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The influence of anhedonia on feedback negativity in major depressive disorder

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ABSTRACT

Anhedonia is associated with reward-processing deficits of the dopamine system, which may increase the risk of depression. Nevertheless, few previous studies have examined the influence of hedonic tone on event-related potential (ERP) measures of reward processing in major depressive disorder. A simple gambling task was used to elicit feedback negativity (FN), an ERP component elicited by feedback indicating gain versus loss, in 27 patients with major depression and 27 healthy participants. We found that participants with depression were characterized by reduced FN responses, especially towards monetary gains, but not losses, compared with healthy individuals. In addition, the amplitude of FN to gain feedback in participants with depression was related to anhedonia severity and depressive symptoms. These findings indicate an association between low hedonic capacity and reduction in FN. As a neural measure of reward sensitivity, FN may be generated in part by reward-related activity.

1. Introduction

Depression is a leading cause of disability worldwide and is associated with a variety of symptoms. While depressed mood is a common component, depression is characterized by the absence of goal directed behavior, e.g., anhedonia, failure to engage socially, and psychomotor retardation. Specifically, a large proportion of these symptoms may be driven at least in part by reward-related abnormality (Eshel & Roiser, 2010; Nestler & Carlezon, 2006). It has been hypothesized that dysfunctional reward circuitry may account for anhedonia (Der-Avakian & Markou, 2012), a core symptom of major depression (APA, 1994), which is partly genetically determined (Hasler, Drevets, Manji, & Charney, 2004; Loas, 1996). Similarly, low reward sensitivity has been suggested to be a possible risk factor and marker of depression (Bress, Foti, Kotov, Klein, & Hajcak, 2013). Converging behavioral (Liu et al., 2011; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2009b) and neuroimaging findings (Epstein et al., 2006; Fitzgerald, Laird, Maller, & Daskalakis, 2008; Forbes et al., 2006, 2009, 2010; Gotlib et al., 2010; Pizzagalli, Holmes, Dillon, Goetz, Birk, Bogdan et al., 2009a) support the notion that depression is associated with reduced sensitivity to rewards. Although reward-related deficits experienced by patients with depression involve more than just an absence or loss of pleasure, multiple reward-related processes are often labeled under the umbrella of anhedonia in clinical practice (Der-Avakian & Markou, 2012). Understanding the link between anhedonia and reward deficits in depression may provide new insights for diagnosis and treatment.

Recent work has assessed neural sensitivity to rewards using feedback negativity (FN), or feedback Error-Related Negativity (fERN), which is derived from the observation of a relatively negative deflection in the ERP for feedback in response to monetary gains and losses between 230 and 330 ms (Gehring & Willoughby, 2002; Goyer, Woldorff, & Huettel, 2008; Hewig et al., 2007; Holroyd, Hajcak, & Larsen, 2006; Miltner, Braun, & Coles, 1997; Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen, 2004; Sato et al., 2005; Yeung & Sanfey, 2004). FN has been interpreted as a negative-going ERP component that reflects the phasic activity of the midbrain dopamine system (Holroyd & Coles, 2002). Previous studies have found evidence to suggest that FN may be a neural process tracking the occurrence of unfavorable outcomes (Holroyd & Krigolson, 2007; Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003). However, recent work has emphasized

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the role of positive feedback in FN responses (Baker & Holroyd, 2011; Foti, Weinberg, Dien, & Hajcak, 2011; Holroyd, Krigolson, & Lee, 2011; Holroyd, Pakzad-Vaezi, & Krigolson, 2008; San Martin, Manes, Hurtado, Isla, & Ibanez, 2010). A study which used Temporal-spatial Principal Components Analysis (PCA) to investigate the underlying structure of the ERP response to monetary feedback identified a positive deflection at fronto-central recording sites in FN time range (Foti et al., 2011). Moreover, this component in the time range of the FN was not only enhanced by monetary gains compared to losses (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Greg Hajcak, 2011; Foti et al., 2011; Holroyd et al., 2008, 2011), but also correlated with brain activation in the mesocorticolimbic reward circuit, including the ventral striatum and the caudate (Carlson et al., 2011; Foti et al., 2011); these areas are associated with reward processing and show reduced functioning in depression (Forbes et al., 2006; Pizzagalli et al., 2009a; Steele, Kumar, & Ebmeier, 2007). Based on this data, FN may be conceptualized as a positivity that is sensitive to unexpected positive feedback, but not negative feedback.

Given the association between FN and reward processing, FN may be a useful measure of abnormalities of reward sensitivity in depression. Studies have found support for a reduced FN response in adolescents at risk of depression (Foti, Kotov, Klein, & Hajcak, 2011) and also in younger samples in late childhood to early adolescence (Bress, Smith, Foti, Klein, & Hajcak, 2012). Moreover, depressive symptoms were also found to be associated with blunted FN responses (Foti & Hajcak, 2009). Finally, self-reported sadness after a mood induction task predicted FN responses (Foti & Hajcak, 2010), and lower FN amplitudes predicted depression onset in later life (Bress et al., 2013). Together, these findings suggest that FN may be a biomarker for studying change in reward sensitivity in depression. However, most of the aforementioned studies did not include individuals with clinical diagnoses of depression. In addition, although anhedonia is a core symptom of depression (APA, 1994) and is closely related to reward-related deficits (Der-Avakian & Markou, 2012), there has been no investigation to examine the extent to which anhedonia and FN are associated in depressed adults. Whether abnormal reward processing relates to depressive symptoms in depressed patients, especially for those with high levels of anhedonia, remains poorly understood.

The present study sought to examine FN responses to monetary gains and losses in patient with depression and healthy individuals and to explore the associations between depressive symptoms and neural sensitivity to rewards. A simple gambling task was used to elicit FN and self-reported scales were used to evaluate hedonic capacity and other emotional information in the participants. We hypothesized that, consistent with findings from non-clinical studies, the magnitude of FN would be attenuated in patients with depression compared to healthy individuals. Furthermore, based on the notion that FN reflects reward-related processing abnormalities, we hypothesized that the magnitude of FN would be related to clinical symptoms, especially hedonic capacity in patients with depression.

2. Methods

2.1. Participants

Twenty-seven patients with depression were selected from the outpatient clinic of the Guangzhou Psychiatric Hospital. All patients met the diagnostic criteria for Major Depressive Disorder according to DSM-IV (APA, 1994) were free from other Axis I disorders and psychotic features, and all had a score of at least 17 on the Hamilton Rating Scale for Depression (HRSD) (Hamilton, 1960). Patients who had received electroconvulsive therapy in the past six months were excluded. The mean HRSD score for depressed participants was 29.29 (standard deviation (SD)= 10.72; range 18–65) and the length of the current depressive episode was 1.8 years (y) (SD=2.01 y). In the depressed sample, 21 patients received antidepressant medications, with a cumulative treatment duration of 17.14 months (SD=6.08). We recruited 27 healthy controls matched for age, gender, handedness and years of education from the local community. Healthy participants were screened for psychopathological disturbances using a phone interview based on DSM-IV criteria. The Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) was used to evaluate the intensity of depression before the experiment. All healthy participants were not taking any medication and had no history of psychiatric illness, neurological disease, major physical illness or drug abuse.

2.2. Task

The simple gambling task was similar to the version used in previous studies (Bress et al., 2012; Dunning & Hajcak, 2007; Foti et al., 2011). The participants were asked to choose one of two doors shown side by side on a computer screen by clicking the left or right mouse button. After the participants made a choice, a fixation mark appeared for 1000 ms, which was followed by a feedback on the screen for 2000 ms. The feedback consisted of either a green "↑", indicating a gain of 1 Chinese Yuan (about 0.16 USD) or a red "↓", indicating a loss of 0.5 Chinese Yuan (about 0.08 USD). These values were chosen in order to give gains and losses equivalent subjective values (Tversky & Kahneman, 1992). After the feedback, a fixation mark appeared for 1500 ms, followed by a message "Click for the next round," which remained on the screen until the participants responded. The task consisted of 40 trials; 20 gain and 20 loss feedback trials were presented to each participant in a random order.

2.3. Emotion assessment instruments

General hedonic tone over the past week (state levels) was measured using the Snaith-Hamilton Pleasure Scale (SHAPS) (Snaith et al., 1995), which covers four domains of hedonic experiences: interests/past times, social interaction, sensory experience, and food/drink. The scale contains 14 items and a higher score indicates more anhedonic symptoms. The Chinese version used for the present study has been validated in Chinese samples (Liu, Wang, Zhu, Li, & Chan, 2012). The Cronbach's alpha in the present sample was 0.93.

The Temporal Experience of Pleasure Scale (TEPS) (Gard, Gard, Kring, & John, 2006) was used to evaluate different components of the long-term experience of pleasure, namely the anticipatory and consummatory pleasurable experiences among the participants. The original English version of the TEPS has good internal consistency and test-retest reliability. The present study used a 20-item Chinese version that was modified from the original English version (18 items) (Gard et al., 2006). A lower total score in the scale indicates a higher level of anhedonia. The Chinese version of the TEPS has been shown to possess adequate reliability in previous studies (Chan et al., 2010; Chan, Shi, et al., 2012; Chan, Wang, et al., 2012). Cronbach's alphas for the TEPS-ANT (anticipatory pleasure) and the TEPS-CON (consummatory pleasure) in the present sample were 0.77 and 0.75, respectively.

Symptoms of depression, anxiety and stress reactivity were measured using the short-form of the Depression Anxiety Stress Scale (DASS-21) (Lovibond & Lovibond, 1995). The scale contains 21 items and each item on the DASS includes four response categories describing increasing severity of depression, anxiety and stress response. The version used for the present study has been validated in the Chinese population (Chan, Xu, et al., 2012). Cronbach's alphas for depression, anxiety and stress subscales in the present sample were 0.92, 0.88 and 0.87, respectively.

2.4. Procedure

The study was approved by the ethics committee of the Guangzhou Medical University and informed consent was obtained from all participants. After completing the self-reported scales, the experimental task was administered to each participant.

2.5. EEG recording and analysis

Electroencephalography (EEG) recordings were obtained using 64 Ag/AgCl electrodes in the International 10/20 system positions. Electrooculography (EOG) was recorded from electrodes placed above and below the left eye and at the outer edge of both eyes to monitor horizontal and vertical eye movements. The ground electrode was placed at the frontal pole (Fpz). All electrode recordings were referenced to an electrode placed on the left mastoid and data were also recorded from the right mastoid, which enabled computation of a linked mastoid reference offline. Data were recorded at a rate of 500 Hz with an online 100 Hz low-pass filter using a Neuroscan Synamps System and the appropriate software. Impedances were kept below 10 kΩ. Stimulus timing was controlled by E-Prime Software.

EEG data were re-referenced to the numeric mean of the two mastoids. The digitized signals were filtered using a 4th order digital Butterworth filter (24 dB) with a pass band of 0.10–30 Hz. The EEG was segmented for each trial, beginning 200 ms before feedback onset and continued for 800 ms following feedback onset. Ocular artifacts were corrected using the eye movement correction algorithm