DIFFERENT BOLD RESPONSES TO EMOTIONAL FACES AND EMOTIONAL FACES AUGMENTED BY CONTEXTUAL INFORMATION

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Literature suggests that relatively simple stimuli such as emotional facial expressions elicit neural activation in subcortical-limbic regions whereas contextually richer emotional pictures generate activation in a broader network of prefrontal as well as subcortical-limbic regions. The extent to which contextual features modulate subjective and neural responses associated with responses to emotional faces is unclear. Normative valence and arousal ratings for a large corpus of affective pictures (IAPS) were reviewed to explore whether emotional pictures containing both faces and context evoked more intense subjective emotional reactions than faces presented alone. This review study demonstrated that subjective emotional reactions to emotional faces with contextual information were greater than those to faces. An fMRI study was conducted to examine neural reactivity to these two types of emotional stimuli. Eleven healthy right-handed subjects viewed passively emotional stimuli during event-related functional magnetic resonance imaging (fMRI) assessment. Emotional faces augmented by contextual information elicited significant brain activity in the prefrontal cortex (BA10/11/47) as well as amygdala and thalamus. In contrast, emotional facial expressions provoked neural responses only in the subcortical-limbic/paralimbic regions including amygdala, thalamus, insula and posterior cingulate gyrus. These findings suggest that there are different but overlapping brain networks engaged by emotional faces and faces augmented by contextual information. The amygdala and

thalamus can be regarded as common regions associated with emotional processing. Prefrontal regions may be unique in more cognitive and conscious processing of emotional faces augmented by contextual information.

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1.0 INTRODUCTION

1.1 TWO TYPES OF EMOTIONAL STIMULI

Looking at emotional pictures provokes a wide range of measurable subjective, autonomic, and somatic responses (Bauer, 1998; Lang et al., 1993, 1998). Emotional pictures have been used to investigate brain regions associated with emotional processing (e.g., Canli et al., 1998; Lane et al., 1999; Lee et al., 2004; Northoff et al., 2000; Phan et al., 2003). Many neuroimaging studies of emotion have successfully employed a specific type of emotional picture, involving facial expressions–often with background features and hair cropped out– as stimuli in examining the role of the subcortical-limbic regions, especially the amygdala, in emotional information processing (e.g., Morris et al., 1996; Phillips et al., 1998, 2001; Yang et al., 2002).

Other neuroimaging studies using contextually richer emotional pictures have demonstrated brain activation in an extended network including cortical regions as well as subcortical-limbic regions (e.g., Canli et al., 1998; Lane et al., 1999), possibly due higher-level elaborative associative processing. Inclusion of contextual features of emotional stimuli other than simple disembodied non-famous faces could potentially allow different insights into emotional information processing across this broader network, encompassing both the subcortical-limbic pathway and cortical pathways associated with emotional processing.

If contextually rich emotional pictures do recruit a broader network of brain activity, it may be that such stimuli elicit more intense subjective emotional experiences compared to emotional facial expressions alone. However, few studies have directly examined subjective emotional ratings and brain activation evoked by emotional facial expressions and emotional pictures in the same subjects. Recently, Schafer, Schienle, and Vaitl (2005) examined subjective experience and neural substrates associated with fear-inducing and disgust-inducing facial expressions and emotional scenes with a passive viewing instruction. Emotional scenes were rated more negative in valence and higher in arousal than facial expressions. Additionally, fear- and disgust-inducing scenes were rated to induce greater subjective fear and disgust reactions, respectively, compared to fear- and disgust-inducing facial expressions. Emotional scenes evoked brain activation in the amygdala, orbitofrontal cortex, and insula whereas facial expressions showed no significantly activated brain regions in exploratory or region of interest analyses. They suggested that facial expressions did not sufficiently elicit the subjective emotional reactions and this fact might be one of reason they failed to cause expected patterns of brain activation.

Though multiple previous studies have contrasted emotional pictures containing faces/people and emotional scenes without faces/people, these could not answer the specific question of what role contextual features *add* to processing of stimuli that include faces. Thus, the present studies contrasted contextually rich emotional pictures with faces/people and pictures of faces alone. These studies may provide with us the ability to understand why emotional pictures containing both faces and contextual information evoke more intense subjective experience and extended brain activation.

1.2 NEURAL RESPONSES TO TWO TYPES OF EMOTIONAL STIMULI

1.2.1 Neural responses to emotional faces

Subcortical-limbic activity, particularly including the amygdala, has been widely replicated in neuroimaging studies employing fearful faces (Adolphs, 2002; Breiter et al., 1996; Lange et al., 2003; Morris et al., 1996; Phillips et al., 1998, 2001; Thomas et al., 2001; Whalen et al., 1998; Yang et al., 2002), angry faces (Ganel et al., 2005), happy faces (Killgore and Yurgelun-Todd, 2004), and sad faces (Killgore and Yurgelun-Todd, 2004). Other subcortical-limbic and paralimbic regions have also demonstrated Blood Oxygen-Level Dependent (BOLD) responses to emotional facial expressions. The anterior insula cortex has been observed in face processing of disgust (Phillips et al., 1997, 1998). Sad faces have been associated with neural activity in the left amygdala and right temporal pole while angry faces enhanced activity in the orbitofrontal and anterior cingulate cortex (Blair et al., 1999). Whalen et al. (2001) demonstrated brain activity in the bilateral insula and amygdala to fearful faces, in the amygdala to angry facial expression, and in the parahippocampal gyrus to both facial expressions. Moriguchi et al. (2005) showed neural activation in the posterior cingulate and amygdala in Caucasians but the left insula in Japanese in response to fearful faces.

There is also some evidence that brain regions within the subcortical-limbic network respond rapidly to facial expressions of emotion, which may reflect LeDoux’ s (1996) notion that the subcortical-limbic pathway represents a “fast” pathway tuned to quick automatic responses to emotional information. Several studies reported habituation of neural responses in the amygdala to emotional faces presented repeatedly (Breiter et al., 1996; Phillips et al., 2001; Thomas et al., 2001). Brain activity to facial expression of emotion in some areas of the subcortical-limbic pathway can occur without awareness (Morris, Ohman, and Dolan, 1999; Rauch et al., 2000; Whalen et al., 1998).

Thus, the majority of neuroimaging studies using emotional faces as stimuli have focused on limbic and subcortical responses to facial expression of emotion even though some studies have showed cortical responses to some specific emotional faces such as anger. Subcortical-limbic regions were specialized for emotional processing associated with specific emotional facial expressions, for example, the amygdala and fearful expressions or the insula and disgust facial expressions (Murphy et al., 2003). Overall, previous neuroimaging studies using emotional faces consistently support the existence of a subcortical-limbic pathway associated with emotional processing.

1.2.2 Neural responses to emotional scenes and pictures

A meta-analysis of over 100 functional neuroimaging studies of human emotions demonstrated neural activity in a widespread network of brain regions associated with emotion processing, many of which involved emotional pictures (Murphy et al., 2003). They emphasized prefrontal regions as general emotional processing centers shared with a wide range of emotions. For example, emotional processing of more complex emotional pictures, especially pleasant and unpleasant pictures from the International Affective Picture System (IAPS), elicited increased activity in the amygdala, thalamus, hippocampus, hypothalamus, medial prefrontal, and orbitofrontal cortex (Canli et al., 1998; Lane et al., 1999; Schafer, Schienle, and Vaitl, 2005; Stark et al., 2004).

Consistently, empirical neuroimaging studies have suggested that several brain regions outside of the limbic system are activated during the passive viewing of emotional pictures. For example, Stark and colleagues (2003) explored neural responses to disgust-inducing and fear-inducing pictures selected from the IAPS. They reported that both aversive emotional pictures provoked increased neural activity in the prefrontal cortex, occipital-temporal lobe, and thalamus. Neural responses to fear-evocative and disgust-evocative pictures have been investigated using fMRI (Wright et al., 2004). Brain activation for fear was revealed in the occipitotemporal gyrus and parahippocampal gyrus whereas activation for disgust appeared in the anterior insula, posterior cingulate, occipital cortex, thalamus, and several prefrontal regions. Thus, emotional scenes or pictures are likely to recruit a broader network of brain mechanisms associated with semantic information processing as well as emotional information processing.

Theories about higher-level emotional processing (e.g., appraisal) also support the existence of a cortical pathway for emotional information processing. According to appraisal theory, emotions always accompany cognitive appraisal of emotional information (Clore and Ortony, 2000; Lazarus, 1991). Several regions of the prefrontal cortex are interconnected with limbic systems including amygdala and cingulate cortex (Davidson et al., 1999, 2000), supporting the interaction between the cortical and subcortical pathways.

To summarize, literature suggests that brain activity in subcortical-limbic and paralimbic areas (especially the amygdala) frequently occurred during passive viewing and implicit emotional processing (e.g., gender discrimination) of facial expressions; a more widespread pattern of cortical activity as well as subcortical activity may occur during passively viewing of a broader range of emotional pictures. It is unclear what factors influence this different neural circuitry underlying emotional processes based on types of emotional stimuli. One possible contributor to these differences may be contextual information within the emotional pictures.

Increased activity in extended prefrontal brain regions may be due to more intense subjective reactions and increased cognitive processing (e.g., appraisal) triggered by contextual information within emotional pictures.

1.3 THE ROLE OF CONTEXTUAL INFORMATION

Contextual information is thought to encourage more accurate emotion recognition (Zagorska, 1987). Contextual information consisting of common, everyday situations helped people to more accurately evaluate facial expressions, especially neutral expression (Carrera-Levillain, & Fernandez-Dols, 1994).

To further illustrate the effects of context on emotional processing, Teasdale et al. (1999) examined how pictures with captions which have emotion-related meaning affect brain activity. They found that the content of the captions changed the cognitive processing of emotional meaning and neural activation in the medial prefrontal cortex. Other studies have also found that negatively and positively valenced contextual information modulated different neural responses to surprised facial expression in the amygdala (Kim et al., 2004).

Similarly, task demands may be considered as contextual information that affects brain responses to emotional stimuli. Lange et al. (2003) examined whether different emotion tasks affect neural responses to fearful facial expressions. A passive viewing task induced significant activity in subcortical-limbic areas including the amygdala and hippocampus whereas explicit emotion tasks generated brain activity in prefrontal regions including the ventral frontal gyrus, but not subcortical regions, in response to fearful facial expressions. Several studies have reported that explicit emotion processing tasks such as emotion labeling increased neural activity in the prefrontal regions (Nakamura et al., 1999; Hariri et al., 2000, 2003) but decreased subcortical region activation (Critchley et. al., 2000; Hariri et al., 2000, 2003). Hariri et al. (2000, 2003) suggested that cognitive evaluation of emotional stimuli might cause increased activity in the cortical regions and decreased activity in the subcortical-limbic regions. Again, these data suggest that context could play a role in cortical recruitment in response to emotional-face stimuli.

1.4 CURRENT STUDIES

This study was designed to investigate how pictorial contextual information modulates neural activity in response to emotional faces, controlling for task demands. Thus, we examined passive viewing of two different types of stimuli, emotional faces presented alone and emotional faces augmented with contextual information.

We conducted two studies including a review study of normative ratings and a neuroimaging study. The normative rating study examined how subjective emotional reactions are different between emotional pictures and emotional facial expressions by reviewing normative valence and arousal ratings for a large corpus of emotional stimuli. We hypothesized that emotional pictures were more likely to be rated as either more positive or more negative and higher arousal than emotional facial expressions.

In the neuroimaging study, we used functional magnetic resonance imaging (fMRI) to investigate neural activation provoked by two different types of emotional stimuli, emotional faces augmented by contextual information and faces alone. Specifically, contextually rich pictures containing emotional faces were selected and new emotional faces stimuli were constructed by cutting faces out of the whole emotional pictures, so as to examine same emotional faces in two different conditions; one with contextual information and another without it. We addressed the following question: are there different subjective and brain processes that occur in response to faces and faces augmented by contextual information? In particular, we were interested in whether emotional pictures involving both faces and contextual information provoked stronger subjective reactions and a widespread pattern of brain activity, including both cortical and subcortical-limbic regions involved in emotional information processing, compared to faces presented alone.

2.0 STUDY I: REVIEW OF NORMATIVE RATINGS

We explored whether subjective reactions to emotional faces with contextual information provokes stronger subjective emotional reactions than faces alone by reviewing normative valence and arousal ratings for a large corpus of affective pictures, the International Affective Picture System, standardized, emotionally-provocative photographs that includes contents across wide range of semantic categories (Lang, Bradley, and Cuthbert, 1997).

2.1 MATERIALS AND METHODS

We used mean normative ratings for 717 emotional pictures on affective valence and arousal dimensions reported by Lang, Bradley, & Cuthbert (2001). These ratings were derived from large normative male and female subject samples. Each dimension was rated using the "Self-Assessment Manikin" (SAM), an affective rating systems developed by Lang (1980), consisting of graphic icons depicting values on a continuously varying scale reflecting emotional reactions. The valence scale contains 5 icons that vary continuously on a 9-point scale from happy (a smiling icon) to unhappy figure (a frowning icon); thus a score of 9 represents happy, a score of 5 is neutral, and a score of 1 is very unhappy. The arousal scale ranges from a high arousal (an excited, wide-eyed icon) to a relaxed state (a sleepy icon); thus a score from 1 to 9 represents from low arousal to high arousal.

2.2 PROCEDURE

The criteria were created to select pictures including only faces or pictures including faces and context. The pictures were classified into four groups; ‘FACE’, ‘NO FACE’, ‘FACE+ CONTEXT’, and ‘OTHERS’. Pictures in the ‘FACE’ group included pictures with only one face, torso, or face with a hat/scarf, but little other detail. Pictures in the ‘FACE+CONTEXT’ group contained pictures with perceivable faces as well as other information, i.e., contextual augmentation. Pictures were coded by two raters, one primary researcher (KHL) and a second independent research assistant, whose agreement was reliable (Kappa=.85, $p<.0001$). For the analysis, we used the groups classified by the primary researcher. Pictures in the ‘FACE’ and ‘FACE+CONTEXT’ groups were included in statistical analyses.

A frequency analysis was applied to show the distribution of pictures in each group and analysis of variance (ANOVA) was conducted to find significant differences in a valence-intensity and an arousal rating between the two groups. Emotion-intensity was determined as the absolute value of deviation of the valence score (range from positive (1) to negative (9)) of each picture from a neutral score (5); for example, valence scores of either 4 or 6 would each have an intensity of 1.

2.3 RESULTS

Thirty-two pictures were assigned to the ‘FACE’ group and 171 pictures were assigned to the ‘FACE+CONTEXT’ group. Pictures in the ‘FACE’ group showed a normal distribution of emotional valence (Shapiro-Wilk statistic=.976, $p=.663$) whereas the 171 pictures in the ‘FACE +CONTEXT’ group showed a bimodal distribution (Shapiro-Wilk statistic=918, $p<.0005$), indicating that pictures in the 'FACE+CONTEXT' group were rated as more positive or negative compared to those in the 'FACE' group. A one-way ANOVA on emotion-intensity and arousal ratings revealed that pictures in the 'FACE+CONTEXT' group evoked greater valence intensity ($F(1, 201)=13.99$, $p<.001$, $M(SD)_{face +context}=1.83$ (0.94), $M(SD)_{face}=1.15(0.92)$, $\eta^2=0.06$) and higher arousal than those in the 'FACE' group ($F(1, 201)=44.18$, $p<.0001$, $M(SD)_{face +context}=5.15$ (1.07), $M(SD)_{face}=3.87(0.67)$, $\eta^2=0.18$) (Figure 1).

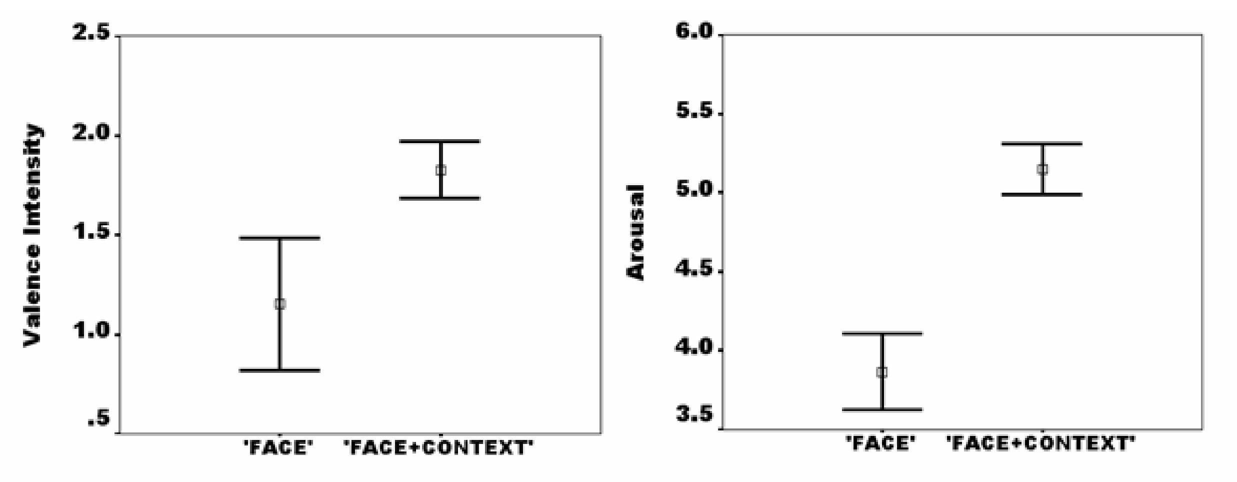

Figure 1. Emotion-intensity difference between the two groups (left) and arousal rating difference between two groups (right). 'FACE+ CONTEXT' showed greater valence intensity and arousal level than 'FACE', indicating emotional faces with contextual information generated stronger subjective emotional reactions.

2.4 SUMMARY

These findings support the hypothesis that faces augmented with contextual information provoke greater subjective emotional reactions than faces alone. This relationship was true when reactivity was measured by valence intensity and by arousal. It was true for both positive and negative pictures.

3.0 STUDY II: AN FMRI STUDY OF FACES AND FACES AUGMENTED BY CONTEXT

Study I supported our hypothesis that subjective emotional reactions to emotional pictures containing both faces and contextual information are greater than those to emotional facial expressions alone. This could suggest that faces augmented by context provoke different patterns of brain activity compared to pictures of faces alone. We therefore conducted an fMRI study to explore brain activity underlying emotional processing provoked by emotional faces and faces augmented contextual information.

3.1 MATERIALS AND METHODS

3.1.1 Subjects

Eleven healthy, right-handed subjects (3 male, 7 Caucasian, ages 22-51, $M(SD)_{age}$=34.82 (11.45), $M(SD)_{education}$=15.82(1.33)) participated in this study. Participants had no current or historical axis 1 psychiatric disorder as assessed by the Structured Clinical Interview for DSM-IV diagnosis (SCID, First et al., 1996), or self-reported neurological disorders. All subjects signed a written consent form approved by University of Pittsburgh Human Subjects Institutional Review Board.

3.1.2 Emotional stimuli

Fifteen positive and fifteen negative emotional pictures from the ‘FACE+CONTEXT’ group from study 1 were selected based on uniformly high or low normative valence ratings, $M(SD)_{positive}=7.22(0.48)$ and $M(SD)_{negative}=2.82(0.60)$; $F(1,28)=489.92$, $p<0.0001$, $\eta^2=0.95$. Corresponding emotional face stimuli were created from each picture (15 positive and 15 negative) by cutting just the face out of these whole pictures and enlarging them to a size comparable to the original picture. The face was placed in a gray background to be consistent with most other neuroimaging studies of facial expressions, which have used face stimuli with a gray or opaque background. All stimuli were converted to grayscale and were balanced for mean luminance and size so as to equate psychophysical characteristics across conditions.

3.1.3 Experimental paradigm

A slow event-related design was employed to prevent amygdala habituation effects associated with fast presentation of affective stimuli. That is, amygdala habituation has been observed primarily with quick repeated presentation of emotional stimuli (3 -.3Hz) in both control populations (Breiter et al., 1996; Fischer et al., 2003; Wright et al., 2001) and depressed samples (Gotlib et al., 2001; Thomas et al., 2001). Consistent with amygdala’s hypothesized role in rapid recruitment of stress-system responses, our work employing slow-event related designs has not found such habituation effects (Siegle et al., 2002; Siegle et al., submitted).

During each task run, subjects were presented with randomly ordered emotional faces augmented by context or emotional faces for 6 seconds and followed by a fixation cross for 6 seconds via E-Prime™ (Figure 2). Subjects were instructed to press a button as soon as possible when the stimuli appeared. There were no instructions related to implicit or explicit emotional tasks to prevent emotion-regulation effects associated with accomplishing a cognitive task (e.g., Lange et al., 2003). Responses were recorded on a Psychology Software Tools™ glove with millisecond resolution.

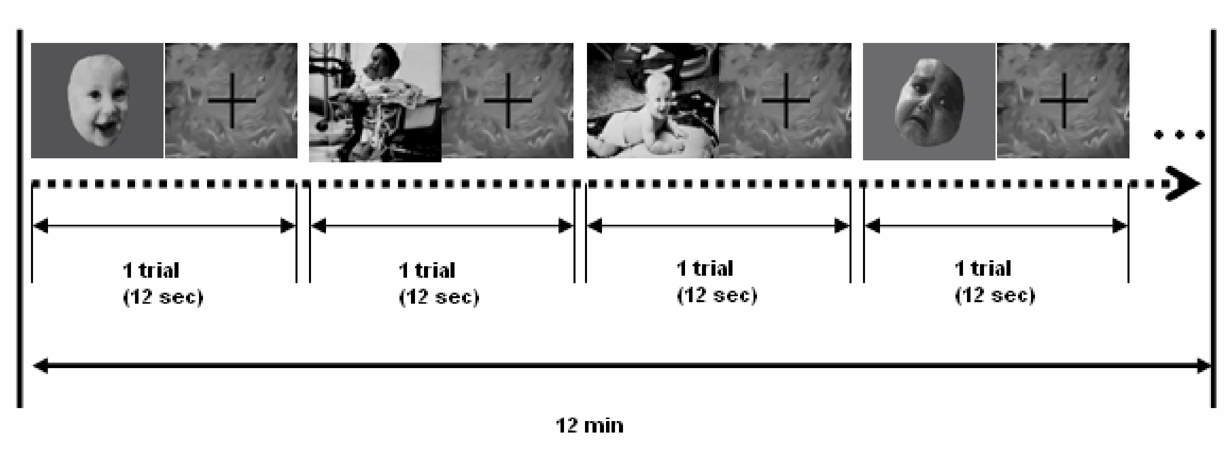

Figure 2. Experimental paradigm

Emotional stimuli were presented for 6 sec followed by a fixation for 6 sec. 60 emotional stimuli were presented with a random order. Subjects were instructed to view pictures passively and press a button as soon as possible when the emotional stimuli appeared.

After the scan, subjects were asked to evaluate their subjective emotional responses to each emotional stimulus using Self Assessment Manikin (SAM) including valence and arousal dimensions and were asked to answer two open-ended questions including "which type of picture is more powerful in inducing your emotional state or feeling?" and "why?" to better understand subjective responses.

3.1.4 Image acquisition

Images were acquired on a 3T GE Signa scanner (General Electric, Milwaukee, WI). Thirty 3.2 mm slices were acquired parallel to the AC-PC line with a reverse spiral pulse sequence (T2*-weighted imaged depicting BOLD signal; TR=1500ms, TE=26ms, FOV=20cm, flip angle=60). Each image was acquired in 1.5 sec, allowing 8 scans per trial. Thirty-four continuous, T1-weighted, 3.2 mm slices parallel to the AC-PC line were collected as structural images.

3.1.5 Data analysis

3.1.5.1 Behavioral data preprocessing

Reaction-time outliers greater than Md+/-1.5*IQR were Windsorized (i.e., replaced with Md+/-1.5*IQR). Trials with reaction times <250ms were eliminated from behavioral analyses. Harmonic means of reaction times were calculated within subjects for each condition to reduce the effects of residual outliers (Ratcliff, 1993).

3.1.5.2 fMRI data preprocessing

fMRI analyses were conducted using locally developed Neuroimaging Software (NIS) (Fissell et al., 2003) and AFNI (Cox, 1996) Functional images were reconstructed from K-space with NIS. Motion artifacts were corrected via a 6-parameter linear transformation using Automated Image Registration (AIR; Woods et al., 1993). Any trials that contained a scan with greater than 5mm movement (5° rotation) from the first image or 1mm movement (1° rotation) from the previous scan were excluded from statistical analysis. Linear trends over runs were removed to eliminate effects of scanner drift, outliers >Md+/-2.2IQR were Windzorized (i.e., rescaled to Md+/-2.2IQR), and fMRI data were temporally smoothed (five-point middle-peaked filter) to obtain time courses representing plausible smooth hemodynamic responses rather than transient noise. Images were cross-registered to a reference brain from the study using the 12-parameter linear AIR algorithm and spatially smoothed (6 mm full width half maximum three-dimensional Gaussian kernel).

3.1.5.3 Exploratory analysis

Spatial F-maps to test for a context effect (‘FACE+CONTEXT’ vs. ‘FACE’) were generated using a random effects whole-brain voxelwise ANOVA model with subject as a random factor and scan and context as fixed factors. Regions were identified by thresholding spatial F-maps at a significance level of $p<.005$ with the requirement of 36 contiguous voxels (empirically determined via AFNI’s Alphasim procedure based on the spatial autocorrelation present in the data), to control for type I error. All activation regions are presented in Talairach coordinates (Talairach & Tournoux, 1988). Voxel coordinates refer to the centroids of clusters.

Hemodynamic responses were displayed as the average percent change from the beginning of each trial, over all voxels in the brain regions identified in the group analysis. To further control for temporal autocorrelation between scans, brain regions identified in the whole-brain voxelwise ANOVAs were restricted to those significant at $p<.005$ in mixed-effects analysis of percent change with scan and condition (‘FACE+CONTEXT’ vs. ‘FACE’) as repeated measures and subject as a random factor using a 1-level autoregressive (AR 1) covariance structure using restricted maximum likelihood estimation (REML).

Furthermore, we examined whether a context effect modulated emotional intensity (HIGH INTENSITY vs. LOW INTENSITY) and valence (POSITIVE vs. NEGATIVE) effects.

A random effects whole-brain voxelwise ANOVA with subject as a random factor and context, emotional intensity (low: normative intensity 1.10 - 2.18 and high: normative intensity 2.22 - 3.17), and scan as fixed factors, and a random effect whole-brain voxelwise ANOVA with subject as a random factor and context, valence (positive: normative ratings 6.40 - 8.17 and negative: normative ratings 2.22 - 3.17), and scan as fixed factors were used to identify brain regions with context x intensity x scan interactions and regions with context x valence x scan interactions, respectively. Regions identified by context x intensity x scan interactions and context x valence x scan interactions were restricted via empirically derived contiguity thresholding (23 voxels, corrected $p<.005$, and 24 voxels, corrected $p<.005$, respectively).

3.1.5.4 Region of Interest (ROI)-based analysis

Anatomical ROI-based analysis was performed on several brain regions associated with emotional face-processing in previous studies including the amygdala, thalamus, and hippocampus. The amygdala was hand-traced on the reference brain's structural MRI using guidelines established in our pervious studies (Siegle et al., 2002), in which adequate intra-and inter-rater reliability was obtained. Boundaries included: posterior (the alveus of the hippocampus), anterior (2mm from the temporal horn of the lateral ventricle), superior (ventral horn of the sub-arachnoid space (SS)), inferior (most dorsal finger to the white matter tract under the horn of the SS), lateral (2mm from the surrounding white matter), and mesial (2mm from the SS). An automated process was used to extract the thalamus and hippocampus regions from AFNI's Talairach atlas, following AFNI's procedure for Talairach-transforming each brain. These regions were then registered to the space of the functional data.

Mean fMRI signal within each anatomical region of interest at each scan was calculated. Hemodynamic responses within each region were analyzed using scan x condition mixed-effects analyses to test for scan main effects and scan x condition interaction effects respectively. Scan and condition were set as repeated measures with a l-level autoregressive (AR 1) covariance structure using restricted maximum likelihood estimation (REML).

3.2 RESULTS

3.2.1 Subjective ratings

A two-way ANOVA was conducted on emotion-intensity and arousal ratings with the repeated measures factors Context ('FACE+CONTEXT' and 'FACE') and Valence ('POSITIVE' and 'NEGATIVE'). For emotion-intensity, the main effect of Context was significant ($F(1,10)=21.27$, $p<.001$; $\eta^2=.68$), indicating that emotional faces with contextual information are either more positive or negative than faces alone. The main effect of Valence ($F(1,10)= 3.68$, $p=.08$) and the Context x Valence interaction ($F(1,10)=0.33$, $p=.58$) were not significant. For arousal ratings, the analogous ANOVA revealed a significant Context x Valence interaction effect, $F(1,10)=11.92$, $p=.006$; $\eta^2=.54$. Emotional faces augmented by contextual information were rated as more arousing than faces alone only in the negative condition ($F(1, 10)=30.96$, $p<.001$; $\eta^2=.76$). These results indicated that, as in Study I, faces with contextual information evoked greater subjective emotional reactions than faces alone (Table 1).

Seven out of nine subjects who answered open-ended debriefing questions (two no-responders) also reported the faces with contextual information were more powerful in inducing an emotional state or feeling. They described reasons, i.e., "you get more detailed information as to why the person is making the facial expression" or "you have an idea as to what is causing the emotion and therefore can better relate/have a reaction to their emotion". These results suggest that faces augmented by contextual information are more emotionally evocative stimuli because contextual information triggers a cognitive appraisal, interpretation and evaluation of events.

3.2.2 Behavioral results

Reaction times were analyzed using a 2 (Context) x 2 (Valence) repeated-measures analysis of variance (ANOVA), which revealed significant main effect of Context, $F(1,10)=6.21$, $p=.03$; $\eta^2=.38$. The main effect of Valence and the interaction were not significant ($p=.25$ and $p=.90$, respectively). These results showed that it took longer to respond to faces with contextual information compared to faces alone (Table 1).

Table 1. Mean (SD) of subjective ratings and reaction time

	"FACE + CONTEXT'		'FACE'	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
Subjective ratings				
Valence intensity	3.23 (0.82)	2.95 (0.56)	2.49 (1.33)	2.08 (0.75)
Arousal	4.84 (2.06)	7.06 (1.14)	4.70 (1.83)	6.11 (0.80)
Reaction Time (ms)	511.24 (165.93)	518.88 (190.98)	470.45 (162.95)	480.26 (162.93)

3.2.3 Imaging results: Brain activity associated with context effect

3.2.3.1 Exploratory analyses

A Context x Scan random effects ANOVA indicates significant Context x Scan interaction effects in the brain regions associated with emotion processing. Table 2 and Figure 3 display all of the significant ROIs identified in this analysis. These regions reflect significant differences in the peak responses (scan 5) to both types of emotional stimuli and are all significant at $p<.005$ on mixed effects follow-up tests. Emotional faces augmented by contextual information showed a widespread pattern of brain activity in prefrontal regions associated with emotional processing whereas faces alone engaged a more restricted pattern of neural activity in the limbic/paralimbic regions associated with emotional processing.

Of particular interest, BOLD responses in prefrontal regions including the inferior/middle frontal cortex (BA10/47) and medial prefrontal cortex (BA10/11), were larger and more sustained in response to emotional faces augmented with context than to faces alone (Figure 4). In contrast, hemodynamic responses in paralimbic regions including the posterior cingulate gyrus (BA23/29) and insula (BA13) showed a reverse pattern of higher and more sustained responses to faces compared to faces augmented with context (Figure 5).

Table 2. Regions with significant interactions of Context and Time ($p<.005$)

Regions	BA	Side	x y z (voxels: maximum F)
'FACE+CONTEXT'> 'FACE'			
Medial prefrontal gyrus	10	R	19 49 -5 (161: 5.65)
	11	R	9 37 -15 (601: 7.79)
		L	-1 42 -17 (32: 4.93)
Superior frontal gyrus	10	R	21 49 -4 (53: 3.97)
		L	-26 57 -5 (345:5.46), -26 49 14 (18: 4.37)

	11	R	21 43 -17 (81: 4.15), 18 51 -12 (13: 3.93)
		L	-18 49 -18 (88: 5.43), -27 54 -17 (52: 6.14)
Middle frontal gyrus	10	L	-33 46 -3 (1803: 12.44)
	11	R	24 38 -13 (441: 6.3), 30 33 -12 (15: 3.66)
		L	-27 32 -15 (45: 4.76), -34 33 -13 (40, 5.65)
Inferior frontal gyrus	11	R	14 35 -20 (86: 6.84), 23 36 -20 (17: 4.81)
			25 35 -9 (15: 3.92)
	47	R	35 30 -6 (78: 5.38)
		L	-32 29 -12 (1510: 9.48)
	–	L	-36 37 1 (328: 12.21)
Orbital frontal gyrus	11	R	11 34 -27 (100: 5.71); 5 41 -21 (63: 4.79)
Anterior cingulate	11	R	5 40 -10 (14:4.07)
Rectal gyrus	11	R	9 34 -23 (432: 8.49)
Middle occipital gyrus	18	R	37 -84 -8 (3459:13.07)
		L	-23 -90 -7 (505: 7.16), -29 -80 -6 (14: 3.89)
Inferior occipital gyrus	18	R	37 -84 –8 (3268: 8.75)
		L	-16 -90 -9 (86: 4.62)
Fusiform gyrus	18	L	-22 -89 -15 (465: 6.94)
	19	R	37 -76 -13 (1355: 12.96)
	37	L	-51 -49 -17 (183: 4.88)
	–	L	-29 -78 -12 (40:3.9)
Lingual gyrus	17	L	-16 -91 -7 (2275: 10.54)
	18	L	26 -81 -4 (1054: 9.05)
Middle Temporal gyrus	20	L	-50 -49 -10 (19: 3.71)
	37	L	-52 -61 0 (46: 4.36)
	–	L	-57 -53 6 (21: 3.65)
Inferior Temporal gyrus	20	L	-51 -50 -13 (86: 4.1)
	37	R	49 -69 -1 (452: 11.26)
		L	-52 -67 -2 (165: 5.34)
Cuneus	17	R	22 -79 9 (212: 5.14), 23 -91 0 (47: 4.59)
	17	L	-17 -94 2 (617: 8.86)
	–	R	11 -91 9 (255: 4.6)
Parahippocampal gyrus	35	R	18 -30 -6 (26: 4.27)
Dentate	–	R	19 -55 -24 (655: 6.3)
Thalamus	–	R	17 -27 -1 (49: 4.46)
Inferior Semi-LunarLobule	–	R	33 -72 -37 (960:5.54)
		L	-35 -73 -37 (1952: 10.14)
Cerebellar Tonsil	–	R	31 -56 -34 (2886: 8.04)
		L	-45 -60 -33 (721: 7.26), -49 -64 -40 (11: 4.11)
Uvula	–	R	31 -71 -25 (824: 10.66), 19 -67 -32 (14: 3.95)
		L	-23 -84 -25 (751: 6.49), -35 -67 -25 (98: 4.8)
Pyramis	–	R	31 -72 -32 (1908: 7.29)
		L	-34 -75 -33 (2242: 9.85)
Tuber	–	R	41 -74 -27 (3989: 10.39)
		L	-41 -69 -28 (3783: 8.98)

Declive	–	R	36 -74 -20 (3630: 12.01)
		L	-24 -85 -21 (453:5.94), -53 -59 -21 (261:7.76), -37 -68 -22 (31: 4.12)
Culmen	–	R	25 -47 -23 (1530: 8.03)
	–	L	-45 -49 -26 (105: 3.92)

‘FACE’ > ‘FACE+CONTEXT’

Posterior cingulate gyrus	23	R	4 -42 20 (143: 4.98), 5 -31 23 (119:7.31)
	29	L	-2 -35 22 (307: 7.5)
Cingulate gyrus	24	L	-17 -9 39 (130: 5.05)
	31	R	3 -26 34 (3892: 8.44)
		L	-12 -9 46 (21:4.74)
Insula	13	R	37 -25 17 (222:5.49)
		L	-36 10 -3 (225: 4.88)
Hippocampus	–	R	31 -14 -17 (73: 4.43), 34 -26 -8 (26: 4.34)
Parahippocampal gyrus	36	R	33 -45 -7 (30: 4.13)
	37	R	36 -25 -12 (10: 3.78)
	–	R	32 -15 -17 (236: 4.84)
Caudate	–	R	36 -26 -5 (48: 4.91), 36 -15 -9 (24: 5.14)
Putamen	–	L	-25 7 5 (83: 6.57), -27 -6 13 (11: 3.6)
Claustrum	–	L	-31 9 -1 (48: 4.46), -30 -4 10 (22:4.12), -28 7 10 (15: 4.92), -28 -4 15 (12:4.13)
Thalamus	–	R	22 -22 6 (18: 3.95)
Medial Frontal Gyrus	6	R	2 -19 55 (556: 5.45), 16 -17 55 (10:4.32)
		L	-11 -8 53 (414: 5.38)
Middle Frontal Gyrus	6	L	-15 -9 58 (19: 3.8)
Inferior Frontal Gyrus	13	L	-33 7 –13 (68: 4.99)
Superior Parietal Lobule	7	L	-18 -43 58 (30: 5.17)
Paracentral lobule	5	R	7 -38 58 (106: 4.24)
	5	L	-9 -38 55 (896:10.69)
	31	–	0 -26 46 (1189: 6.07)
Precentral Gyrus	4	R	25 -22 54 (69: 4.36)
Postcentral Gyrus	3	R	23 -31 54 (34: 4.05)
		R	16 -37 58 (13: 3.79)
Supramarginal Gyrus	40	R	55 -52 29 (1043: 6.92)
Superior Temporal Gyrus	38	R	39 -38 6 (42: 4.23)
	39	L	-35 5 -13 (50: 4.28)
	41	R	52 -57 23 (941: 7.69), 38 -30 16 (24: 4.12)
Middle Temporal Gyrus	39	R	50 -67 22 (1257: 7.54), 39 -41 6 (10:3.65)
	–	R	38 -54 22 (101:6.68)
Middle Occipital gyrus	19	R	40 -83 20 (11: 4.13)
Fusiform gyrus	37	R	35 -43 -11 (32: 3.71)
Angular gyrus	40	R	55 -57 34 (26: 5.08), 55 -63 30 (22, 3.88)
Precuneus	7	L	-12 -45 54 (440: 8.70), -1 -34 44 (268: 7.16)

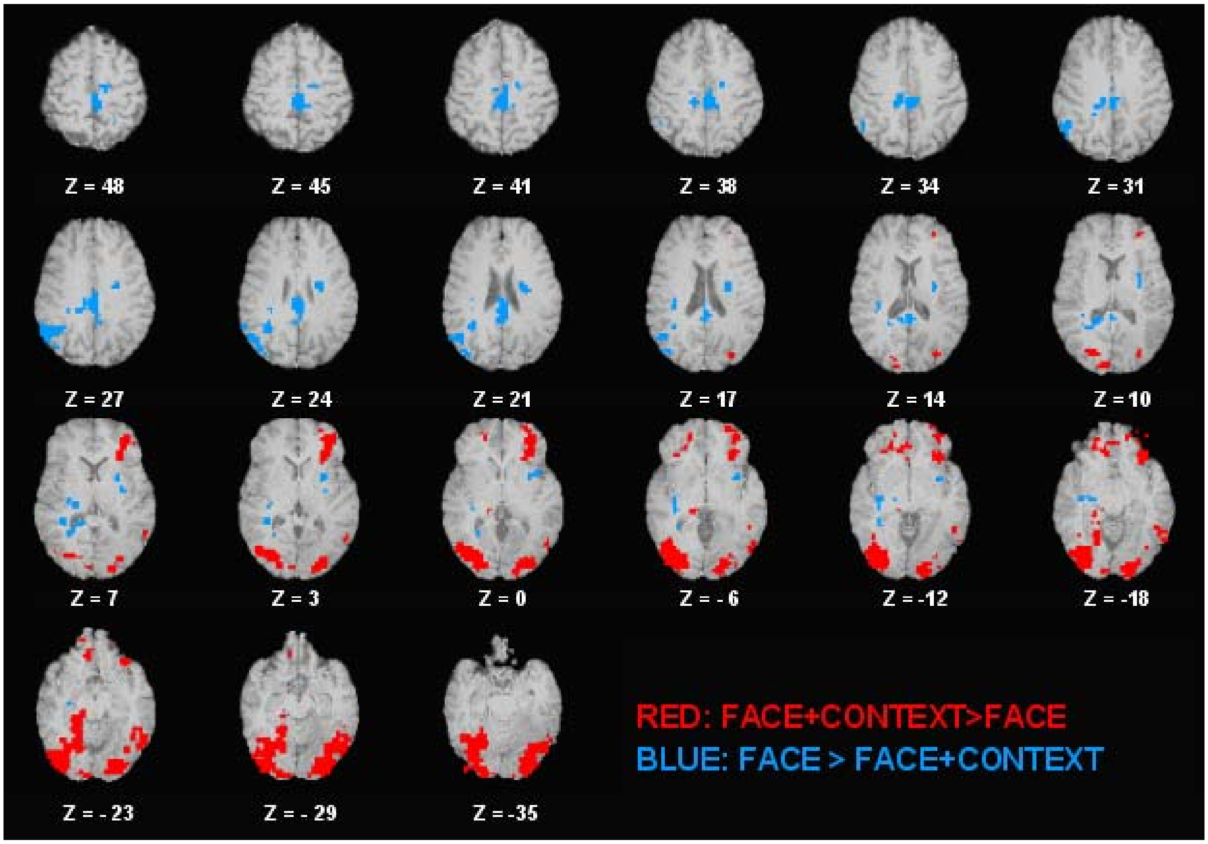

Figure 3. Brain regions derived from random effects whole-brain voxelwise ANOVA with subject as a random factor and scan and context as fixed factors.

These regions indicate interaction effect between context and scan (context effect over time). Color represents magnitude of the condition difference in response to emotional stimuli.

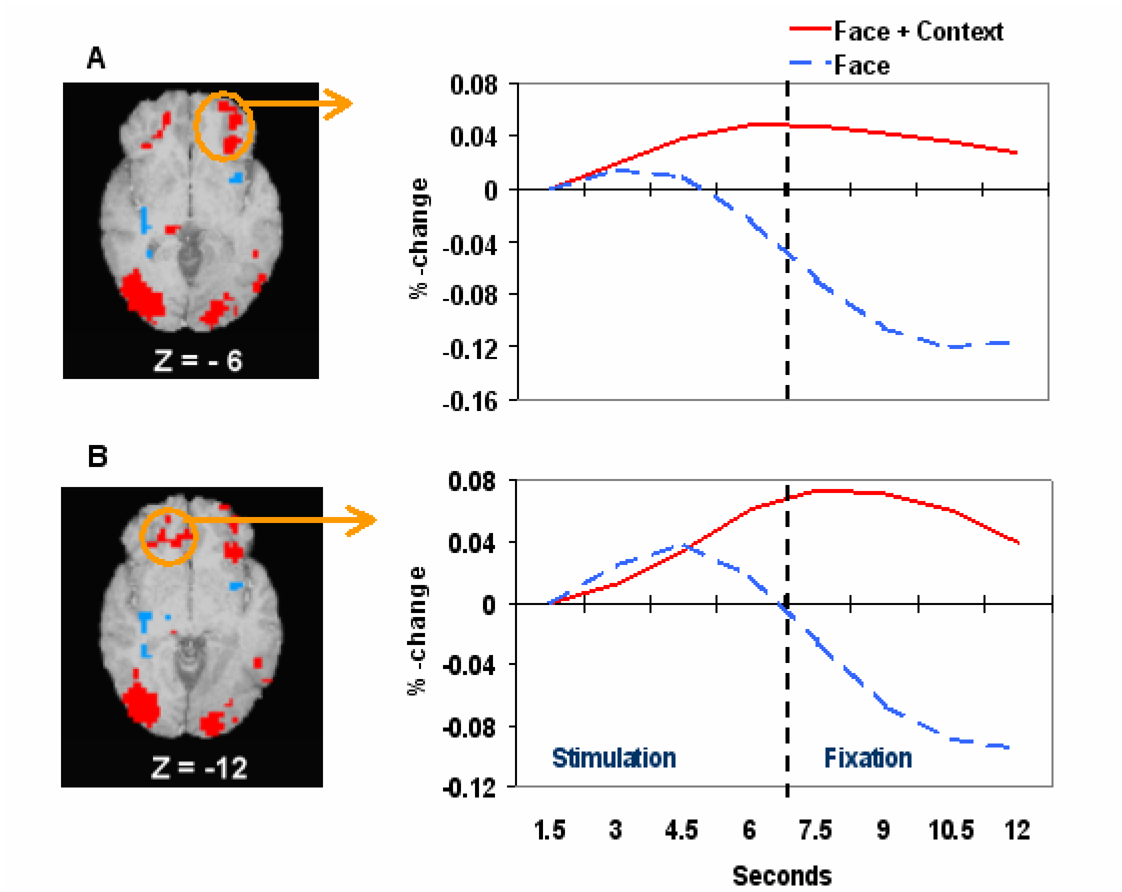

Figure 4. Time course across scans in empirically derived inferior/middle frontal cortex (BA10/47) ROI (A) and medial prefrontal cortex (BA10/11) ROI (B).

BOLD signal in the 'FACE+CONTEXT' condition increased with presentation of emotional stimuli and was sustained during the fixation. However, BOLD signal in the 'FACE' condition did not increase with emotional stimuli.

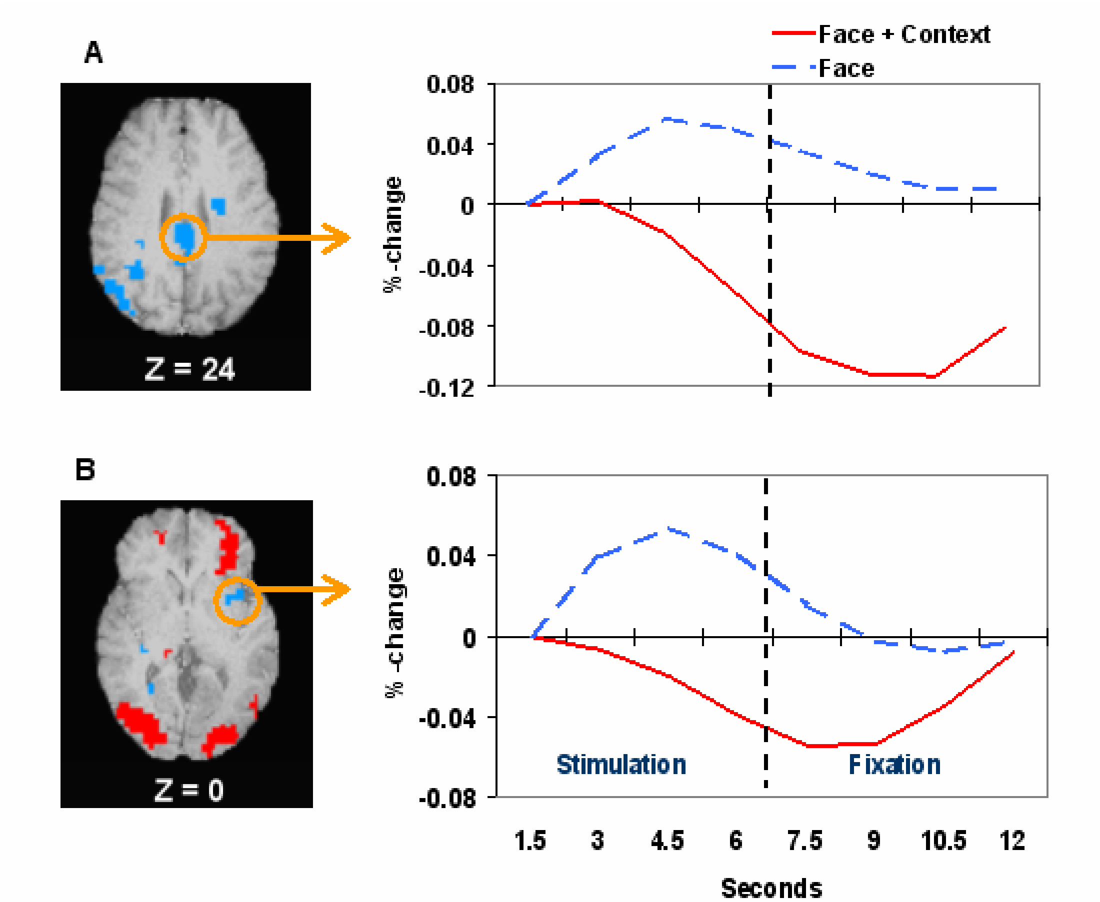

Figure 5. Time course across scans in empirically derived posterior cingulate gyrus (BA23/29) (A) and insula (BA13) (B).

BOLD signal in the 'FACE' condition increased with presentation of emotional stimuli and decreased without emotional stimuli in the posterior cingulate gyrus, but was sustained in the insula. However, BOLD signal in the 'FACE+CONTEXT' did not increase during the presentation of emotional stimuli.

3.2.3.2 ROI-based analyses

Mixed-effects analysis in the extracted anatomical ROIs revealed a significant Context x Scan interaction effect in the right hippocampus ($F(7, 142.340)=2.267$, $p=.032$; $\eta^2=.10$). The BOLD response to emotional faces alone was greater than to faces augmented by context, indicating a similar pattern to BOLD response to the posterior cingulate gyrus and insula. There were no significant Context x Scan interaction effects in other *a priori* extracted regions including the amygdala and thalamus.

However, Scan main effects were significant in the bilateral amygdala (right: $F(7, 136.317)=3.892$, $p<.005$; $\eta^2=.17$), left: $F(7,133.750)=3.283$, $p<.005$; $\eta^2=.15$) and the thalamus ($F(7,136.868)=8.892$, $p<.001$; $\eta^2=.31$), indicating that there were significant BOLD responses to both types of emotional stimuli in the amygdala and thalamus. Figure 6 shows neural responses to emotional stimuli in the bilateral amygdala. These findings suggest that the amygdala and thalamus similarly contribute to processing emotional information conveyed by emotional faces augmented by contextual information and faces alone.

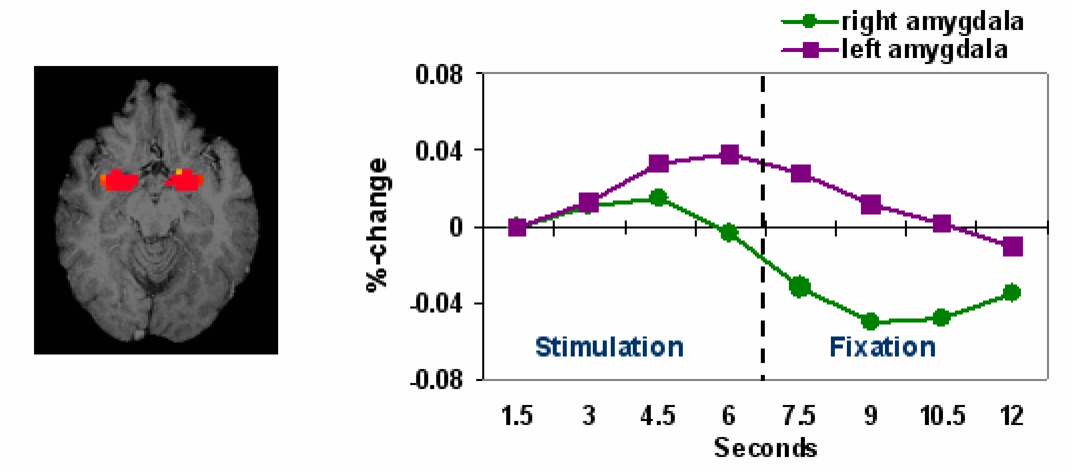

Figure 6. Time course across scans in the amygdala derived from ROI-based analysis. BOLD signal in the amygdala was not significant in Context x Scan interaction, but was significant in Scan main effect. The amygdala showed enhanced brain activity to the emotional stimuli relative to fixation, regardless of the types of emotional stimuli.

3.2.4 Imaging results: Interaction of context and emotionality

The results of the Context x Scan analysis revealed that there were different brain networks engaged by emotional faces and faces augmented with contextual information. This context effect may be associated with emotional factors including emotional intensity and emotional valence. Emotional factors may modulate patterns of brain activity provoked by the context effect. A random effect ANOVA with context, intensity, and scan as factors and context, valence, and scan as factors were conducted to test interaction effects between context effect and emotionality.

3.2.4.1 Interactions of context and emotional intensity

A random effects ANOVA revealed significant context x intensity x scan effects in several prefrontal regions including the inferior, middle, and medial PFC, anterior cingulate cortex (ACC), parahippocampal region, and other cortical regions (Figure 7). These regions have frequently been reported in previous emotion studies, indicating that they were involved in emotional processing. In particular, hemodynamic responses in the right inferior PFC (BA45/47) and the medial PFC (BA10) were the highest and most sustained over time in emotional faces with contextual information with high emotional intensity compared to other three conditions (Figure 8). However, as shown in Figure 7, there were just a few areas such as a small part of PFC and occipital cortex in which the observed context effect qualified the three-way interaction.

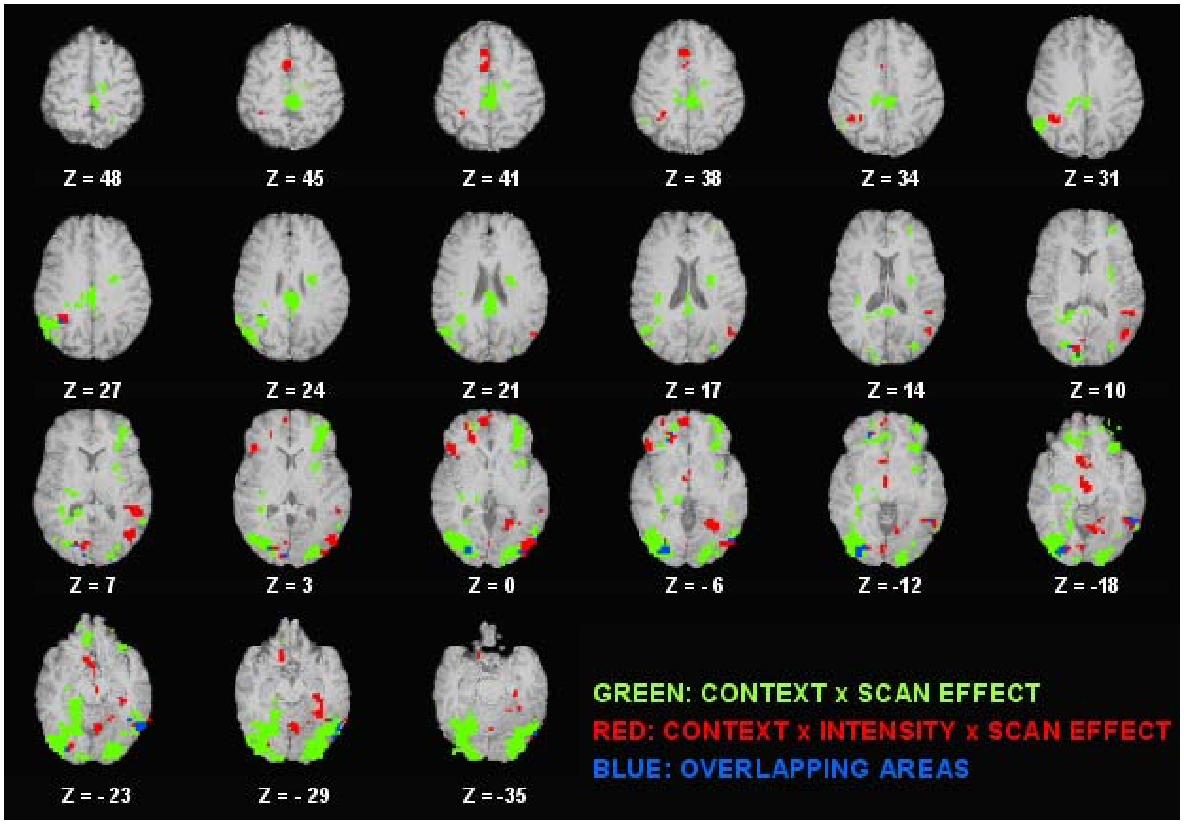

Figure 7. Brain regions derived from random effects whole-brain voxelwise ANOVA with subject as a random factor and context, intensity, and scan as fixed factors.

These regions indicate a three-way interaction of context, intensity, and scan. There were just a few overlapping areas, indicating that the context effect did not always interact with the emotional intensity effect, but that context did interact with the effect of emotional intensity in multiple areas associated with emotional reactivity and regulation.

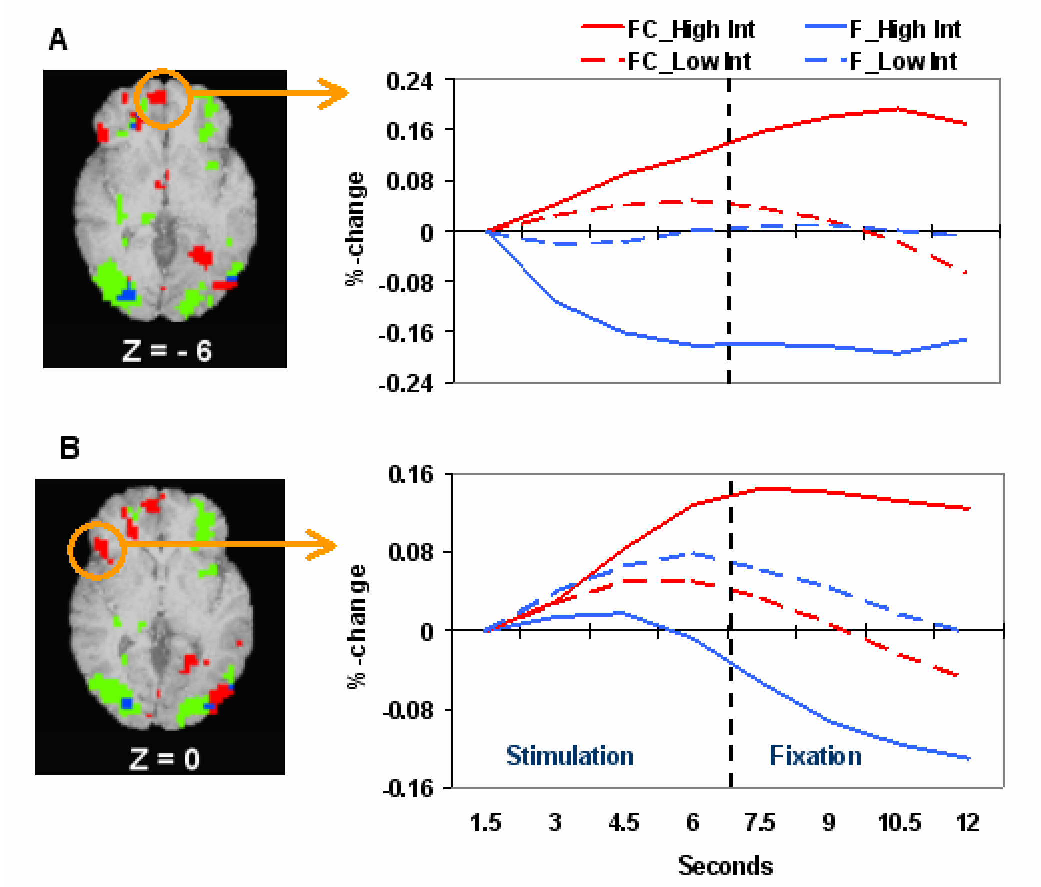

Figure 8. Time course across scans in empirically derived inferior PFC (BA45/47) ROI (A) and medial PFC (BA10) ROI (B).

BOLD signal in the 'FACE+CONTEXT' with high emotional intensity condition increased with presentation of emotional stimuli and was sustained during the fixation in several frontal regions (FC: Face+Context, F: only Face, Int: Intensity).

3.2.4.2 Interactions of context and emotional valence

The test of the three-way interaction of context, intensity, and scan also revealed several brain areas associated with emotional processing such as PFC, ACC, amygdala, hippocampus, and parahippocampal gyrus (Figure 9). In particular, the amygdala showed a significant context x valence x scan interaction. Activity in the left amygdala increased significantly to negative facial expressions compared to negative faces with contextual information during presentation of stimuli and was significantly sustained in positive facial expressions relative to positive faces presented with contextual information (Figure 10). There were just a few areas such as a small part of PFC, occipital cortex, and cerebellum in which the observed context effect qualified the three-way interaction.

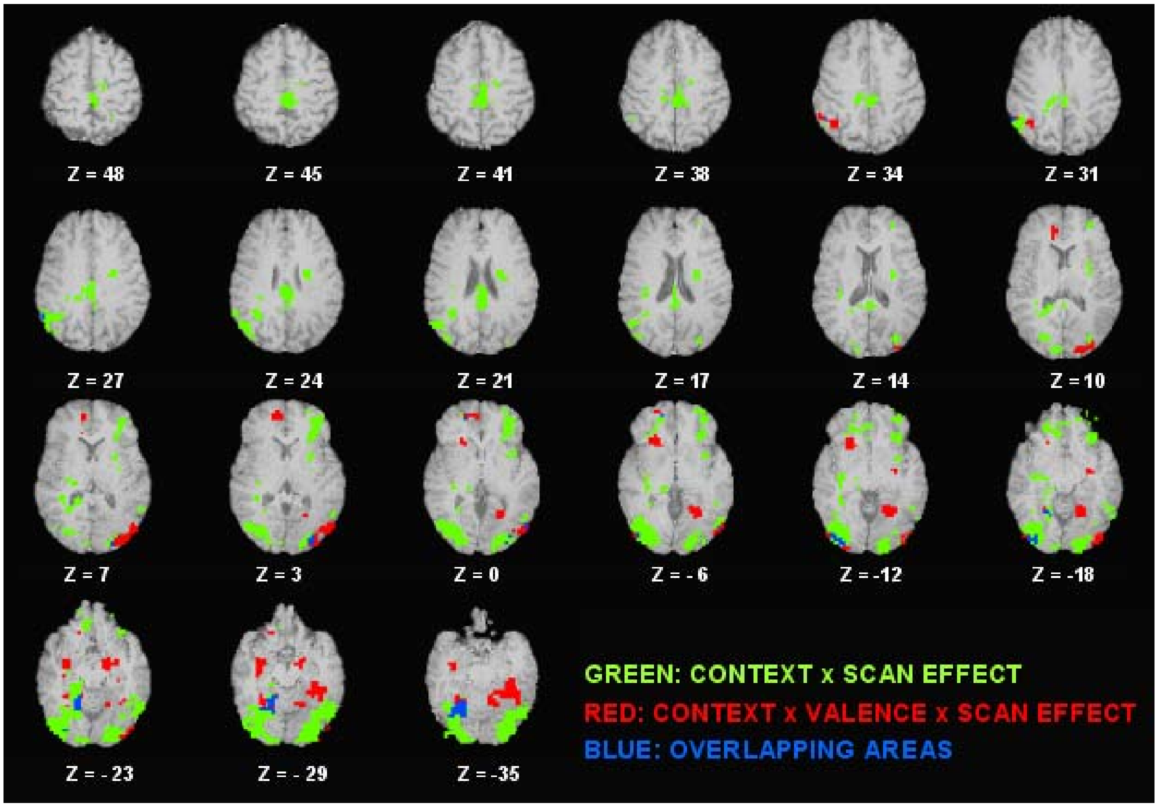

Figure 9. Brain regions derived from random effects whole-brain voxelwise ANOVA with subject as a random factor and context, valence, and scan as fixed factors.

These regions indicate three-way interaction of context, valence, and scan. There were just a few overlapping areas, indicating that the context effect did not always interact with the valence effect, but that context did interact with the effect of valence in several areas associated with emotional reactivity and regulation.

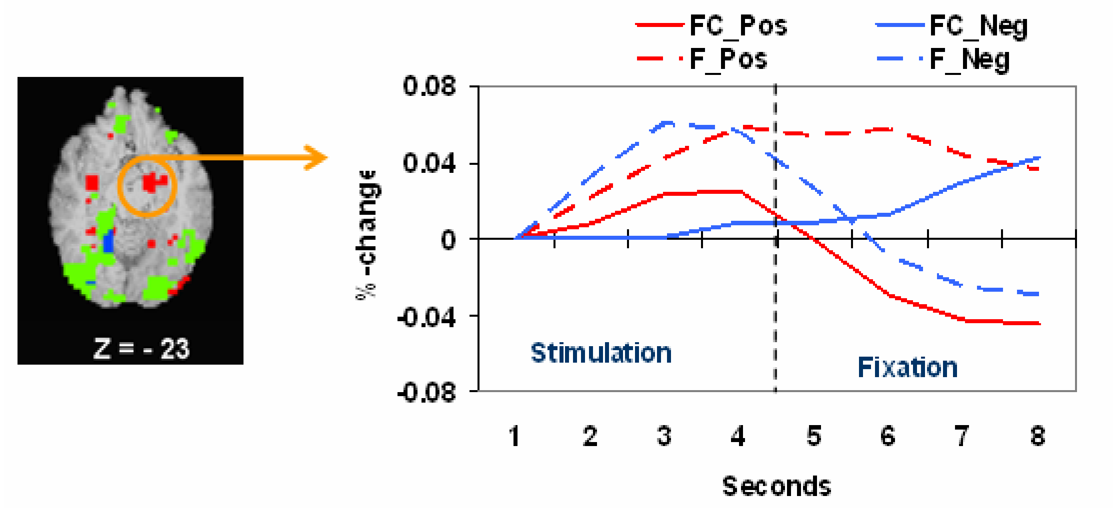

Figure 10. Time course across scans in empirically derived amygdala.

BOLD signal increased with presentation of positive face stimuli and was sustained during the fixation, but more rapidly enhanced with presentation of negative face stimuli and returned to baseline during the fixation (FC: Face+Context, F: only Face, Pos: Positive, Neg: Negative).

3.3 SUMMARY

These data suggested that as in Study I, emotional faces augmented by context were rated as more emotional than faces alone. Responses to faces augmented by context were delayed compared to faces alone. Similar subcortical regions were engaged to both types of stimuli, though both positive and negative faces provoked more amygdala activity than faces with contextual information. More generally, faces augmented by context provoked activity in a broader cortical network involved in emotional information processing, and context effect interacted with emotional intensity and valence effect in the patterns of brain activity in the several PFC regions and the amygdala.

4.0 OVERALL DISCUSSION

We investigated whether faces augmented by contextual information led to more intense subjective emotional reactions than facial expressions presented alone by reviewing normative subjective ratings, and how these two classes of emotional stimuli were associated with neural networks underlying emotional processing using fMRI. Ratings from a large normative corpus and subjects who participated in the fMRI study showed that emotional faces augmented with contextual information provoked more intense subjective emotional reaction than faces alone. This finding is accordance with previous study that negative emotional scenes evoked more negative valence and higher arousal than negative facial expressions (Schafer, Schienle, & Vaitl, 2005). As suggested by Schafer, Schienle, & Vaitl, the contextually richer emotional pictures may require more attention, yielding increased emotional reactions.

Behavioral reactions measured during the scan to faces augmented with contextual information were delayed compared to faces alone. This result suggests that faces with contextual information or emotional content may require more time to process, potentially because they have additional information compared to faces alone. These data are consistent with the idea that different and overlapping neural pathways are associated with responding to emotional stimuli. Emotional faces may be processed via a fast path including thalamus and amygdala whereas faces with contextual information may be processed through a slow path including both cortical regions and amygdala.

Yet, Sato et al. (1999) demonstrated a different time course and different brain regions between non-emotional scene and face processing using MEG. Scene processing took a longer time than face processing. The source of neural responses to scenes was estimated to be in the right parahippocampal gyrus and parieto-occipital junction whereas that of responses to faces was observed in the fusiform gyrus. These results are consistent with our behavioral results that emotional faces augmented with context took a longer time to respond than faces and could suggest that behavioral differences in reaction time are not due to emotional processing per se, but rather to the engagement of different brain networks serving face and non-face processing.

Exploratory and ROI analyses of the current data revealed significant neural activity in brain regions associated with emotion processing including the amygdala, thalamus, hippocampus, hypothalamus, posterior cingulate gyrus, insula, visual cortex, and several prefrontal regions. These results are in agreement with previous neuroimaging studies of human emotion. Subcortical-limbic regions such as the amygdala and thalamus were activated by both classes of emotional stimuli in the same way. Other subcortical-limbic/paralimbic areas including the hippocampus, insula, and posterior cingulate gyrus (BA23/29) showed greater neural responses to emotional facial expression than faces augmented by contextual information. In contrast, the cortical areas including prefrontal regions and visual cortex were more activated by emotional faces with contextual information than by faces alone.

Neuroimaging studies of emotion demonstrate that the amygdala responds to a variety of emotional stimuli (Murphy et al., 2003; Phillips et al., 2003; Zald, 2003). They suggest that the amygdala may be involved in a wide range of emotional processing regardless of types of stimuli, emotion, or level of awareness and generally play an important role in the initial response to emotionally salient stimuli. The thalamus functions as a relay center, which receives sensory information and sends it to several brain regions. In the direct thalamo-amygdala pathway, the thalamus serves a fast transmission of emotional information to the amygdala (LeDoux, 1996). Lee et al. (2005) found that the thalamus was commonly activated by three types of emotional stimuli such as scenes, faces, and words and by two types of emotional state; happy and sad. As a result, the amygdala is sensitive to emotional salience information received from the thalamus and the thalamus may be associated with the subcortical integration of visceral responses and emotional reactions for further interaction with the cortical regions (Canli et al., 2002).

However, the three-way interaction of context, valence, and scan demonstrated that amygdala activity was modulated nonlinearly by context and valence across time. The amygdala responded to all four different conditions, which could explain the reasons why neuroimaging studies of emotion have often found a significant neural activity in the amygdala, regardless of emotional types of stimuli and emotional valence (Zald, 2003). Yet, the amygdala showed different temporal patterns of response to the different conditions, especially involving rapidly enhanced hemodynamic response to negative faces and sustained hemodynamic responses to positive faces compared to emotional faces with contextual information. The results indicated that amygdala reactivity to different conditions of emotional stimuli is complex and dynamic across time. Sustained amygdala activity has been demonstrated to negative word stimuli in depression (Siegle et al., 2002; Siegle et al, in press). This study suggested that sustained amygdala activity might be involved in sustained emotional processing in healthy individuals. Though no studies reported sustained amygdala activity across time in healthy individuals, our finding of sustained amygdala activity could suggest that positive faces is involved in sustained emotional processing.

Other limbic/paralimbic regions appear more uniquely associated with emotional processing provoked by emotional faces. Passively viewing emotional faces induced greater neural responses in the posterior cingulate gyrus and hippocampus compared to faces augmented by contextual information, in line with previous neuroimaging studies (e.g., Phillips et al., 1997, 1998; Whalen et al., 2001; Moriguchi et al., 2005). This finding is also consistent with previous studies which demonstrated more activation in the subcortical-limbic regions during the indirect emotional face processing such as implicit tasks (e.g., gender discrimination tasks) in which emotional faces were presented for enough time to process both the gender and the expression of faces compared to direct emotional face processing like explicit tasks (e.g., emotional evaluation) (Critchley et al., 2000; Keightley et al., 2003). It is suggested that neural responses to emotional faces occur prior to cognitive processing (e.g., appraisal) of these emotional stimuli.

We also found that the anterior insula, near the orbitofrontal cortex, and posterior insula, close to the temporal gyrus, appeared to activate more strongly to emotional faces. Several imaging studies have revealed that the anterior insula responded to emotional olfactory stimuli (Royet et al., 2003; Zald and Pardo, 2000), gustatory (Small et al., 2003), facial and expressions of disgust (Phillips et al., 1997,1998). The posterior part of insula is also responsible for a sensory representation regarding the physiological states of the body (Craig, 2002; Gallese et al., 2004), and activates in response to visual (Kosslyn et al., 1996) and somatosensory (Craig, et al., 2000; Singer et al., 2004) stimuli. Several neuroimaging studies have demonstrated posterior insula activity to facial expressions of fear (Phillips et al., 1997), disgust (Winston et al., 2003), and disgust accompanied by arousal (Williams et al., 2005) and self-generated anger (Damasio et al., 2000), implying that the posterior insula plays a role in emotional processing. Thus, its role in processing emotional faces in the current study is understandable.

Cortical areas including prefrontal regions and visual cortex showed greater neural responses to emotional faces augmented by contextual information than to faces alone. This finding was partially in accordance with other studies (Canli et al., 1998; Lane et al., 1999; Stark et al., 2003), in which passively viewing complex emotional scenes and pictures provoked large hemodynamic responses in the medial prefrontal regions and occipital cortex. As in previous studies, the current data reflected neural activation in the cortical areas as well as subcortical-limbic regions, though activation for contextually augmented faces was greater than that for faces alone remarkably in cortical regions. One reason why the subcortical-limbic regions such as the amygdala, thalamus, and hippocampus were not more activated by emotional faces with contextual information than by faces alone, even though they provoked intense subjective emotional reactions, may be related to cognitive appraisal processes triggered by contextual information. Results from the open-ended questions showed subjects at least thought about the relationship between emotional faces and contextual information, indicating that they tried to evaluate emotional faces based on contextual information in the background of emotional pictures.

Several studies using cognitive evaluation of emotional stimuli and cognitively provoked emotions have demonstrated enhanced neural activation in the prefrontal cortex, but decreased neural responses in the subcortical-limbic regions (Critchley et al., 2000; Hariri et al., 2000, 2003; Nakamura et al., 1999; Reiman et al., 1997; Teasdale et al., 1999). This finding suggests that prefrontal regions play an important role in modulating appropriate emotional responses by an inhibition mechanism via interconnections with subcortical-limbic regions. Similarly, more complex instruction sets appear to down-modulate subcortical activity in response to emotional stimuli (Lange et al., 2003).

The visual cortex was also activated more strongly by emotional faces augmented with contextual information than faces alone. The activation in the visual cortex could reflect emotional arousal (Lang et al., 1998), emotionality (Geday et al., 2003), and aversive intensity (Taylor et al., 2000). Thus, greater activation in the visual cortex may be associated with greater emotional intensity and higher arousal provoked by emotional faces with contextual information than those provoked by faces alone. Alternatively, the greater visual complexity of the faces augmented with context could be responsible for the increased activity in visual cortex regions.

This study had several limitations. Foremost, we did not use neutral control stimuli. Thus, the extent to which our fMRI results are specific to emotional information processing is unclear. It is also unclear that neutral stimuli would be appropriate control stimuli and baseline expressions. Freed et al. (2004) demonstrated that neutral faces evoked a greater neural response in the right amygdala compared to calm facial expressions, which are considered as alternative baseline expressions. Similarly, multidimensional scaling analysis showed that neutral faces were not located on the center of the emotional dimensions; valence and arousal (Shah & Lewis, 2003). Despite these problems, including neutral stimuli could help to understand context effects. Yet, our primary conclusions, supporting the different brain networks for processing faces and faces augmented by context, would not be expected to change upon inclusion of neutral stimuli. Importantly, the context effects were not qualified by interactions with valence.

Use of a passive viewing task prevented us from directly examining how specific cognitive processing influenced our findings. We have suggested that contextual information in the emotional pictures may trigger cognitive processing that induces more intense subjective emotional reactions and more distributed neural activation in brain regions. Further research with specific task demands or cognitive probes is needed to confirm this explanation. Importantly, our debriefing data suggested that subjects did experience cognitive interpretation and appraisal generated by contextual information.

Taken together, results from empirical analysis and ROI-based analysis suggest that there are different but overlapping brain networks engaged by emotional faces and faces augmented with contextual information. Brain networks revealed in this study were more similar to the two neural pathways underlying emotional processing initially proposed by LeDoux (1996, 2000), including a thalamo-amygdala pathway (fast, automatic processing system) and indirect cortical pathway (slow processing system). Since that time, several researchers have elaborated these two neural pathways based on neuroimaging studies. Teasdale et al. (1999) suggested a cortical network ("cognitive" route) is associated with processing of affect-related meanings in the induction of emotion using picture-caption pairs. Processing of emotion-related meanings involved in provoking brain activity in the cognitive route. In this framework the medial prefrontal cortex represents a particularly important part of the brain for processing emotional meaning. Lee et al. (2004) confirmed that limbic regions including the amygdala and anterior cingulate gyrus involved in automatic and unconscious emotional states whereas the mesial and dorsolateral prefrontal regions are more associated with cognitive and conscious emotional states.

In summary, our findings confirmed that neural networks underlying emotional information processing include both subcortical-limbic regions and the prefrontal cortex. The primary findings were that there are common brain regions including the amygdala and thalamus associated with emotional information processing regardless of types of emotional stimuli and unique brain regions, which are specialized for different types of emotional stimuli. Subcortical-limbic/paralimbic regions are responsible for emotional faces alone whereas prefrontal regions are specialized for faces with contextual information.

Finally, this study was initiated to react to the popular use of facial expressions in neuroimaging studies of emotional information processing, particularly involving restricted brain regions such as the amygdala, which has been associated with recognition of facial expressions. A variety of experimental designs varying emotion-evocative stimuli and task demands or simply comparing different conditions have been developed to examine prefrontal activity and interactions between subcortical-limbic and prefrontal regions. However, it is important to elucidate which factors contribute to neural substrates underlying emotional processing. Our data suggest that contextual information augmenting emotional faces could represent an important contributor to a widespread pattern of brain activity in both cortical and subcortical-limbic regions by provoking strong emotional subjective reactions and cognitive processing.

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