ASSESSMENT OF EMOTIONAL PROCESSING BIASES IN COGNITIVE CONTROL PERFORMANCE

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Abstract: Due to the paucity of behavioral studies on emotionally modulated cognitive control processes in healthy individuals and in remitted bipolar patients, it is difficult to determine the extent to which emotional stimuli can modulate cognitive control processes in both populations. We examined emotional processing biases in cognitive control processes in large groups of healthy volunteers and bipolar outpatients. Participants were matched for gender and age, and completed a computerized Emotional Go/NoGo task. Results revealed greater impact of emotionally loaded stimuli compared to neutral stimuli on response inhibition. Among emotional stimuli, negative stimuli exerted the most pronounced differential effect on target recognition and response inhibition in both groups. Healthy volunteers demonstrated better cognitive control performance and altered pattern of emotional processing biases than bipolar patients. Results are discussed with regard to the preferential processing of emotional over non-emotional stimuli and existing between-group differences in emotional processing biases, attributable to bipolar disorder characteristics.

Key words: emotional processing biases, cognitive control, Emotional Go/NoGo, healthy adults, bipolar outpatients

INTRODUCTION

Within cognitive psychology and neuroscience there has been a renewed focus on hierarchical organization of human behavior and on its underlying neural mechanisms (O’Reilly et al., 2010; Botvinick, 2008). Behavioral hierarchy is related to goal-directed behavior and refers to nested subroutines that involve interaction of top-down and bottom-up processes (Botvinick, 2008). Bottom-up processes are sensory-driven and automatic, whereas controlled top-down processes rely on limited capacity of attentional resources, which are needed in novel and complex situations. Goal-directed behavior emerges as a consequence of cognitive control processes that coordinate thoughts and behavior to current goals by selecting and integrating relevant information from the context (Botvinick et al., 2001; Blasi et al., 2006). Mechanisms of cognitive control involve biasing on-going processing by facilitating processing of task relevant information, while filtering out contextually irrelevant information (Braver et al., 2009). The latter mechanism reflects core as-
pects of cognitive control, i.e. *interference monitoring with suppression*, involving cognitive management of irrelevant information in the process of making a decision, and *inhibition*, referring to suppression of predominant but inappropriate responses (Blasi et al., 2006). Both aspects have in common competition between two or more sources of information demanding control over responses. *Context* in the form of task instructions, specific prior stimulus or as a result of processing of prior stimuli acts in a top-down manner and influences the processing and the outcome of these competitions (Braver et al., 2009).

Studies show that prefrontal cortex and anterior cingulate are the brain regions subserving cognitive control (Botvinick et al., 2001; Blasi et al., 2006; O’Reilly et al., 2010). Specifically, activity of posterior medial and lateral regions of prefrontal cortex corresponds to regulatory aspect of cognitive control by exerting top-down attentional control, whereas activity of anterior cingulate is associated with evaluative aspect of cognitive control as it is thought to be implicated in detection of processing conflicts during task performance and signaling the extent to which attentional control is required (Botvinick et al., 2001). Cognitive conflict arises from association between irrelevant automatically processed information and inappropriate response and may occur at different phases of task processing, i.e. stimulus encoding, target detection, response selection or response execution (van Veen, Carter, 2006). For example, interference tasks such as the Stroop and Go/NoGo tests, involve conflict not only at a response level, but also at a target-detection level.

Conflict monitoring leads to compensatory adjustments in cognitive control. This process can be observed in forced-choice decision tasks when participants after committing an error tend to shift performance strategy to a more conservative speed-accuracy balance in terms of longer reaction times, which indicates a tendency to “correct” the error (Botvinick et al., 2001; van Veen, Carter, 2006).

The Go/NoGo task has proved to be a suitable test for assessment of conflict monitoring as it induces the need for adjustment in cognitive control (Botvinick et al., 2001, Schulz et al., 2008). The traditional Go/NoGo task is a type of a two-choice task and involves two stimuli: a Go stimulus and a NoGo stimulus. Participants are instructed to respond rapidly, to presentation of Go stimuli only. Response inhibition is measured by the ability to appropriately withhold responding to NoGo stimuli and can be interpreted according to a diffusion model (Gomez et al., 2007) as related to implicit negative decision boundary, i.e. decision not to respond. The model behind the rationale of the Go/NoGo task emphasizes the process to reach either of the two possible decision boundaries which results in response initiation (for Go stimuli) or inhibition (for NoGo stimuli). Decision process starts with a *drift rate*, which depends on the quality of the information extracted from stimulus (cf. with target detection).

### Involvement of Emotional Processes in Cognitive Control

Emotional and cognitive functions are widely regarded as distinct, but also intertwined in that they selectively influence one another at certain levels of cognitive control (Gray, 2001). This interaction is posited to be bidirectional; not only emotional processes...
modulate cognitive control, but also cognitive control influences emotional functioning. Modulatory effect of emotions on cognitive control can result in a transient and rapid enhancement of behavioral performance, aiding in resolution of cognitive conflicts that some studies refer to as emotional facilitation (Chiu et al., 2008). Moreover, emotional processes can be involved in cognitive control through impairment of performance which is reported in studies as emotional inhibition or attentional biases to emotional information. Nonetheless, cognitive control also modulates emotion processing by affecting emotion regulation and maintenance of emotional states (Gray, 2004; Hare et al., 2005).

Growing recognition of the interaction between emotional processing and cognitive control has contributed to development of neuropsychological paradigms designed to differentially assess the impact of these processes. The emotional Go/NoGo task has been broadly used in electrophysiological and neuroimaging studies to discern correlates of emotional processing in healthy adults and patients with affective disorders (Schulz et al., 2008). Due to the paucity of behavioral studies employing emotional interference tasks (e.g., Vuilleumier et al., 2001), it is difficult to determine the extent to which emotional distractors can impair cognitive control in healthy individuals. However, findings revealed that emotionally loaded distractors can significantly interfere with task performance, thus demonstrating disrupted aspects of cognitive control in healthy adults (Vuilleumier et al., 2001). Deficits in cognitive control due to emotional interference are nevertheless more frequently detected in clinical groups (Murphy, Sahakian, 2001; Hare et al., 2005).

Examining emotional influence on cognitive processes in experimental paradigms is particularly relevant in affective disorders (Murphy, Sahakian, 2001). Compared to abundance of studies on mood-congruent information biases in depression, emotional biases in bipolar disorder are still understudied. Bipolar disorder is a disabling affective disorder characterized by recurrent episodes of mania, depression and intermittent periods of remission. Converging evidence shows that patients with bipolar disorder even in remission continue to display neuropsychological deficits that include disrupted aspects of cognitive control, reported as poor response selection and inhibition and mood-congruent attentional biases (Murphy, Sahakian, 2001; Wessa et al., 2007). Neural systems implicated in cognitive-emotional interference in affective disorders include a hypoactive dorsal-cognitive network (prefrontal cortex and anterior cingulate) which has been involved in cognitive control and conflict monitoring, and a hyperactive ventral-limbic network associated with emotional regulation (Wessa et al., 2007). Though studies using the emotional Stroop and Go/NoGo tasks found mood-congruent response biases in both manic and depressed bipolar patients and impairments in capacity to inhibit emotional material in manic patients, behavioral data remain inconclusive regarding the state of emotionally modulated cognitive control in remitted patients (Wessa et al., 2007; Schulz et al., 2008; Kaladjian et al., 2008).

PRESENT STUDY

Our research is based on the paradigm that postulates an interaction between emotional and cognitive control processes, suggest-
ing that emotional stimuli can modulate components of cognitive control (Gray, 2001, 2004). To our knowledge, behavioral studies assessing emotional biases in cognitive control processes in healthy individuals are scarce in relation to the scope of similar studies in patients with bipolar disorder. In spite of existing evidence on mood-congruent attentional biases to emotional stimuli and impaired response inhibition in emotional contexts in acute affective episodes (Murphy, Sahakian, 2001), the presence of diminished emotionally modulated cognitive control has not yet been consistently confirmed in remitted bipolar patients (Wessa et al., 2007).

The present study examined emotional processing biases in cognitive control processes in groups of remitted bipolar outpatients and healthy volunteers by employing the Emotional Go/NoGo task. Specifically, the aims of the study were: a) to assess the impact of different emotionally loaded stimuli on various levels of cognitive control processes (i.e., target recognition, response inhibition, response execution), b) to compare differences in emotionally modulated cognitive control performance between healthy volunteers and bipolar patients in remission.

We predicted that emotional valence of presented stimuli in the Go/NoGo task would differentially modulate cognitive control processes. In addition, we hypothesized that bipolar patients in remission would demonstrate diminished cognitive control when inhibiting different emotional distractors, which would be reflected in longer reaction times, less accurate and more erroneous performance in addition to altered emotional processing biases in task performance compared to healthy volunteers.

**METHOD**

**Participants**

The sample consisted of 102 healthy volunteers (49 males, 53 females) and 105 outpatients (44 males, 61 females) diagnosed with bipolar affective disorder, currently in remission. Remission in bipolar outpatients was defined by a psychiatrist’s assessment with Hamilton Depression Rating Scale (Hamilton, 1960) score <12 and a Young Mania Rating Scale score <10 (Young et al., 1978). Healthy subjects were recruited through snowball sampling, whereas bipolar outpatients were recruited from the Outpatient Psychiatry Unit at the University Psychiatric Hospital Ljubljana. Mean age and mean years of formal education of healthy volunteers were 36.75 years (SD = 11.56 years) and 14.62 years (SD = 2.34 years), respectively. Overall mean age in the group of bipolar outpatients was 39.37 years (SD = 10.89) and mean duration of formal education was 13.83 years (SD = 2.28 years). Both groups did not differ regarding gender ($\chi^2(1) = 0.79; p = 0.36$) and age ($t(205) = 1.80; p = .09$), though healthy volunteers had more years of schooling completed than bipolar outpatients ($t(205) = -2.44; p = .02$).

**Instrument and Procedure**

The emotional Go/NoGo task has been used extensively to examine the role of cognitive control processes in emotional information processing (Hare et al., 2005). The experimental design was adapted from a previous study (Hare et al., 2005; Milavec, Šprah, 2008). The task was administered using the
Presentation® software (Neurobehavioral Systems, San Francisco, USA).

Our adapted version of the emotional Go/NoGo task employed paired emotional stimuli in the alternating combinations of positive, negative and neutral pictures taken from a standardized picture set International Affective Picture System (Lang et al., 2001). Duration of each displayed emotional stimulus was 800 milliseconds (ms), with the inter-stimulus interval of 1000 ms.

The task comprised one practice block followed by 6 test blocks of 30 stimuli each. Half of the pictures were targets (Go stimuli), and half were distractors (NoGo stimuli).

In each block, positive, negative or neutral stimuli were specified as targets as indicated in instructions, e.g. “respond to pictures with positive emotional load”. The following 6 blocks were presented: Positive Go/Negative NoGo, Negative Go/Positive NoGo, Neutral Go/Positive NoGo, Positive Go/Negative NoGo, Neutral Go/Negative NoGo, Negative Go/Neutral NoGo.

Participants were instructed to respond as quickly as possible to a particular target (Go) stimulus by a button press, but to withhold response to a distractor (NoGo) stimulus. Pictures were presented sequentially in the middle of the screen on a grey background and in a randomized order within each block for each participant. Participants had the chance of a break during the task and the entire task took approximately 10 minutes to complete. Outcome measures from the emotional Go/NoGo task included mean reaction times to correct Go stimuli, hit rates and false alarms rates (commission errors) and parameters $d'$ and $c$ for each emotional valence in Go and NoGo trials. Parameters $d'$ and $c$ are derived from a signal detection theory (Stanislaw, Todorov, 1999). The former parameter represents an index of the participant’s ability to distinguish signal (target) from noise (distractors) and is independent from respondent’s biases, whereas the latter is an index of the decision criterion that respondent uses to differentiate signals from noise (Stanislaw, Todorov, 1999). Larger values of $d'$ indicate greater ability to distinguish signals from noise. Negative values of the $c$ signify a bias toward withholding the response and positive values signifying a bias toward executing the response.

All participants gave written consent prior to testing and were tested individually in a quiet room by trained students of psychology. The study was approved by Slovene Medical Ethics Committee and was a part of a larger study on the effects of psychoeducation and pharmacotherapy on cognitive-emotional functioning in bipolar affective disorder (Šprah et al., 2010).

RESULTS

Repeated-measures mixed ANOVA with emotional valence (negative, positive, neutral) and trial type (Go, NoGo) as the within-subjects factors and group as a between-subjects factor was conducted separately on mean reaction time to targets, hit and false alarms rates and parameters $d'$ and $c$. Contrast analyses were performed on significant main and interaction effects. Parameters $d'$ and $c$ were computed according to the signal detection theory (Stanislaw, Todorov, 1999). All effects are reported as significant at $p < .05$.

Effects of Valence, Trial Type and Group on Performance Measures

Repeated-measures ANOVA on reaction time revealed significant main effects of va-
lence (F(2, 410) = 4.82, \( \eta^2 = .02 \)) and group (F(1, 205) = 10.28, \( \eta^2 = .05 \)), indicating shorter reaction times to both negative and positive stimuli compared to neutral stimuli and faster responding of healthy volunteers compared to bipolar patients (see also Figure 1). Significant interaction effects between valence and trial type (F(2, 410) = 87.19, \( \eta^2 = .30 \)) and between valence, trial type and group (F(2, 410) = 4.36, \( \eta^2 = .02 \)) were observed. Reaction times for recognition of emotional targets were shorter than for inhibition of emotional distractors (negative: 633.71 ± 5.4 versus 673.89 ± 5.51; positive: 642.89 ± 4.78 versus 670.07 ± 5.14), however, longer reaction times to neutral targets than to neutral distractors (694.6 ± 5.49 versus 626.91 ± 4.27) were observed. In addition to overall slower responding pattern of bipolar patients, their reaction times did not differ with respect to positive and negative valence of targets (655.77 ± 7.69 versus 650.69 ± 6.8), neither with regard to positive nor negative emotional valence of distractors (687.88 ± 7.33 versus 680.8 ± 7.85). Yet reaction times in healthy volunteers were influenced by emotional valence of targets (positive: 635.08 ± 6.71 versus negative: 611.65 ± 7.22) and distractors (positive: 652.27 ± 7.58 versus negative: 666.98 ± 7.73).

When hit and false alarm rates were examined in different emotionally loaded trial types, a significant main effect of valence was observed on both measures of accuracy and response inhibition (hits: F(2, 410) = 371.78, \( \eta^2 = .64 \), false alarms: F(2, 410) = 404.12, \( \eta^2 = .66 \)), indicating more accurate and less erroneous responses to negative stimuli than to positive and neutral ones. There was also a significant main effect of trial type on both measures (hit rate: F(1, 205) = 2508.92, \( \eta^2 = 0.92 \), false alarm rate: F(1, 205) = 108.87, \( \eta^2 = 0.35 \), with target trials
yielding more accurate and less erroneous responses than distractor trials. Furthermore, a significant interaction effect between valence and trial type emerged on both measures (hit rate: F(2, 410) = 782.13, \( \eta^2 = 0.79 \), false alarm rate: F(2, 410) = 53.79, \( \eta^2 = .21 \)). With regard to hit rates, negative targets were more accurately identified than negative distractors (0.89 ± 0.01 versus 0.37 ± 0.01), in contrast with neutral targets with fewer accurate responses compared to neutral distractors (0.66 ± 0.01 versus 0.87 ± 0.01). However, when responding to positive stimuli, there were similar hit rates for targets and distractors (0.79 ± 0.01 versus 0.74 ± 0.01). Alongside with greater hit rates, there were also more commission errors made in negative target trials compared to negative distractor trials (0.12 ± 0.01 versus 0.05 ± 0.01).

Commission errors varied among trial types in the same manner also for positive stimuli (positive targets: 0.23 ± 0.01 versus positive distractors: 0.16 ± 0.01). Alternatively, participants were more erroneous when responding to neutral distractors compared to neutral targets (0.25 ± 0.11 versus 0.16 ± 0.01). There was also a significant interaction effect between group and trial type on false alarm rates (F (1, 205) = 7.05, \( \eta^2 = .03 \)), indicating that bipolar patients, but not healthy volunteers, made more false alarms in target trials compared to distractor trials. More details regarding group differences in accuracy and error rates are provided in Figures 2 and 3.

In order to assess processing efficiency in responding to different emotional targets and distractors, efficiency scores were calculated.
Figure 3. Group differences in mean false alarms rates (+ SD) by valence and trial type. Healthy volunteers made fewer commission errors when responding to negative and neutral targets and when inhibiting negative distractors. * p < .05, ** p < .01

Figure 4. Group differences in mean false alarms rates (+ SD) by valence and trial type. Healthy volunteers demonstrated both enhanced processing efficiency of evaluating negative and neutral targets and greater efficiency of inhibiting positive and neutral distractors relative to bipolar patients.
as a sum of standardized reaction time and hit rate scores (Vrshek-Schallorn et al., 2006). Positive values of efficiency scores represent greater response efficiency, indicating shorter reaction times and greater hit rates, whereas negative values indicate reduced response efficiency. Repeated-measures ANOVA only yielded a significant main effect of group \(F(1, 205) = 10.38, \eta^2 = .05\), indicating greater efficiency processing in healthy volunteers compared to bipolar patients (see also Figure 4), while other effects did not reach statistical significance.

Effects of Valence, Trial Type and Group on Signal Detection Measures (d' and c)

Descriptive statistics for measures \(d'\) and \(c\) is provided in Table 1.

When \(d'\) was compared between different emotionally loaded target and distractor trials, significant main effects of valence \(F(2, 410) = 309.44, \eta^2 = .60\), trial type \(F(1, 205) = 14.36, \eta^2 = .07\) and group \(F(1, 205) = 9.22, \eta^2 = .04\) were observed. Perceptual sensitivity differed with regard to emotional valence, with enhanced detection of negative stimuli compared to positive and neutral stimuli. In addition, perceptual sensitivity was greater in target trials than in distractor trials. Moreover, healthy volunteers were better at detecting emotional targets and distractors relative to bipolar patients. There was also a significant interaction effect between valence and trial type \(F(2,410) = 60.83, \eta^2 = 0.23\), indicating greater perceptual sensitivity for negative targets than for negative distractors \((2.53 \pm 0.05\) versus \(2.05 \pm 0.05\)), reduced perceptual sensitivity for neutral targets to a greater degree than for neutral distractors \((1.48 \pm 0.04\) versus \(1.88 \pm 0.04\)) and similar level of sensitivity for positive targets and positive distractors \((1.70 \pm 0.04\) versus \(1.67 \pm 0.04\)).

When response bias \(c\) was examined in different emotional Go and NoGo trials, there

Table 1. Between-group differences in perceptual sensitivity and response biases to emotional Go and NoGo stimuli (means ± SD)

<table>
<thead>
<tr>
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<th>Healthy volunteers</th>
<th>Bipolar patients</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>target (Go)</td>
<td>distractor (NoGo)</td>
</tr>
<tr>
<td>(d') (sensitivity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>negative</td>
<td>2.68 ± 0.70*</td>
<td>2.16 ± 0.61**</td>
</tr>
<tr>
<td>positive</td>
<td>1.75 ± 0.54</td>
<td>1.72 ± 0.44</td>
</tr>
<tr>
<td>neutral</td>
<td>1.57 ± 0.54*</td>
<td>1.95 ± 0.50</td>
</tr>
<tr>
<td>(c) (bias)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>negative</td>
<td>0.04 ± 0.34</td>
<td>-0.38 ± 0.31</td>
</tr>
<tr>
<td>positive</td>
<td>0.02 ± 0.47</td>
<td>-0.14 ± 0.25</td>
</tr>
<tr>
<td>neutral</td>
<td>-0.31 ± 0.33</td>
<td>0.17 ± 0.39</td>
</tr>
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Note: Healthy volunteers demonstrated greater perceptual sensitivity when responding to negative and neutral targets and when inhibiting negative distractors relative to bipolar patients

* \(p < .05\), ** \(p < .01\)
was a significant main effect of valence ($F(2, 410) = 41.04, \eta^2 = .17$) on participants’ response bias, with more decreased response bias for negative stimuli than for neutral stimuli. Furthermore, there was also a significant main effect of trial type ($F(1, 205) = 36.38, \eta^2 = .16$), indicating greater response bias in Go trials than in NoGo trials.

There was also a significant interaction effect between valence and trial type ($F(2, 410) = 107.99, \eta^2 = .35$), indicating higher response bias for neutral distractors than for neutral targets ($0.20 \pm 0.03$ versus $-0.30 \pm 0.02$), which is in contrast to the observed pattern for positive and negative stimuli, where there was greater response bias for emotional targets compared to distractors of the same emotional valence (positive targets versus positive distractors: $0.05 \pm 0.03$ versus $-0.17 \pm 0.02$, negative targets versus negative distractors: $0.03 \pm 0.02$ versus $-0.36 \pm 0.02$). There was no significant main effect of group, indicating similar levels of criteria used to make decisions about emotional stimuli in both groups.

DISCUSSION

We examined emotional processing biases in cognitive control processes in groups of remitted bipolar outpatients and healthy volunteers.

Overall between-group differences indicate that healthy volunteers demonstrated superior and more efficient cognitive control performance marked by heightened perceptual detection of negative targets and distractors, possibly related to a more successful inhibition of negative distractors and to faster processing during inhibition of positive and neutral distractors. This finding is only partially in agreement with previous studies reporting undetected performance abnormalities of remitted bipolar patients (Wessa et al., 2007; Schulz et al., 2008; Kaladjian et al., 2008), as it revealed heightened sensitivity to emotional triggers in relation to diminished cognitive control also in remitted state of bipolar disorder.

The results of this study revealed that bipolar patients demonstrated an altered pattern of emotional modulation of cognitive control processes compared to healthy volunteers. The most prominent between-group difference emerged regarding the differential impact of negative versus positive valence on processing speed with respect to the trial type that was observed in healthy volunteers, yet undetected in bipolar patients. Specifically, negative stimulus valence influenced the performance of healthy volunteers in a manner of more accelerated processing of negative targets relative to positive targets, while slowed down processing of negative distractors compared to the processing of positive distractors. Comparable processing speed of negative and positive stimuli observed in bipolar patients may be viewed as indicator of emotion dysregulation implicated in bipolar disorder which is characterized by misinterpretations of emotional stimuli (Murphy, Sahakian, 2001).

Further evidence for an altered emotional influence on cognitive control processes in bipolar patients is supported by the finding that negative distractors interfered with response inhibition more grossly in bipolar patients than in healthy volunteers, as indicated by higher rate of commission errors in negative distractor trials made by bipolar patients. Diminished response inhibition of negative distractors could have been due to a reduced perceptual sensitivity to negative distractors displayed in bipolar patients.
Despite the between-group differences found in emotionally modulated cognitive control performance, there were also some similarities in the observed pattern of emotional influence on recognition accuracy and magnitude of response bias in both groups. With regard to the latter, emotional stimuli influenced response biases in participants in a predicted manner; namely, when inhibition of emotional distractors was required, participants showed an evident bias toward withholding response and when target recognition was required, the decision criteria were bounded toward executing response.

However, neutral stimuli influenced response biases in the opposite way, i.e. biasing toward non-response in target recognition trials and biasing toward response initiation in inhibition trials. This finding suggests that processing of non-emotional stimuli differs from processing of emotional stimuli in that it is in competitive disadvantage for attentional resources, as emotional valence processing seems to be prioritized over the processing of neutral stimuli (Pessoa et al., 2002). Another evidence pointing to the preferential processing of emotional over non-emotional stimuli is recorded in higher false alarms rates when inhibition of neutral distractors was required. Neutral distractors indeed facilitated response inhibition compared to negative stimuli, but at the same time neutral targets were more poorly recognized compared to emotional targets. The possible explanation for this finding is that neutral targets were competing in unprivileged position for the same attentional resources, already engaged in processing of emotionally loaded stimuli, alongside with requiring more top-down attentional control than processing of emotionally loaded stimuli. Taken together, we observed a biasing effect of neutral stimuli toward facilitating response inhibition and interfering with target recognition, which is in contrast with the influence of emotional stimuli exerted on cognitive performance toward facilitating target recognition and impairing response inhibition. The latter effect was significantly more marked for negatively than for positively loaded stimuli. This finding could be interpreted in the light of enhanced detection and preferential processing of threatening stimuli (stimuli with negative valence) which is thought to be more adaptive from both evolutionary and psychological perspectives, since engaging in avoidance behavior prevents potential harm or unpleasant social exchanges (Nasrallah et al., 2009).

Furthermore, the results of our study indicate that emotional stimuli not only differentially modulated performance measures, but were also more readily attended to than neutral stimuli, as indexed by diminished perceptual sensitivity to neutral stimuli, and thus further supporting existing evidence for preferential access of emotional stimuli to perceptual processing (Nasrallah et al., 2009; Pessoa et al., 2002).

Though congruent with existing evidence (Schulz et al., 2008), it is nevertheless an interesting notion that positive distractors more grossly interfered with response inhibition compared to negative and neutral distractors. This finding is in line with previous behavioral as well as electrophysiological evidence for positive distractors requiring greater mobilization of inhibitory resources than negative ones (Albert et al., 2009), and resonates with the observation that positive affect enhances the scope of attention by reducing the functionality of inhibitory control mechanisms (Rowe et al., 2007).
Some limitations of our study should be mentioned. First, comparison groups differed in achieved educational level, which may have accounted for the differences in performance on the emotional Go/NoGo test in favor of healthy volunteers. Therefore, we entered education as a covariate in ANOVA, but the corrected performance results for the education effect did not differ from the original data, so uncorrected results are reported here. Second, bipolar patients were not a uniform group with regard to taking diverse combinations of different psychotropic medication and, therefore, medication effects were not statistically controlled. As a consequence, the effects on task performance due to medication cannot be fully disentangled from the effects of cognitive deficits, inherent to bipolar disorder. Third, there was a lack of data on current state of remission in bipolar patients, as there was a 2-4 week time delay between psychiatric assessment of mood status and cognitive testing. Despite the psychiatric assessment of remission status prior to testing, results might have been influenced by subsyndromal depression or manic symptoms, which might have appeared in bipolar patients afterwards.

To sum it up, the results of this study suggest that processing emotionally salient pictorial stimuli modulates performance on task-engaging cognitive control processes at different levels, from target detection to response inhibition in healthy volunteers and bipolar patients. Specifically, negative emotional valence exerted greater impact over positive and neutral valence on cognitive performance, in that negative stimuli modulated several aspects of cognitive control, as suggested by enhanced detection and faster processing of negative targets and greater interference with response inhibition of negative distractors. Consistent with pronounced interference between emotional and cognitive processing in bipolar disorder (Murphy, Sahakian, 2001), bipolar patients showed decrements in cognitive control processes as indexed by a reduced perceptual sensitivity to negative and neutral stimuli, more impaired response inhibition and slower processing of these stimuli.

Our findings add to the converging evidence on the incorporation of experimental paradigms, requiring task-adjusted cognitive control processes in the assessment of the interaction between emotional processing and response inhibition, as in this manner emotional processing biases can be elicited more directly. These paradigms might also assist in eliciting and characterizing dysfunctional, emotional processing biases implicated in affective disorders and might help to specify regulatory functions of cognitive control processes that are not yet clear.

To conclude, results of the present study revealed that negative emotional valence most strongly modulated different levels of cognitive control processing, from target detection, response execution to response inhibition, with this effect even enhanced in cognitive performance of bipolar patients. The evidence for the interaction between emotional and cognitive control processing occurring at the behavioral level is scarce, due to the paucity of relevant studies not only in Slovenia, but also abroad. The use of the Emotional Go/NoGo task may have important therapeutic implications in the regulation of over-exaggerated response to emotional triggers in both at-risk and clinical populations.

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Súhrn: Nedostatok behaviorálnych štúdií o vplyve emócií na procesy kognitívnej kontroly sťažuje možnosť určiť stupeň vplyvu emočných podnetov na procesy kognitívnej kontroly. Skúmali sme skreslenia spôsobené vplyvom emócií v procesoch kognitívnej kontroly u veľkých skupín zdravých jedincov a pacientov s bipolárnu poruchou. Skúmané osoby sme rozdelili podľa veku a pohlavia, ktoré na počítači riešili úlohu Emotional Go/NoGo. Výsledky ukázali, že v porovnaní s neutrálnymi podnetmi, emočne ladené podnety spomaľujú reakcie. Najviac diferencujúci vplyv na rozpoznanie cieľa a spomalenie reakcie v oboch skupinách mali negatívne ladené emočné podnet. V porovnaní s pacientmi s bipolárnu poruchou sa u zdravých skúmaných osôb zistila vysoká kognitívna kontrola a zmena v schéme skreslenia spracovania emócií. Výsledky diskutujeme vzhľadom na preferenčné spracovanie emočných podnetov a na existujúce medziskupinové rozdiely pri spracovávaní emócií, ktoré sa dajú pripísať charakteristikám bipolárnej poruchy.