International Journal of Psychophysiology 97 (2015) 93–98

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Depressive states amplify both upward and downward counterfactual thinking

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ARTICLE INFO

Article history:
Received 12 December 2014
Received in revised form 6 April 2015
Accepted 13 April 2015
Available online 30 April 2015

Keywords:
Depression
Counterfactual thinking
Outcome evaluation
Event-related potential
P3

ABSTRACT

Depression has been linked to counterfactual thinking in many behavioral studies, but the direction of this effect remains disputed. In the current study, the relationship between depression and counterfactual thinking was examined using the event-related potential (ERP) technique. In a binary choice gambling task, outcome feedback of the chosen option and that of the alternative option were both provided, so as to elicit the process of counterfactual comparison. By investigating ERP signals in response to outcome presentation, we discovered that when the fictive outcome was better or worse than the factual outcome, the amplitude of the P3 component was positively correlated with individual levels of depression, but not levels of anxiety. These results indicate that depression strengthens both upward counterfactual thinking and downward counterfactual thinking. The implication of this finding to clinical research is discussed.

1. Introduction

Depression is a state of low mood associated with multiple psychophysiological symptoms including stress, anhedonia, and abnormalities in appetite and sleep (Krishnan and Nestler, 2008). High levels of depression give rise to biased thoughts and beliefs, such as negative self-image and self-focused attention (Beevers et al., 2011). This effect may increase the risk for the development and recurrence of depressive disorder (Gotlib and Joormann, 2010). Therefore, investigating altered belief systems in depression has important implications for pathophysiological research.

The current study explores the relationship between depression and counterfactual thinking, which refers to the process of comparing reality and “what might have been” had a different decision been made (Coricelli et al., 2007). Comparisons based on alternatives that improve on reality (i.e., upward counterfactual) generate feelings of regret and disappointment (Mandel, 2003; Zeelenberg et al., 1998), while comparisons based on alternatives that worsen reality (i.e., downward counterfactual) generate feelings of rejoice and gratification (Galinsky et al., 2002; Medvec and Savitsky, 1997). The influence of depression on counterfactual thinking has been examined by many studies, but the precise nature of this influence is still debated. Markman and Miller (2006) reported that participants suffering from severe depressive symptoms generated counterfactuals that were less controllable (see also Eryilmaz et al., 2014; Monroe et al., 2005; Zhou and Kong, 2009). In contrast, depressed patients showed attenuated counterfactual thinking in Chase et al. (2010) (see also Quelhas et al., 2008). Finally, some studies have found no correlation between levels of depression and counterfactual thinking (e.g., Landman et al., 1995).

In our opinion, these heterogeneous findings may be attributable in part to methodological issues that distinguish some or all of those studies. First, most previous studies devoted to this topic have relied on self-report instrument rather than clandestine tools such as measures of brain activity (see Eryilmaz et al., 2014, for an exception). The limitations of these types of assessments are worth noting, including response bias and socially desirable responding (Crowley et al., 2009). Second, many studies estimate counterfactual thinking by asking retrospective questions (e.g., Markman and Miller, 2006), which may be vulnerable to the memory bias associated with depression (Bar, 2009). Finally, while most studies focus on the potential relation between depression and upward counterfactual which elicits feelings of regret, whether

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http://dx.doi.org/10.1016/j.ijpsycho.2015.04.016
0167-8760/

depression affects downward counterfactual remains largely unanswered. Eryilmaz et al. (2014) recently reported that activities of the brain regions associated with gratification (i.e., a consequence of downward counterfactual thinking) were negatively correlated with Beck Depression Inventory (BDI) scores during resting state.

This study investigated the impact of depression on counterfactual thinking in a decision-making scenario (e.g., Chase et al., 2010) with event-related potentials (ERPs) as a neural measurement. In this task, participants chose between two options and received positive or negative outcomes of the chosen option and the alternative option (Gu et al., 2011b; Yeung and Sanfey, 2004). Thus, the comparison between positive *alternative outcome* (AO for short) and negative *chosen outcome* (CO for short) elicits upward counterfactual thinking, while the comparison between negative AO and positive CO elicits downward counterfactual thinking (Giorgetta et al., 2012). For instance, when a participant discovers that the option he/she selected led to monetary loss (CO) while the other option could have resulted in monetary gain (AO), he/she may feel regret and imagine the preferable alternate selection (upward counterfactual thinking). Two ERP components, the feedback-related negativity (FRN) and the P3, were chosen as they are the major biomarkers of outcome evaluation (Gehring and Willoughby, 2002; Yeung and Sanfey, 2004). Both components have been reported to be affected by depression levels (Proudfit, 2015; Proudfit et al., in press; Roschke and Wagner, 2003). Numerous studies have confirmed that both the FRN and the P3 are sensitive to the comparison between subjective expectation and reality (Hajcak et al., 2005, 2007; Wu and Zhou, 2009). In order to clarify the discrete roles played by these components in counterfactual contexts, Osinsky et al. (2014) recently proposed that the FRN indicates a binary categorization of gain versus no-gain for both CO and AO, while the P3 indicates motivational salience derived from counterfactual comparisons of CO and AO. Consistent with this idea, Liang et al. (2015) reveal that counterfactual comparisons manifest on the P3 rather than the FRN (see also Gu et al., 2011b; Wu and Clark, 2014). Accordingly, we suggest that the P3 elicited by the comparison between CO and AO reflects the process of counterfactual thinking when other major factors that could modulate this component (e.g., event probability, stimulus novelty, and task complexity; for reviews, see Polich, 2007; Polich and Criado, 2006) are controlled. We predicted that P3 amplitude in response to the comparison between CO and AO would increase as a function of individual differences in depressive traits, indicating a stronger tendency of counterfactual thinking among depressed individuals. In contrast, such associations would be absent for FRN amplitude.

2. Methods

2.1. Participants

20 right-handed Chinese students (11 females; mean age 22.75 years, $SD = 1.68$) from three universities in Tianjin participated in the experiment. All the participants were included in the final sample. All had normal or corrected-to-normal vision. None of the participants had sought medication for emotional problems before. All the participants denied regular use of any substance with the potential to affect the central nervous system. None had a history of neurological disease. None of the participants reported knowledge of the Cyrillic alphabet. All participants gave their informed consent prior to the experiment. The study was approved by the ethics committee of Academy of Psychology and Behavior, Tianjin Normal University.

2.2. Procedure

The task procedure replicated that of Gu et al. (2011b). Before the experiment, participants were informed about the rules and framework of the task and encouraged to respond so as to maximize the total score. Participants sat approximately 100 cm from a computer screen in an electrically shielded room. Each trial began with the presentation of two options represented as Cyrillic letters ("д" and "ю" respectively), each of which was presented inside a white rectangle (2.51° × 2.51° of visual angle) appearing on either side of a fixation point. The position of these letters was counterbalanced across trials. Participants selected one option by pressing the "F" or "J" keys on the keyboard with left or right index finger, respectively. The selected rectangle was outlined in red for 500 ms. After that, the AO was presented in the unselected rectangle for 1000 ms simultaneously with the disappearance of the two letters. Then the AO faded away, leaving the rectangles and the fixation point on screen for 500 ms. Finally, the CO was presented in the chosen rectangle for 1000 ms. The formal task consisted of two blocks of 100 trials each. Stimulus display and behavioral data acquisition were conducted using E-Prime software 1.1 (PST, Inc., Pittsburgh, PA).

There were two kinds of outcome valence: positive ("+") and negative ("−"). A positive and a negative CO indicated that participants gained or lost one point in the current trial, respectively (Fig. 1). Unbeknownst to the participant, no matter which option was chosen, the probability of receiving a positive or negative CO or AO in each trial was 50%. Moreover, the valences of AO and CO were independent of one another. Thus, we suggest that event probability, stimulus novelty, and task complexity have been controlled across conditions.

After participants finished the task, he or she was instructed to fill the Chinese version of Zung's self-rating depression scale (SDS) and the trait form of Spielberger's State-Trait anxiety inventory (STAI-T), both of which have demonstrated good internal consistency reliability, convergent validity, and discriminate validity (STAI-T: Shek, 1993; Spielberger et al., 1983. SDS: Shu, 1993; Zung et al., 1965). The STAI-T was included in this study in appreciation of the strong relationship between anxiety and depression (Stavrakaki and Vargo, 1986).

During debriefing, participants were informed that the outcomes were predetermined and there was no optimal strategy for the task. Accordingly, each participant was paid 30 Chinese Yuan (approximately 5 US dollars) for participation.

2.3. Electrophysiological recording and preprocessing

The EEG activity was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan, Inc., Herndon, VA), with an online reference to the left mastoid and off-line algebraic re-reference to the average of the left and right mastoids. Horizontal electrooculogram (EOG) was recorded from electrodes placed at the outer canthi of both eyes. Vertical EOG was recorded from electrodes placed above and below the left eye. All interelectrode impedance was maintained at <5 k Ω. EEG and EOG signals were amplified with a 0.05–100 Hz bandpass filter and continuously sampled at 500 Hz/channel.

During the off-line analysis, ocular artifacts were removed from the EEG signal using a regression procedure implemented in the Neuroscan software (Semlitsch et al., 1986). The EEG was digitally filtered through a zero phase shift, with 0.05–30 Hz band-pass filtering for the FRN and 2 Hz low-pass filtering for the P3 component (Gu et al., 2011a; Yeung and Sanfey, 2004). The data were then averaged into 1000 ms epochs (200 ms baseline) time-locked to outcome presentation. Any trials where EEG voltages exceeded a threshold of ±100 μV during the recording epoch were excluded from the analysis. After the artifact rejection processing, the numbers of trials survived in each condition were as follows: AO (+) CO (+): 45.63 of the 50 trials (91.26%); AO (−) CO (+): 44.84 (89.68%); AO (+) CO (−): 45.21 (90.42%); and AO (−) CO (−): 46.05 (92.10%).

2.4. Data analysis

The time windows for peak identification were determined through visual inspection of grand-averaged waveforms. The electrode at which the ERP components reached their maximum was detected along the