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Advancing understanding of affect labeling with dynamic causal modeling

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ABSTRACT

Mechanistic understandings of forms of incidental emotion regulation have implications for basic and translational research in the affective sciences. In this study we applied Dynamic Causal Modeling (DCM) for fMRI to a common paradigm of labeling facial affect to elucidate prefrontal to subcortical influences. Four brain regions were used to model affect labeling, including right ventrolateral prefrontal cortex (vlPFC), amygdala and Broca's area. 64 models were compared, for each of 45 healthy subjects. Family level inference split the model space to a likely driving input and Bayesian Model Selection within the winning family of 32 models revealed a strong pattern of endogenous network connectivity. Modulatory effects of labeling were most prominently observed following Bayesian Model Averaging, with the dampening influence on amygdala originating from Broca's area but much more strongly from right vlPFC. These results solidify and extend previous correlation and regression-based estimations of negative corticolimbic coupling.

Introduction

The unique human ability to consciously control one's emotional experience also counts among the more difficult to execute. Nonetheless the psychology and neuroscience of explicit emotion regulation have been fruitfully studied for over two decades, yielding much understanding of the neural mechanisms of emotions and behavioral control (Gross, 2007). Neurobiologically, we are now aware of major prefrontal and emotional regions involved (Ochsner and Gross, 2005; Ochsner et al., 2012) and are beginning to understand the important connections between emotion regulation and health (DeSteno et al., 2013). However, research has more recently suggested that there is a disconnect between self-reported use of explicit emotion regulation strategies and their spontaneous use in daily life (Gruber et al., 2012; Volokhov and Demaree, 2010). One reason for this may be due to the substantial cognitive resources and time required to enact such strategies (Mauss et al., 2006). As a result, research on emotion regulation at a non-conscious level has emerged as an equally interesting and alternative avenue of investigation into how we commonly control our emotional experiences (Berkman and Lieberman, 2009; Koole and Rothermund, 2011).

By explicit emotion regulation we refer to strategies such as reappraisal of an emotional stimuli or suppression of an emotional response, while in contrast non-conscious emotion regulation (also called implicit or incidental emotion regulation) refers to those cognitive processes that result in the lessoning of emotional reactivity and where this effect was not consciously intended by the person engaging in it (Lieberman et al., 2011). Although incidental emotion regulation at a non-conscious level cannot easily be self-reported, functional magnetic resonance imaging (fMRI) offers a window into the process. This technology can reveal the presence of incidental emotion regulation via lessoned emotional reactivity and the extent to which prefrontal regions are recruited that overlap those used to explicitly control emotion (Burklund et al., under review; Payer et al., 2012).

There are a variety of psychological paradigms currently being used to probe non-conscious forms of emotion regulation using fMRI (Berkman et al., 2009; Egner et al., 2008; Meyer et al., 2011). One frequently studied cognitive process is affect labeling (Hariri et al., 2000; Lieberman et al., 2007) which is gaining increasing evidence as a form of incidental emotion regulation (Kircanski et al., 2012; Lieberman et al., 2011). This paradigm lies at the confluence of emotion, control, and language systems. Labeling emotional faces results in decreased amygdala response and the increased recruitment of prefrontal control and language regions, particularly the ventrolateral prefrontal cortex (vlPFC) in the right hemisphere and Broca's area (BA 44/45) in the left. To this end, a task-induced negative coupling between the activity in the amygdala and vlPFC has been shown using regression-based techniques (Foland-Ross et al., 2008; Hariri et al., 2000) and has been interpreted as a dampening of amygdala reactivity by the vlPFC. However, causal inferences using such methods remain circumspect. To advance beyond the simple identification of activation patterns or the changes in coupling between only two regions one must use more sophisticated analyses (Friston, 2011).

In this study, we examined the nature of the vlPFC–amygdala coupling (specifically, the directed influences between these regions)

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during affect labeling, and additionally assessed the understudied contribution of Broca's area to amygdala activity. To do so we used Dynamic Causal Modeling (DCM), a validated and reliable Bayesian statistical framework for effective connectivity analysis which encourages the comparison of multiple user-defined models of causal interactions between a set of brain regions (Friston et al., 2003; Rowe et al., 2010; Schuyler et al., 2010). Ours is, to the best of our knowledge, the first application of this method to this common paradigm.

Materials and methods

Subjects

Fifty-two healthy subjects were recruited as part of a larger study of emotion regulation in bipolar disorder by advertisement in local newspapers and campus flyers. They provided informed consent in accordance with the Institutional Review Boards at the University of California, Los Angeles (UCLA). All participants completed the Structured Clinical Interview for DSM-IV Structured Clinical Interview for DSM-IV Axis I Disorders (SCIDI/P; First, 2002). Exclusion criteria included any concurrent or past psychiatric diagnosis (including history of substance abuse), neurological illness, left-handedness, metal implants, a history of skull fracture or head trauma with loss of consciousness of more than 5 min, or taking any medications with psychotropic effects.

Experimental design

The affect labeling paradigm consisted of three experimental conditions: 'match facial affect,' 'label facial affect,' and 'match forms' (Fig. 1) (Hariri et al., 2000). They were presented as nine experimental 30-second blocks: four displayed emotional faces and were interleaved with five control blocks displaying geometric forms. Of the four displaying faces, two required the subject to match a facial expression with one of two other facial expressions (*match faces* condition). Faces were shown with neutral or negative affect such as fear, surprise or anger. The other two blocks required subjects to choose one of two presented words (e.g., 'ANGRY', 'AFRAID') that best matched an emotional face (*label faces*). For each affect condition, 12 different faces were used, taken from a standard set of photographic stimuli (Ekman and Friesen, 1976). Each emotion was randomized across blocks and the order of task presentation was counterbalanced among subjects. Subjects responded with one of two buttons with their right hand and were told to answer "…as quickly as possible without making too many mistakes". Response times were collected and accuracy was calculated for each condition.

Image acquisition

All subjects were scanned on a 3 T Siemens Trio scanner. A high resolution structural T1 MPRAGE was acquired with parameters of TR = 1.9 s, TE = 2.26 ms, Flip-Angle = 9°, Matrix = 256 × 256, FOV = 250 mm, voxel size 1 mm isotropic, and total sequence time 6 min and 50 s. The fMRI scan was acquired using a T2*-weighted EPI gradient-echo pulse sequence with IPAT, with TR = 2.5 s, TE = 25 ms, Flip-Angle = 78°, Matrix = 64 × 64, FOV = 192 mm, in-plane voxel size 3 × 3 mm, slice thickness 3 mm, 0.75 mm gap, and 30 total interleaved slices. To allow for scanner equilibration, 2 TRs at the beginning of the scan were discarded. The total sequence time was 5 min and 45 s, with 135 volumes acquired. For co-registration we additionally acquired a matched-bandwidth structural scan with parameters TR = 5 s, TE = 34 ms, Flip-Angle = 90°, Matrix = 128 × 128, FOV = 192 mm, in-plane voxel size 1.5 × 1.5 mm, slice thickness 3 mm, and a total sequence time of 1.5 min. We were not able to acquire MPRAGE scans for four subjects, so their lower resolution matched-bandwidth images were used instead for registration. Foam padding was placed around the heads of participants to suppress motion, responses were recorded by button box, and stimuli was presented by LCD goggles.

Image preprocessing

All preprocessing and analyses were performed within SPM8/DCM10 (www.fil.ion.ucl.ac.uk/spm/). Subjects' functional volumes were slice-timing corrected (Descamps et al., 2007; Kiebel et al., 2007), then motion realigned, coregistered to the MPRAGE, normalized to a T1-weighted standard brain in MNI space, resliced 3 mm isotropically, and smoothed with a 6 mm FWHM Gaussian kernel. All subjects had maximum translational head movement of less than 2.5 mm, with means and standard deviations across subjects for three translation (x, y, z; in mm) parameters: 0.16(0.2), 0.10(0.11), and 0.29(0.31) and three rotation (pitch, roll, yaw; in radians) parameters: 0.005(0.005), 0.003(0.004), and 0.003(0.005).

First level (within-subject) analysis

First-level general linear modeling (GLM) of the preprocessed functional images included convolving task design blocks with a canonical hemodynamic response function, high-pass filtering at 128 s to remove low frequency drifts, adding six motion realignment parameters as covariates of no interest and specifying an F-statistical contrast for subsequent VOI extraction (i.e. when adjusting for effects of interest). The first level statistical maps were run twice; the second time with an explicit whole-brain mask derived from an optimal thresholding of the initial masks to ensure coverage of vlPFC (Ridgway et al., 2009).

Second level group GLM analysis

The standard mass univariate summary statistics approach was used to bring single-subject contrast images into a group random effects analysis. The contrast *label emotion vs match forms* was of interest to elucidate the incidental emotion regulation network while the

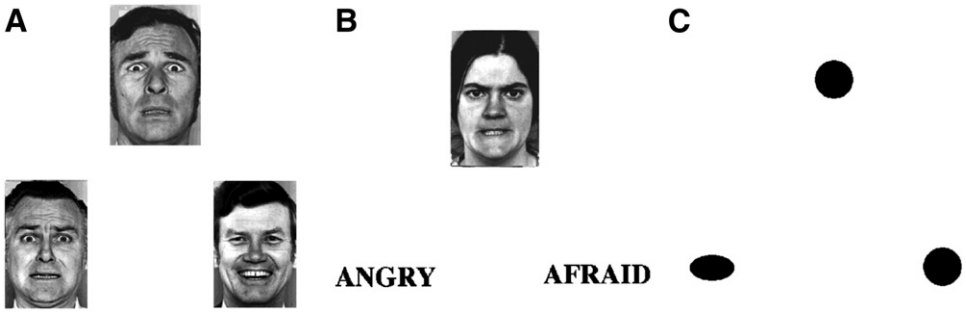

Fig. 1. Affect Labeling paradigm. (A) Match emotion condition; (B) label emotion; (C) match geometric forms. Hariri et al. (2000).