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Individual differences in emotion regulation and hemispheric metabolic asymmetry

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ABSTRACT

Recent studies of emotion regulation have reported that frequent use of reappraisal is associated with greater experience of positive emotions and increased sense of well-being, which, in turn, have been observed in individuals with greater left-sided prefrontal cortical activity. We hypothesized that frequent use of reappraisal would be correlated with greater left-sided biases of metabolic activity in prefrontal regions as well as in subcortical structures to which the former are interconnected. Twenty male volunteers were scanned at rest with ^{18}F-fluorodeoxyglucose positron emission tomography. Self-reported emotion regulation style and an emotional regulation task were administered outside the scanner. Results revealed that frequent reappraisers showed greater left-sided biases of metabolic activity in the dorsolateral prefrontal and caudate regions. Regulation successes in increasing emotions were associated with left-sided metabolic asymmetry in the anterior cingulate. Findings suggest that asymmetric metabolism in prefrontal and subcortical regions are associated with emotion regulation style and also with regulation success.

1. Introduction

Resting state hemispheric asymmetry of prefrontal activity has been shown to be associated with individual differences along various affective and cognitive dimensions (Sutton and Davidson, 2000; Tomarken et al., 1992). Recent electroencephalographic (EEG) investigations have suggested that the degree of left-sided bias in prefrontal activity may be a good indicator of an individual's ability to regulate emotions (Jackson et al., 2003; Kim and Bell, 2006) and psychological well-being (Urry et al., 2004). EEG studies have thus far provided the majority of evidence linking dispositional and situational affective constructs to resting frontal hemispheric asymmetries in brain activity. The limited spatial resolution of this method has restricted the focus to cortical structures (Davidson, 2004). Recently, rapid development of neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) has provided us with tools to extend the examination to subcortical structures involved in emotion regulation (e.g., Tomer et al., 2008).

Using these neuroimaging technologies, recently, there have been increased attempts to identify structural and functional neural correlates of dispositional traits of emotional regulation. Two distinct types of emotion regulation have received great attention, namely, cognitive reappraisal and expressive suppression (Gross and John, 2003). Reappraisal refers to changing the interpretation of emotion-generating events whereas suppression involves changing emotional expressive behaviors. Frequent use of reappraisal has been positively related to greater experience and expression of positive emotion and increased sense of well-being (Gross and John, 2003). Studies using fMRI or PET techniques have found that dispositional traits of reappraisal and suppression were associated with structural volume or resting-state blood flow in the anterior cingulate (Abler et al., 2007; Giuliani et al., 2011). Dispositional reappraisal scores were also associated with brain activity measured in the amygdala and prefrontal regions (Drabant et al., 2009), and insular (Carlson and Mujica-Parodi, 2010) while participants were engaged in emotional processing. Similarly, dispositional mindfulness, a trait measure of self-regulation (Lutz et al., 2008), predicted activity in the dorsomedial prefrontal region involved in emotional reappraisal (Modinos et al., 2010). These studies indicate that dispositional traits of emotion regulation may have

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distinct resting and activity-dependent neurobiological correlates. To our knowledge, however, no previous studies have examined relationships between prefrontal and subcortical asymmetry and individual differences in emotion regulation.

Based on previous research on hemispheric asymmetry and emotional experience, we hypothesized that individuals who use reappraisal strategies more frequently in everyday life would show greater left-sided biases in subcortical as well as lateral prefrontal metabolism. Because reappraisal was also associated with self-reported measures of regulation success (Gross and John, 2003), we also hypothesized that individuals who use reappraisal strategies more frequently would show greater success in a laboratory emotion regulation task.

To examine these hypotheses, we obtained ^{18}F-fluorodeoxyglucose (FDG) PET images and calculated both prefrontal and subcortical metabolic asymmetry. We assessed dispositional traits of emotion regulation using the Emotion Regulation Questionnaire (ERQ) (Gross and John, 2003). We also assessed individual differences in regulation success using a laboratory reappraisal task (Kim and Hamann, 2007; Ochsner et al., 2004). Regulation success was defined as reappraisal-induced changes in self-reports of emotional intensity elicited by colored photographs depicting emotional contents (Banks et al., 2007; Kober et al., 2010). Personality traits, such as neuroticism and extraversion, have been associated with both emotion regulation measures (John and Gross, 2004) and asymmetry in prefrontal activity (Deckersbach et al., 2006; Gale et al., 2001; Hagemann et al., 1999; Minnix and Kline, 2004); thus, we obtained and controlled for trait levels of neuroticism and extraversion in our statistical examination.

2. Methods

2.1. Participants

Twenty right-handed healthy men (mean age = 23.5, *SD* = 3.10) were recruited. All volunteers were college students and reported no history of psychiatric and neurological illnesses or current medical conditions. Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971). We limited this study to men because of reported sex differences in resting state glucose metabolism in the brain (Gur et al., 1995) and possible influences of hormones associated with the menstrual cycle on metabolic activity (Reiman et al., 1996). This study was performed in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Seoul National University. All volunteers gave written informed consent before participation.

2.2. PET image acquisition and analysis

A Phillips Allegro PET scanner (Phillips Medical System, Cleveland, OH) was used to acquire FDG PET images at rest. PET images for all participants were obtained in the afternoon between 5:00 and 6:30 pm after fasting for at least 6 h before scanning. FDG (4.8 MBq/kg) was injected intravenously in a quiet waiting room and the participants were instructed to rest and remain sitting quietly for a 40 min uptake period. The participants were then placed inside the PET scanner. Emission scans were obtained for 10 min with a PET camera with an in-plane and axial resolution of 4.2 mm full width at half-maximum intensity (FWHM) and 90 contiguous slices with 2 mm separation. Attenuation-corrected PET images were reconstructed with the 3D row action maximum-likelihood algorithm (RAMLA) on a 128 × 128 × 90 (2.0 mm × 2.0 mm × 2.0 mm pixels) matrix. Preprocessing and statistical analysis were performed using SPM2 (Wellcome Department of Cognitive Neurology, London). PET images were normalized to the standard coordinate system developed and distributed by the Montreal Neurologic Institute (MNI) implemented in SPM2. All images were smoothed with a 12 mm FWHM 3D Gaussian filter. At each voxel the PET data were normalized by the global mean and fit to a linear statistical model by the method of least squares. To calculate hemispheric metabolic asymmetry, a total of eight lateral prefrontal and subcortical regions that have been implicated in emotion processing were selected as region of interests (ROIs): the superior frontal gyrus, middle frontal gyrus, inferior frontal gyrus, anterior cingulate, amygdala, caudate, putamen and insula. Metabolic means of selected ROIs were automatically extracted bilaterally from normalized images using the SPM toolbox, WFU PickAtlas (Wake Forest University, Winston-Salem, NC) and the Automated Anatomical Labeling (AAL) templates (Tzourio-Mazoyer et al., 2002). Resting glucose metabolism was extracted from each pair of bilateral ROIs and an asymmetry score was computed using the formula, (left−right)/(left + right). We entered a total of 8 metabolic asymmetry scores in SPSS12.0 (SPSS Inc., Chicago, IL) to conduct Pearson's correlation coefficient analysis with other behavioral measures.

2.3. Individual difference measures of emotion regulation style

Outside the scanner, all participants completed a Korean version of the Emotion Regulation Questionnaire (ERQ; http://www-psych.stanford.edu/~psyphy/resources.html). The ERQ assesses individual differences in the use of reappraisal versus expressive suppression in regulating emotions in daily life (Gross and John, 2003). The group means and standard deviations of reappraisal and suppression scores were 5.09 ± 0.95 and 3.51 ± 0.90, respectively. Trait levels of neuroticism and extraversion were measured using the Korean Version Eysenck Personality Questionnaire (Lee, 2004). The group means and standard deviations of neuroticism and extraversion scores in our participants were 4.00 ± 2.72 and 6.59 ± 3.12, respectively.

2.4. Off-line emotion regulation task

Participants were asked to return for an emotion regulation task. The time between PET imaging and behavioral test varied from 3 to 5 weeks. Three of 20 participants failed to return. Task procedures were modified from those described task in Kim and Hamann (2007). In brief, 144 colored pictures of negative, positive or neutral scenes were selected from the International Affective Picture System (IAPS; Lang et al., 1995) and presented under three regulation conditions: to increase the emotional responses, to decrease the responses and to naturally view pictures. Pictures across different regulation conditions were matched in terms of normative ratings of emotional arousal and valence. Each trial of the task began with an instruction label of 'Increase', 'Decrease', or 'Watch', appearing on the screen for 2 s, followed by a picture for 8 s. After the picture disappeared, a rating scale of 1–4 was presented for 4 s during which the participants rated their level of emotional arousal by pressing a corresponding button (1 = no or weak arousal; 4 = strong arousal). A fixation cross was presented for 2 s in between trials. Picture assignment to each regulation condition was counterbalanced across participants. Participants had 27 practice trials prior to performing the real task.

The participants' regulation success by reappraisal was defined as reappraisal-induced changes in subjective ratings of emotional intensity elicited by emotional pictures. We computed the difference scores of arousal ratings between regulation and control conditions. Specifically, up- or down-regulation success for each emotion was assessed by the following contrasts: [up-regulation: increase–watch], [down-regulation: watch–decrease]. Success scores of positive and negative emotions were calculated separately. Positive scores for each contrast reflect successful emotion regulation. These success scores were entered in a 3 × 3 repeated-measures ANOVA with emotion (positive, negative, neutral) and regulation (increase, decrease, watch) as variables.

3. Results

3.1. Emotion regulation style and regulation success

The means and standard deviations of arousal ratings during the emotion regulation task are presented in Table 1. A 3 (emotion) × 3 (regulation) repeated-measures ANOVA for arousal ratings revealed significant main effects of emotion ($F(2,32) = 23.26$, $p < 0.0001$) and regulation ($F(2,32) = 23.87$, $p < 0.0001$). Simple contrasts on regulation revealed that, compared to watch trials, participants reported an increased level of arousal during the increase trials ($F(1,16) = 40.71$, $p < 0.0001$) and a decreased level of arousal during the decrease trials ($F(1,16) = 7.37$, $p < 0.02$), compared to watch trials, indicating that participants successfully modulated their emotional arousal to pictures. This behavioral finding confirms that reappraisal did influence subjective feelings of the emotions elicited by pictures.

Table 1
Means and standard deviations of arousal ratings during the task.

	Regulation condition		
	Decrease	Watch	Increase
	Mean (SD)	Mean (SD)	Mean (SD)
Positive	2.91 (0.85)	3.49 (0.79)	4.12 (0.49)
Negative	2.96 (0.99)	3.15 (0.87)	4.12 (0.98)
Neutral	1.85 (0.59)	2.50 (0.52)	3.04 (0.64)