



Decoding negative affect personality trait from patterns of brain activation to threat stimuli



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ABSTRACT

Introduction: Pattern recognition analysis (PRA) applied to functional magnetic resonance imaging (fMRI) has been used to decode cognitive processes and identify possible biomarkers for mental illness. In the present study, we investigated whether the positive affect (PA) or negative affect (NA) personality traits could be decoded from patterns of brain activation in response to a human threat using a healthy sample.

Methods: fMRI data from 34 volunteers (15 women) were acquired during a simple motor task while the volunteers viewed a set of threat stimuli that were directed either toward them or away from them and matched neutral pictures. For each participant, contrast images from a General Linear Model (GLM) between the threat versus neutral stimuli defined the spatial patterns used as input to the regression model. We applied a multiple kernel learning (MKL) regression combining information from different brain regions hierarchically in a whole brain model to decode the NA and PA from patterns of brain activation in response to threat stimuli.

Results: The MKL model was able to decode NA but not PA from the contrast images between threat stimuli directed away versus neutral with a significance above chance. The correlation and the mean squared error (MSE) between predicted and actual NA were 0.52 (p -value = 0.01) and 24.43 (p -value = 0.01), respectively. The MKL pattern regression model identified a network with 37 regions that contributed to the predictions. Some of the regions were related to perception (e.g., occipital and temporal regions) while others were related to emotional evaluation (e.g., caudate and prefrontal regions).

Conclusion: These results suggest that there was an interaction between the individuals' NA and the brain response to the threat stimuli directed away, which enabled the MKL model to decode NA from the brain patterns. To our knowledge, this is the first evidence that PRA can be used to decode a personality trait from patterns of brain activation during emotional contexts.

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Introduction

A personality trait is composed of a set of emotional qualities that characterize and define each individual. Emotional experience has been described in two dominant dimensions, namely, negative affect (NA) and positive affect (PA) (Watson and Clark, 1992). The negative affect dimension refers to the extent to which a person feels a negative mood, including anger, nervousness, fear, guilt, and sadness (Clark and Watson, 1991). The NA trait is linked to poor self-esteem, pessimism, and a propensity to make somatic complaints (Clark et al., 1994; Watson and Clark, 1984; Watson and Pennebaker, 1989).

Similarly, the positive affect dimension reflects positive mood states, including joyful, interested, excited and alert (Watson and Clark, 1992). Studies have found that negative affect and positive affect are related to neuroticism and extraversion, respectively (Watson and Clark, 1992; Watson and Naragon-Gainey, 2014; Watson et al., 2005). For example, a meta-analysis conducted by Kotov et al. (2010) showed that anxiety, depression, substance use disorder (SUD) and posttraumatic stress disorder (PTSD) are strongly correlated with neuroticism. Moreover, extraversion was inversely associated with depression and social phobia and positively associated with bipolar disorder (Watson and Naragon-Gainey, 2014). Neuroticism and extroversion are some of the “Big Five” basic dimensions of affect (Watson and Clark, 1992) and are strongly linked to psychopathology and mental disorders (Kotov et al., 2010; Watson and Naragon-Gainey, 2014; Watson et al., 2005). The “Big Five” dimensions refer to a model that describes human personality

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using 5 factors or dimensions, which include traits of extraversion, neuroticism, agreeableness, conscientiousness, and openness/intellect (Costa and McCrae, 1992; DeYoung, 2010; Markon et al., 2005; Watson et al., 1994).

Individual variability can influence brain responses to specific stimuli, particularly to emotional ones (Calder et al., 2011; Canli et al., 2002; Sanchez et al., 2015). In fact, with respect to emotional stimuli, individual differences in responses are the rule rather than the exception (Eugène et al., 2003; Hamann and Canli, 2004). For instance, the amygdala response to happy faces was not statistically significant in a group analysis, but the emotional effect became significant when the personality trait of extraversion was taken into account (Canli, 2004). In the same vein, trait anxiety shows a positive relationship with the amygdala response to angry and fearful faces (Ewbank et al., 2009). Considering that emotional brain responses vary according to personality traits, a challenging question is whether pattern recognition methods can decode an individual's personality trait from his or her pattern of brain activation to emotional stimuli.

Pattern recognition methods applied to fMRI have made it possible to decode sensorial and cognitive states solely from patterns of brain activation. Examples of these applications include decoding the category of an object (Behroozi and Daliri, 2014; Cox and Savoy, 2003; Shinkareva et al., 2008; Spiridon and Kanwisher, 2002), the orientation of a visual stimuli presented to the subject (Carlson, 2014; Haynes and Rees, 2005; Kamitani and Tong, 2005), mental states related to memory retrieval (Chadwick et al., 2010; Polyn et al., 2005), hidden intentions (Haynes et al., 2007), reading ability (He et al., 2013), age-related differences in connectivity networks (Vergun et al., 2013) and emotion expression (Harry et al., 2013). Pattern recognition approaches have also been used to identify relationships between patterns of brain structure or activity and continuous measures of behavior, i.e., as a *pattern regression analysis* (Cohen et al., 2011; Stonnington et al., 2010). Pattern regression analysis techniques are therefore very promising tools for identifying neurobiological measures that can predict or decode measures of individual variability such as personality traits, but its full potential is still unknown.

In the literature, few studies report the prediction of personality traits from patterns of brain activation or behavior measures. Recently, Kosinski et al. (2013) showed that accessible digital records of behavior (i.e., Facebook likes) can be used to automatically and accurately predict dimensions of personality traits. Nevertheless, the vast majority of studies of neuroticism and extraversion have focused on finding associations between the signal of individual regions and personality trait dimensions at the group level using univariate statistical analysis (Britton et al., 2007; Cohen et al., 2005; Deckersbach et al., 2006; Haas et al., 2006; Hooker et al., 2008; Paulus et al., 2003). For example, functional neuroimaging studies have suggested associations between neuroticism and neural activity in the anterior cingulate cortex (ACC) (Eisenberger et al., 2005), insula (Deckersbach et al., 2006), anterior fronto-median cortex (Britton et al., 2007), and amygdala (Hooker et al., 2008). Extraversion has been associated with neural activity in the striatum (Cohen et al., 2005), ACC (Canli, 2004), orbitofrontal cortex (Paulus et al., 2003), and amygdala (Canli et al., 2001). While studies such as these have employed univariate statistical analyses to identify associations between the signal within individual regions and dimensions of personality trait, the analysis methods used are limited in that they do not enable predictions at the individual subject level. Pattern recognition approaches such as the one used in the present study have the following 2 main advantages with respect to univariate analyses: (1) due to their multivariate properties they can achieve relatively greater sensitivity and are therefore able to detect subtle and spatially distributed effects; (2) they enable predictions for unseen subjects, providing information at the individual—rather than the group level. Here, we used a multiple kernel learning (MKL) approach, considering the whole brain multivariate pattern as a combination of regional patterns (Schrouff et al., 2014) to investigate the link between personality trait and patterns of brain activation to threat stimuli. The idea of the MKL

approach is to hierarchically combine information from different brain regions into a whole brain model in which regions that carry more predictive information about the variable of interest (e.g., NA) will have a higher contribution to the model based on the region weights. The brain regions can then be ranked according to their contribution to the decision function, which facilitates the interpretation of the predictive model in terms of the contributions of different anatomical regions.

To best of our knowledge, the present study is the first to investigate whether NA and PA traits, as evaluated using the Positive and Negative Affective Schedule (PANAS, Watson et al., 1988), can be decoded from patterns of brain activation to threat stimuli in a healthy sample. In summary, the main aim of our study was to investigate whether pattern recognition methods could decode dimensional measures of personality traits from patterns of brain activation to threat. We focused on NA and PA traits because they are a relatively stable personality characteristics over time (Watson, 1988a, 1988b). As previously stated, NA can be considered as a risk factor for the development of mental health disorders, especially affective disorders, such as anxiety and depression (for review, see Ormel et al., 2004). On the other hand, PA trait could be an important component for determining human variability in threat perception and for modulating the emotional reactivity to threat stimuli (Oliveira et al., 2009; Sanchez et al., 2015). Thus, decoding NA and PA traits from patterns of brain activity could be potentially useful as a biomarker to identify individual risk for the development of psychiatric disorders.

Methods

Participants

Thirty-four undergraduate or graduate students without a history of neurological or psychiatric illness participated in the study (15 women; age range: 18–38 years). All of the participants had normal or corrected vision and gave written informed consent to participate in the study after the study was explained to them. The study was performed in accordance with the local Ethics Committee of the Federal Fluminense University, Brazil.

Positive affect and negative affect traits

All of the participants completed personality traits assessment measures at the start of the experimental session, before entering the MRI scanner. The negative and positive affect traits were measured with the Positive and Negative Affect Schedule (PANAS) scale (Watson et al., 1988). The PANAS scale was designed to assess mood in general and can be used to assess mood at various time scales depending on the instructions. Possible time scales include moment, today, past few days, week, past few weeks, year, and general. In the present study, we assessed the mood state in general which relates to the participants' traits. The scale contains 20 words that describe different feelings and emotions. Ten words are related to positive moods (active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud and strong), and 10 words are related to negative moods (distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous and jittery). Participants were asked to rate the degree to which they feel each emotion in general on a 5-point scale (1 = very slightly or not at all, 5 = extremely).

Data acquisition

The data for this study were collected at the Department of Radiology at the Hospital Universitário Clementino Fraga Filho (Federal University of Rio de Janeiro, Brazil) on a 1.5-T Siemens (Magnetom Avanto) scanner. The fMRI runs were acquired on sequential ascending framework and using a gradient echo EPI single-shot sequence covering 25 axial slices (4 mm thick; 0.6 mm gap; TR/TE = 2000/40 ms; IST =

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