants were randomly assigned to one of two instructional groups: RATE ( $n = 14$ ) and VIEW ( $n = 14$ ). This assignment determined the instructions participants received prior to their initial viewing of the full set of film clips.

Inside the MR scanner, all participants were shown the series of sad, amusing, and neutral film clips in a single functional run, during which they were instructed to allow themselves to respond as naturally as possible to the films. Attention to emotion was induced in half of the participants (RATE group) by instructing them to make continuous ratings of the intensity of their emotion experience at each moment in time.

Participants in the RATE group were instructed on the use of the rating dial prior to the first functional run. The ratings were made with a rotating dial placed under their right hand. The position of this dial was indicated by an 8-point light display situated next to the film display, which gradually lit up as participants turned the dial clockwise, so they could see what emotion and intensity level they were indicating. The display was anchored at one end as feeling extreme sadness, and at the other end as feeling extreme amusement, with neutral at the point in the middle. Participants were also shown that the lights lit up gradually, allowing them to indicate even small changes in how they were feeling.<sup>1</sup> This generated a continuous measure of how that person felt at each moment during initial film viewing, as well as providing a context in which to investigate the mechanisms by which people consciously attend to their emotions. Participants in the VIEW group viewed the films without making ratings.<sup>2</sup>

For all participants, the first run was immediately followed by a second viewing of the same stimuli, during which all participants provided a continuous rating. The VIEW group was instructed between runs on the use of the rating dial, while the RATE group was reminded of how to use the dial. Thus, all participants were instructed just before the second functional run to make a continuous rating of how they *had been feeling* the *first* time they viewed the film clips. (See Fig. 1 for a schematic illustration of this

<sup>1</sup> Precise instructions to the RATE group before the viewing of the first set of films were as follows: "We will now be showing you a set of film clips. Please watch them and allow yourself to respond as naturally as possible. As you watch the clips, we want you to make a continuous rating of how you are feeling at each moment, by using the turning dial in your right hand. The lights that you see on the side of the screen light up to show you what the dial indicates. Between 4 and 5 lights means you are feeling neutral; turning the dial to the right, in other words, increasing the number of lights, means you are feeling increasing amusement; turning the dial all the way to the top means you are feeling extremely amused. Turning the dial to the left, in other words, decreasing the number of lights, means you are feeling increasing sadness; turning the dial all the way to the bottom means you are feeling extremely sad. Notice also that the lights light up gradually, so that you can indicate even small changes in how you are feeling. Again, remember to use the rating dial to rate how you are feeling at each moment while you view the film clips."

<sup>2</sup> Precise instructions to the VIEW group before the first set of films were as follows: "We will now be showing you a set of film clips. Please watch them and just allow yourself to respond as naturally as possible to them."

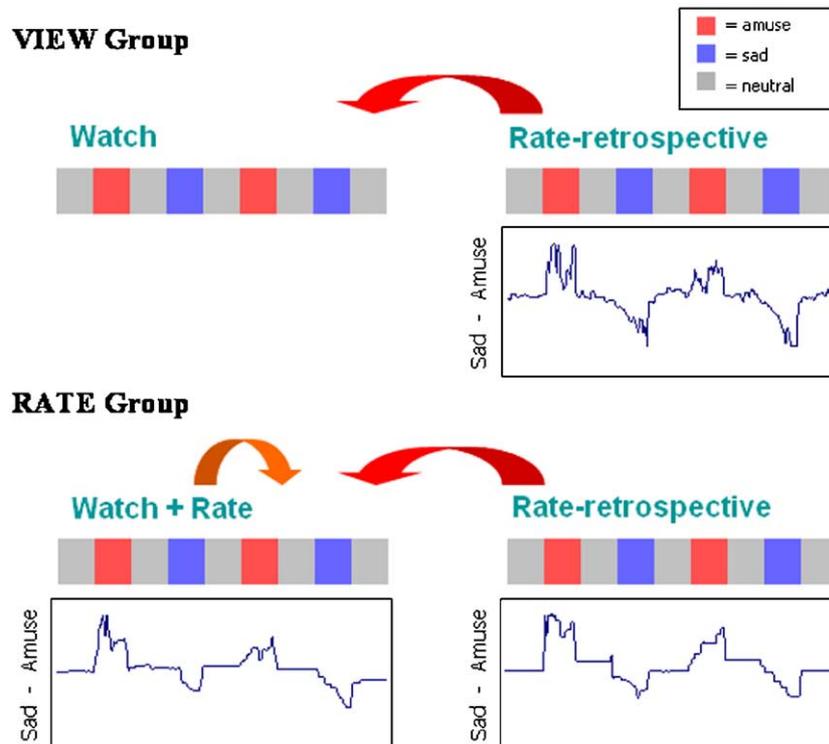


Fig. 1. Design. Group 1 (VIEW) watched the series of films (top left), then watched them again while producing a continuous rating (top right). Group 2 (RATE) produced a continuous rating while watching the films for the first time (bottom left) and then rated again how they had felt the first time during a second run (bottom right).

design.) This design provided both a between-group (RATE group run 1 vs. VIEW group run 1) and within-subject (VIEW group run 2 vs. VIEW group run 1) measure of the impact of rating. After exiting the scanner, participants completed a short set of questionnaires retrospectively assessing overall emotional reactions to each of the films, were debriefed, and paid.

#### Image acquisition

Imaging was performed on a General Electric 3-T Signa magnet using a T2\*-weighted gradient echo spiral in/out pulse sequence using blood oxygenation level-dependent (BOLD) contrast (Glover and Lai, 1998) and using a custom-built quadrature “dome” elliptical bird cage head coil. Head movement was minimized using a bite bar formed with the subject’s dental impression. Functional images (560 volumes per functional run) were obtained from 25 sequential axial slices using the following parameters: TR (relaxation time) = 2000 ms, TE (echo time) = 30 ms, flip angle = 60°, FOV = 24 cm, matrix = 64 × 64, single shot, in-plane resolution = 3.75 × 3.75 mm, slice thickness = 5 mm, no gap. A T1-weighted fast spin echo anatomical scan was acquired in the same plane as the functional slices prior to acquisition of functional scans (TR = 500 ms, TE = 14 ms, in-plane resolution = 0.9375 mm, and slice thickness = 5 mm).

#### Preprocessing of fMRI data

Analysis of functional neuroimages (AFNI; Cox, 1996) was used for preprocessing and statistical analysis of these data. During preprocessing, every brain volume of each participant’s functional run was quantitatively and visually examined to identify

artifacts due to either subject head movement or to MR scanning system properties (e.g., spikes in the magnetic field or thermal noise). To correct for head movement, each functional time series was aligned to a base image approximately in the middle of the first 2-min film clip using a 3-dimensional, iterated, least-squares co-registration algorithm provided in the AFNI library (3dvolreg). Fourier interpolation was used to realign images to the base image.

The motion correction procedure shifted images around three rotational axes (pitch, yaw, and roll) and in three directions [left to right ( $x$ ), anterior to posterior ( $y$ ), and superior to inferior ( $z$ )]. Estimates of these six motion parameters indicate the extent of head motion along the time series. Individual brain volumes with greater than  $\pm 1.5$  mm motion correction in  $x$ ,  $y$ , or  $z$  direction were eliminated from further analyses. This resulted in the elimination of 13 brain volumes for one participant and 3 brain volumes for a second participant. Because there was no evidence of stimulus-correlated motion effects, all functional runs were included in analyses. All functional runs were subjected to an outlier detection and interpolation algorithm (program 3dDespike) to correct potentially spurious time points for each voxel MR signal time series.

#### Statistical analysis of fMRI data

Analyses of BOLD responses to amusing and sad films were conducted using a conventional block contrast approach. To conduct statistical analyses on the functional BOLD signal, we used 3dDeconvolve to implement linear regression models to fit stimulus reference vectors to the MR time series values for each voxel. For the block analysis, reference vectors were coded 1 and

–1 to compare BOLD response for two amuse versus five neutral film clips and for two sad versus five neutral film clips, separately. We used all five neutral films as the baseline comparison condition because together they provide a better estimate of baseline BOLD response than only two neutral films.

Individual subject statistical maps were then spatially smoothed using a Gaussian kernel of  $\text{FWHM} = 3.75 \text{ mm}^3$ , resampled into  $3.75 \text{ mm}^3$  isotropic voxels, and spatially normalized into Talairach and Tournoux atlas coordinate space.

#### Whole-brain and a priori ROI analyses

To correct quantitatively for the multiple comparisons in whole-brain analyses, AlphaSim, a Monte Carlo simulation bootstrapping program in the AFNI software library, was employed to identify a joint voxel-wise threshold and cluster minimum volume threshold combination to set a cluster-wise  $P$  value of less than 0.05 corrected for multiple comparisons across the whole brain and in a priori specified anatomical regions of interest (Forman et al., 1995). This method has been used in a number of prior studies (e.g., Konishi et al., 1998, 1999; Ochsner et al., 2004a; Poldrack et al., 1999).

We report significant changes in activation according to the following criteria. Based on experimenter-selected parameters, including 10,000 sampling iterations, a voxel-wise threshold of  $P < 0.005$ , and spatial smoothing Gaussian kernel of full-width half-maximum ( $\text{FWHM} = 3.75 \text{ mm}^3$ ), the AlphaSim program determined that across all voxels included in the whole-brain analysis, a minimum cluster volume threshold of  $263 \text{ mm}^3$  ( $5 \text{ voxels} \times 3.75 \text{ mm}^3$ ) was required to protect against the probability of false positives (i.e., Type I error) at a cluster-wise level of  $P < 0.02$  in the whole-brain analyses. In a priori specified regions of interest (amygdala, thalamus, anterior cingulate cortex, and medial prefrontal cortex), cluster-size thresholds were separately determined based on the search volume of each anatomical ROI (defined using the Talairach and Tournoux brain atlas as implemented in AFNI) and using the AlphaSim method described above. Clusters were determined as significant with a volume larger than  $105 \text{ mm}^3$  ( $2 \text{ voxels} \times 3.75 \text{ mm}^3$ ) in the amygdala, thalamus, and caudate, and  $210 \text{ mm}^3$  ( $4 \text{ voxels} \times 3.75 \text{ mm}^3$ ) in the anterior cingulate and medial prefrontal cortex, which preserve a cluster-wise significance level in each of these ROIs of  $P < 0.02$ .

Based on the output of 3dDeconvolve for generating individual participant contrast maps, second-level  $t$  tests were conducted to produce random effects group  $t$  maps. Block contrast analyses of the VIEW group identified regions displaying significant activation associated with passive viewing of amusing films or passive viewing of sad films, compared with neutral films. Activated regions from the VIEW group contrast were then used as functionally derived ROI masks applied to the RATE group functional run 1 (emotion ratings) and also to the VIEW group during functional run 2 (emotion ratings) to examine the effect of attention to emotion.

Independent-sample  $t$  tests between the RATE group and the VIEW group during functional run 1, and paired  $t$  tests within the VIEW group between functional run 1 and functional run 2 were conducted to identify regions activated or deactivated by attention to emotion. To identify areas demonstrating a significantly different impact of attention based on the type of emotion attended to, a 2 (Task: Rate vs. View)  $\times$  2 (Emotion: Amusement

vs. Sadness) ANOVA was used, as implemented by the program 3dANOVA in AFNI.

#### Passive-viewing ROI analyses

Functional ROI masks derived from the one-sample  $t$  maps for block contrast analyses for amusing vs. neutral and sad vs. neutral films in the VIEW group run 1 were applied to each of the 28 participants to extract the mean BOLD signal magnitude (i.e., beta weight) across all voxels in each functionally derived ROI. These averages were used to determine differences in activation due to attention in regions activated by emotion in the uninstructed viewing condition.

Significant clusters of BOLD response are reported by location of the voxel with the highest signal magnitude in Talairach coordinates, Brodmann Areas, and neuroanatomical labels for regions included in each cluster. BOLD responses are reported in  $Z$  values. Identification of neuroanatomical structures associated with areas of significant functional BOLD signal were determined using: (1) Talairach and Tournoux (1988) atlas, (2) Talairach Daemon (Lancaster et al., 2000), and (3) Atlas of the Human Brain (Mai et al., 1997).

## Results

#### Behavioral results

Manipulation checks were conducted by combining continuous online ratings for participants in the RATE group, and continuous retrospective ratings for participants in the VIEW group. These continuous ratings indicated that we were successful in eliciting the target emotion during each of the stimulus films. Relative to the neutral films ( $M_{\text{AveNeut}} = 0.3$ ), each of the amusing films was on average reported as significantly more positive ( $M_{\text{Cosby}} = 3.5$ ,  $t = 7.86$ ,  $df = 27$ ,  $P < 0.001$ ;  $M_{\text{Williams}} = 2.7$ ,  $t = 6.65$ ,  $df = 27$ ,  $P < 0.001$ ), and each of the sad films was reported as significantly more negative ( $M_{\text{Stepmom}} = -1.6$ ,  $t = -5.89$ ,  $df = 27$ ,  $P < 0.001$ ;  $M_{\text{Champ}} = -3.5$ ,  $t = -9.83$ ,  $df = 27$ ,  $P < 0.001$ ).

To assess whether attention affected emotion ratings, we compared retrospective ratings of each type of emotion stimulus separately for the VIEW and RATE groups (we of course could not compare online ratings for the two groups as these online ratings were only available for one of the two experimental groups). Retrospective ratings revealed no differences in the reported intensity of emotion experienced in response to amusing, neutral, or sad films for either group of participants (Amusing:  $M_{\text{Rate}} = 2.5$ ,  $M_{\text{View}} = 3.4$ ,  $t = 1.31$ ,  $df = 27$ , ns; Neutral:  $M_{\text{Rate}} = 0.4$ ,  $M_{\text{View}} = 0.2$ ,  $t = -0.46$ ,  $df = 27$ , ns; Sadness:  $M_{\text{Rate}} = -2.6$ ,  $M_{\text{View}} = -2.5$ ,  $t = 0.26$ ,  $df = 27$ , ns), indicating that attending to emotion did not have an impact on immediately remembered emotion experience. These results are nearly identical if online ratings in the RATE group and retrospective ratings from the VIEW group are compared.

One concern with using this approach is that accuracy in retrospective continuous reports may be compromised. Because we asked participants to indicate how they *had been feeling* at an earlier time point, this leads to the worry that even if the two groups do not differ in their retrospective reports, these reports do not accurately reflect their real online experiences. However, an analysis of the moment-by-moment correlation of the online and

Table 1

BOLD activation to amusing (versus neutral) films while passively viewing (VIEW group) or rating (RATE group)

Region	BA	Volume (in mm <sup>3</sup> )	x	y	z	Peak Z score
VIEW group						
R. posterior insula	13	844	44	−10	−5	4.46
L. anterior temporal gyrus	22	264	−52	15	7	4.34
R. superior temporal gyrus	22	1477	57	−41	16	6.91
L. superior temporal gyrus	22	686	−64	−34	19	5.79
L. middle temporal gyrus	22	2162	−53	−37	0	5.06
L. cuneus	18	633	−8	−97	8	5.76
RATE group						
R. superior frontal gyrus	6	475	6	17	58	4.57
R. superior frontal gyrus	6	2742	7	−2	65	7.16
R. inferior frontal gyrus	44	316	52	17	11	4.54
L. inferior frontal gyrus	44	4746	−49	13	1	6.05
L. medial frontal gyrus	6	369	−15	3	56	4.05
R. anterior cingulate gyrus	24/32	1107	8	12	39	4.76
R. precentral gyrus	6	1107	45	−6	47	4.78
R. insula	13	3744	44	9	3	5.66
R. posterior insula	13	264	42	−3	−7	4.29
L. superior temporal gyrus	21	686	−45	−12	−4	4.78
R. middle temporal gyrus	22	475	50	−22	−4	5.86
R. superior temporal gyrus	22	9545	52	−49	13	4.34
L. superior temporal gyrus	22	7225	−57	−49	16	3.71
L. postcentral gyrus	40	527	−43	−32	49	5.25
R. thalamus/caudate		6855	7	−17	12	5.71
L. thalamus/caudate		5168	−19	−11	16	4.35
R. lentiform nucleus		369	19	−4	8	4.87
L. putamen		264	−30	−15	−2	5.09
R. declive		1107	34	−85	−21	5.09

Note. BA = Brodmann's Area. Coordinates specify peak voxel in cluster according to Talairach and Tournoux brain atlas.

retrospective ratings over all the film clips in the RATE group indicates a substantial degree of similarity (average  $r = 0.86$ ), giving us confidence that retrospective reports can be quite accurate.

#### Amusing films: rating vs. viewing

For the VIEW group, amusing films activated regions of superior and middle posterior temporal cortex, anterior temporal cortex, posterior insula, and cuneus (see Table 1 and Fig. 2, top).<sup>3</sup> For the RATE group, there was a similar pattern of activations in regions of temporal cortex, as well as activations in additional areas of anterior insula, dorsal anterior cingulate cortex, bilateral regions bordering the thalamus and the caudate, and several other regions (see Table 1).

In comparison to passive viewing, enhanced BOLD responses were observed when rating in both between- and within-group comparisons in several brain regions, including right dorsal anterior cingulate cortex, bilateral insula, and bilateral inferior parietal lobule (Fig. 3, top). The pattern of increases was strikingly similar when comparing either the RATE group to the VIEW group (between-group contrast) or when comparing rating during the second viewing to passive viewing in the VIEW group (within-group contrast) (Table 2). There were no regions in which

viewing was associated with significantly more activity than rating.

#### Sad films: rating vs. viewing

For the VIEW group, sad films activated regions in dorsal medial prefrontal cortex, thalamus, temporal cortex, precuneus/posterior cingulate cortex, and left amygdala (see Table 3 and Fig. 2, bottom). For the RATE group, there was a similar pattern of activations in medial prefrontal cortex, thalamus, temporal cortex, and amygdala. Activations in these regions tended to be more extensive, and in no case were they significantly less activated than in the VIEW group. Additional regions of activation were evident in cerebellum, insula, and inferior frontal gyri (see Table 3).

Directly comparing activation to sad films in the two groups (RATE vs. VIEW) revealed greater activation during rating in four left lateralized foci of activation, including two regions in the middle frontal gyrus (BA 6 and BA 9), as well as regions in the left cuneus and inferior parietal lobule, with similar activations in both the between-group and within-group comparisons (Fig. 3 and Table 4, bottom). Parallel to the findings for amusement, there were no regions in which viewing was associated with significantly more activity than rating.

#### Interaction effects: rating sadness vs. rating amusement

Despite apparent differences in the activation maps associated with rating of amusement and sadness separately, an ANOVA yielded no significant interactions between type of emotion and

<sup>3</sup> Regions identified in the view only condition for amusement and sadness separately were then selected as ROIs for use in follow-up analyses investigating the impact of rating on activation in these areas (see Results section).

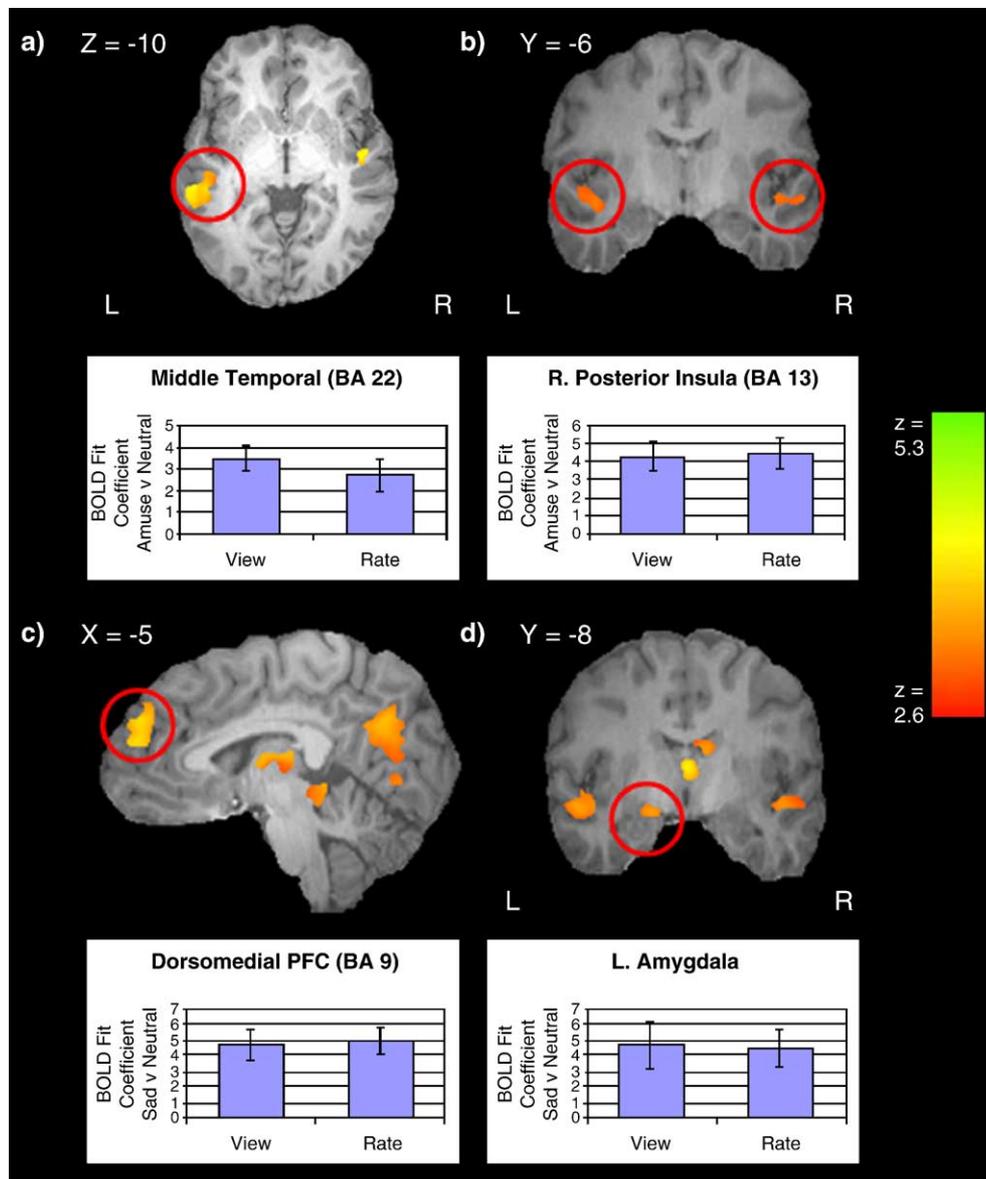


Fig. 2. Attentional impact on activation in regions associated with passive viewing of emotional films. Top (a, b): Amusing films. Bottom (c, d): Sad films. (a) L. middle temporal gyrus activated by amusing films in both VIEW and RATE. (b) Bilateral insula activated by amusing films in both VIEW and RATE. (c) L. dorsomedial prefrontal cortex activated by sad films in both VIEW and RATE. (d) Bilateral amygdala (circled) activated by sad films in both VIEW and RATE. Note: Activations depicted in figure derived from contrast of emotion vs. neutral during passive viewing. Bars represent mean beta-weight in each ROI. Error bars depict standard error.

attentional condition. Thus, the impact on activation of rating sadness and amusement followed the same pattern, although the degree to which activations in particular regions such as anterior cingulate cortex and insula were affected varied by emotion.

#### Emotion ROIs: rating vs. viewing

We compared average activation between and within the groups in emotion ROIs functionally derived from the activation maps associated with amusement and sadness (compared to neutral films) in the VIEW group. In none of the regions identified as activated by amusement (Table 1) or sadness (Table 3) was there a significant effect of rating on activation, even at a less stringent criterion of  $P < 0.05$  (see Fig. 2).

#### Discussion

In the present study, we identified a network of regions involved in passively experienced emotional responding that is similar to regions others have reported, including activations in areas such as the middle temporal cortex for amusement (e.g., Aalto et al., 2002; Goel and Dolan, 2001; Mobbs et al., 2003) and medial prefrontal cortex and amygdala for sadness (e.g., Pelletier et al., 2003; Posse et al., 2003). Rating was associated with activation in regions implicated in attention, including anterior cingulate, anterior insula, and parietal cortices (Wager et al., 2004). However, none of the regions associated with emotion during passive viewing, including the amygdala, evidenced significantly diminished or enhanced activation during attention to emotion. Additionally, we noted no effect of attention on the

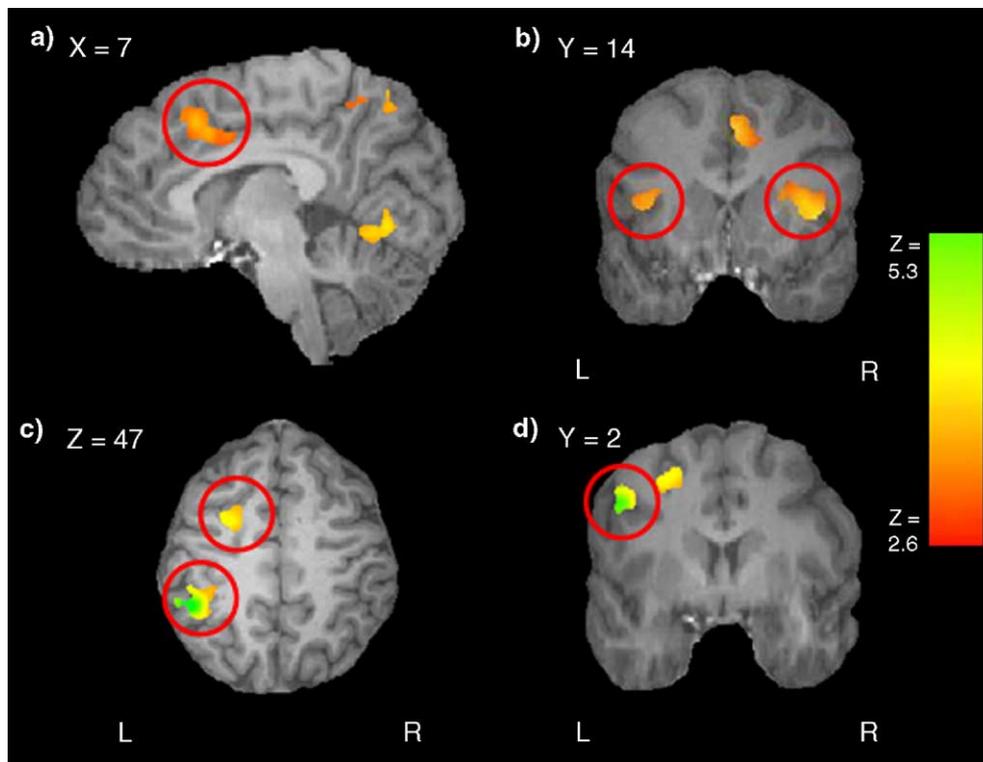


Fig. 3. Direct comparison of rating vs. passive viewing. Top (a, b): Amusing films. Bottom (c, d): Sad films. (a) R. anterior cingulate cortex (circled) activated by rating amusing films. (b) Bilateral insula (circled) activated by rating amusing films. (c) L. inferior parietal lobule activation and L. middle frontal gyrus (circled) activated by rating sad films. (d) L. middle frontal gyrus/BA 6 (circled) activated by rating sad films. Note: all activation maps depicted were derived from the between-group contrast.

self-reported intensity of emotional experience, suggesting that in the context of powerfully evocative, temporally variable amusing and sad film stimuli, attention's impact on these emotions may be minimal.

In contrast to the hypothesis that attention focused on emotion via subjective rating enhances the emotional response—as might be suggested by analogies with the literature on the effects of attention to particular aspects of visual stimuli (e.g., O'Craven et al., 1999)—our results indicate that attending to one's emotional response does *not* necessarily enhance activation in regions supporting the emotional response (Gorno-Tempini et al., 2001; Keightley et al., 2003; Liberzon et al., 2000). Our results also do not support the hypothesis that the attentional demands of rating one's feelings diminish activation in these regions (Critchley et al., 2000; Hariri et al., 2000; Taylor et al., 2003). Instead, our results suggest that rating one's feelings leaves intact activation in regions associated with passive viewing, and additionally activates a separate set of regions, including anterior cingulate cortex, which may support the increased attentional demands of making an emotional rating.

Taken together with the findings of others, our results suggest that the consequences of attending to emotion can be highly heterogeneous. This observation speaks to the importance of considering the unique nature of the processes involved in emotional responding and experience. Attention to one's feelings may invoke many additional responses, such as evaluation of the appropriateness of the emotional response, evaluation of the meaning one's response has for hedonic goals, or reevaluation of the abstract properties of the stimulus itself, which could in different situations evoke

processes either to increase or decrease the emotional response (e.g., Ochsner et al., 2004b).

#### *Addressing differences: a comparison to other studies*

As noted above, our findings diverge in important ways from those of other researchers. Why might this be? Several possible explanations for this divergence present themselves. However, before turning to consider these explanations, it is important to note that we did observe activation in regions previously associated with emotional responding, particularly the amygdala and medial prefrontal cortex for sadness, and temporal cortex and insula for amusement, but did not observe significant diminishment of activation in these areas during rating. It is possible that the manner in which we evoked emotions in this context makes them less susceptible to disruption by attention. The films we employed create a strong narrative context in which intense, emotionally evocative events occur. It may be that determining one's feelings to events already embedded in a storyline requires less abstraction or cognitive processing than does determining how one feels in response to decontextualized, punctate emotional stimuli, such as static pictures (cf. Taylor et al., 2003). In this way, lessening the cognitive demands required during rating may result in less disruption of the emotional response. Similarly, the differences we observed may also be due to the nature of the attentional task we used. We employed a continuous rating method where others have used a discrete response to a number of separately presented stimuli. Our method was appropriate to the context of the emotions evoked, but it may be that it is also less intrusive than other measures.

Table 2  
Amusing films: comparison of emotion rating vs. passive viewing

Region	BA	Volume (in mm <sup>3</sup> )	x	y	z	Peak Z score
Regions activated in both between- and within-group contrasts						
R. superior frontal gyrus	6	422	17	56	66	4.10
R. middle frontal gyrus	6	2320	27	−1	55	3.95
R. anterior cingulate cortex	32	2004	7	15	41	3.94
L. precentral gyrus	6	2953	−23	−6	55	4.54
R. insula	13	3111	35	10	11	5.04
L. insula	13	527	−37	13	13	3.91
L. mid-occipital/precuneus	37	422	−40	−66	0	4.47
L. lingual gyrus	18	2848	−17	−66	−4	5.10
R. mid-occipital/cuneus	31/18	32,062	27	−61	23	5.10
L. mid-occipital/precuneus	31	1951	−35	−80	16	4.49
R. cerebellum		1266	15	−49	−25	4.31
L. cerebellum		791	−33	−52	−32	3.61
Regions activated in between contrast only						
R. middle frontal gyrus	9	1529	39	29	31	4.99
L. fusiform gyrus	37	633	−37	−56	−14	4.48
L. inferior parietal lobule	40	5484	−47	−37	44	5.30
L. precuneus	7	2215	−23	−70	42	4.93
L. precuneus	7	475	−17	−56	58	4.10
L. thalamus		2057	−21	−24	10	4.65
R. caudate tail		422	19	−26	18	3.97
Regions activated in within contrast only						
L. cerebellum		527	−31	−38	−31	4.45
L. cerebellum		316	−28	−45	−25	4.60
R. putamen		527	24	5	7	3.99

Note. BA = Brodmann's Area. Coordinates specify peak voxel in cluster according to Talairach and Tournoux brain atlas.

#### Interpreting activation: processes involved in rating emotion

While speculative, the location and distribution of the network of regions that we observed when participants attended to their emotions, including the anterior cingulate cortex, insula, and parietal areas, support the hypothesis that the attentional demands in our rating manipulation may have differed somewhat from those in other studies. We observed activation in an anterior cingulate region located more caudally and dorsally than the region associated with attention to emotion reported by both Lane et al. (1997) and Taylor et al. (2003) (cf. Gusnard et al., 2001; Ochsner et al., 2004a). The region detected in our task lines up with an area found to be activated by attending to one's heartbeat (Critchley et al., 2004), and whose activation correlates with the production of skin conductance responses (Nagai et al., 2004), suggesting that the region we observed might also be involved in translating the occurrence of autonomic responses into representations of the intensity of one's emotional state. However, the area of anterior cingulate that we find also corresponds to a region implicated previously in response conflict monitoring (Carter et al., 2000) and integrating subgoals to perform a complex task (Badre and Wagner, 2004). In addition, the regions of anterior insula and parietal cortex we observed have been noted in a recent analysis to be engaged by working-memory processes and, to a lesser extent, attentional shifting (Wager et al., 2004). Our findings thus suggest that the network of regions we observed in attending to emotion may mediate switching attention between visceral responses and the emotional properties of the stimuli, in order to determine the emotional intensity experienced. Alternatively, they may have mediated attention not to emotion per se, but to aspects of the task of rating, such as shifting attention between the film stimuli and the rating dial. Whichever explanation is correct, it is important to note that the act of attending to and rating

one's emotions did not *diminish* activation in any regions associated with the generation of the emotional response itself.

Although the regions we find activated by attention to emotion thus differ slightly from those reported by others, it is interesting to note that the region of dorsomedial prefrontal cortex that we find activated by sadness overlaps substantially with areas reported by others to be activated by attending to emotion over not attending (Gusnard et al., 2001; Northhoff et al., 2004; Taylor et al., 2003). This region has been shown to be equally activated by attending to one's own emotion or another's emotion (Ochsner et al., 2004a), and is also activated by observing social interactions (Iacoboni et al., 2004), suggesting that it may play a particularly important role in representing the emotions or mental states evoked by interpersonal interactions, either in oneself or in another, rather than in attending to emotion per se. Thus, although we observed activation in dorsomedial prefrontal cortex only during sad films, it may be that, had we evoked amusement through social interactions requiring attribution of mental states, we would have observed similar activation. More generally, these findings point to the potential importance of distinguishing the neural correlates of interpersonal emotion evoked by social situations and intrapersonal emotions evoked by less social concerns (e.g., fear or disgust). In the future, it will be useful to clarify the specific contribution of the dorsomedial prefrontal cortex to interpersonal or intrapersonal emotional experience and introspection, as well as to better characterize the source of the differing results in this and other studies.

#### Limitations and future directions

Activation differences (or lack thereof) noted in between-group comparisons are subject to a number of limitations, including the potential for individual differences to create spurious differences

Table 3  
BOLD activation to sad (versus neutral) films while passively viewing (VIEW group) or rating (RATE group)

Region	BA	Volume (in mm <sup>3</sup> )	x	y	z	Peak Z score
VIEW group						
L. medial prefrontal cortex	8/9	2320	-3	50	27	4.70
L. superior temporal gyrus	21	2109	-43	-5	-6	5.61
R. superior temporal gyrus	21	1318	48	-7	-7	5.51
L. middle temporal gyrus	21	844	-63	-48	9	4.95
L. precuneus	31	4166	-5	-67	20	6.15
Thalamus		1529	-1	-17	10	5.44
L. amygdala		158	-21	-4	-9	3.21
L. caudate		738	-11	-10	21	4.35
Brainstem		1160	-2	-33	-6	5.89
RATE group						
R. medial frontal gyrus	8/9	2742	4	48	43	5.82
R. inferior frontal gyrus	13	844	44	22	12	4.90
L. inferior frontal gyrus	45	1688	-51	20	-1	4.85
R. superior frontal gyrus	6	3217	4	7	66	6.87
R. precentral gyrus		580	45	-3	46	5.35
R. superior temporal gyrus	22	2320	51	11	-8	5.99
R. middle temporal gyrus	21	1582	51	-17	-10	5.26
L. middle temporal gyrus	21	1740	-63	-20	9	5.66
R. fusiform gyrus	20	580	43	-27	-15	5.15
R. middle temporal gyrus	37/39	10,283	48	-60	11	7.06
L. superior temporal gyrus	22	5906	-56	-56	20	5.57
R. cuneus	18	738	12	-80	12	4.85
Thalamus/lingual gyrus/cerebellum		40,289	1	-20	11	7.30
L. amygdala		158	-18	-8	-12	3.15
R. caudate		369	9	-8	21	4.82
L. caudate		791	-17	-12	24	4.92
R. cerebellum		1582	39	-58	-24	5.19
R. cerebellum		422	20	-72	-41	3.78
R. cerebellum		264	11	-77	-38	3.08
L. cerebellum		5168	-39	-77	-25	5.59
R. cerebellum		1635	41	-80	-16	5.74

Note. BA = Brodmann's Area. Coordinates specify peak voxel in cluster according to Talairach and Tournoux brain atlas.

between the groups (e.g., Eugène et al., 2003). However, the strikingly similar patterns of activation when rating in both the within- and the between-group comparisons lend assurance that these results are due to the effects of the rating manipulation on neural activity. Moreover, because participants were not required to attend to a particular stimulus during passive viewing, it is possible that they were attending to emotion in *both* the passive-viewing condition and the rating condition, making a comparison between the two conditions a conservative test of true activation differences.

Table 4  
Sad films: comparison of emotion rating vs. passive viewing

Region	BA	Volume (in mm <sup>3</sup> )	x	y	z	Peak Z score
Regions activated in both between- and within-group contrasts						
L. inferior parietal lobule	40	4113	-44	-39	42	4.69
Regions activated in between-group contrast only						
L. middle frontal gyrus	6	791	-24	2	47	4.59
L. middle frontal gyrus	9	686	-47	6	37	4.56
L. lingual gyrus	18	527	-44	-58	10	4.23
No regions activated in within-group contrast only						

Note. BA = Brodmann's Area. Coordinates specify peak voxel in cluster according to Talairach and Tournoux brain atlas.

While this does not present a problem for interpreting the activations we observe, it does place caveats on our observation that attending to emotion had no impact on regions activated during passive viewing. However, we did observe significant activation of regions indicated by others to be involved in the two emotions we elicited, including the amygdala, suggesting a minimal attentional impact. We also do not believe that the lack of a significant attention-related difference in areas associated with emotion can be attributed to a lack of power to detect them, because we did in fact observe significant differences—in the positive direction—on other regions, with a fairly large number of subjects in each group. Furthermore, scrutiny of the activation levels in emotion-related regions in the two groups also indicates nearly identical values (Figs. 2 and 3). Our results thus indicate recruitment of additional areas by the emotional response when rating, but *not* a disengagement of areas typically involved in the production of the naturally unfolding emotion process.

What is less clear, however, is the precise role played by regions that showed attention-related activations, such as the anterior cingulate and insula. Are they dedicated mechanisms necessary for the conscious representation of an emotional or autonomic responses (e.g., Critchley et al., 2004; Lane, 2000), or do they support other more general-purpose processes brought online by but not necessary for reporting of emotional states, such as shifting of attention between emotional experience and the demands of the task (i.e., moving the rating dial)? Research

incorporating physiological measures such as skin conductance and cardiovascular responses may help to disambiguate the activity associated with non-emotional task demands from neural correlates of attention focused on representing emotional or autonomic states.

The process of translation between autonomic arousal and emotional experience may well also distinguish particular emotional states, which may vary somewhat in their profile of physiological response (Levenson, 1992). Few studies to date have separated out the effects of attention to different emotions, and to our knowledge, no previous study has analyzed the impact of attention to discrete feeling states (as opposed to facial expressions) separately. Although activation in anterior cingulate, insular, and parietal cortices was slightly stronger when rating amusement, there were no areas where attending to one emotion had a strongly separable effect from attending to the other emotion. However, it remains possible that for other types of emotional experiences, such as anxiety, anger, or pride, attention to emotion might recruit different mechanisms or have a larger impact on the unfolding response than it does for amusement and sadness.

One other important direction for future research concerns the relation between neural activation and subjective reports of emotion experience. Although there were significant differences in neural activations when participants were rating compared to when participants were passively viewing the films, these differences were not reflected in the subjective reports of emotion experience. This highlights the important, and as of yet unanswered, questions of how emotion researchers should interpret neurophysiological differences in light of a lack of behavioral difference, and what information can be gleaned from neural activity that does not directly correlate with self-report.

These questions notwithstanding, our findings support the idea that in some contexts at least, the additional attentional demands evoked by rating of one's emotions do not significantly disrupt neural or self-reported emotional responding. This may be of use in future studies examining both the neural correlates of emotional experience and the interaction between attentional focus and emotion. A film viewing context has the advantage of being robustly engaging, temporally variable, and powerfully evocative, allowing for the investigation of the dynamic changes involved in the emotional response (Gross and Levenson, 1995). Of equal importance, the rating dial used in this context does not seem to disrupt emotional responding in the way that other rating measures have (e.g., Taylor et al., 2003).

An analysis of affective dynamics was not the focus of the present report, but this paradigm may provide a rich context in which to explore the neural correlates of the dynamic unfolding of emotional responses, and a comparison of this approach with other standard methods is discussed elsewhere (Goldin et al., *in press*). It may also be a method which can be used to explore the times during which attending to one's emotions *does* have an impact, in order to further understand when and why focusing on one's emotions increases or decreases them.

#### Concluding comment

One of the seminal contributions of quantum theory to physics in particular and scientific thought in general has been the idea that the mere act of observing a process may fundamentally alter that process (Heisenberg, 1958). We explored whether this proposition applies similarly in the field of affective science: does the emotional response unfold independently of the spotlight of

attention or is it a fleeting will o' the wisp, vanishing as one's gaze turns to catch it? If it *is* fleeting, how are we to study emotion *without* directing our research participants' attention to their emotional responses? We have reported a new method of studying the impact of attention in an engaging, continuously varying, emotionally evocative film context, and have found that, while there is a network consistently engaged by the addition of a rating task, this type of attentional manipulation has little impact on the emotional response itself. These findings point to the importance of a consideration of the context in which attention and emotion interact. We have also suggested that this context may be a powerful one for future exploration of these issues, because it may allow researchers a more fine-grained way of sampling each individual's subjective emotional response and may shed new light on attention, emotion, and their interaction.

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