Biological Psychiatry: CNNI

Competition Effects in Visual Cortex Between Emotional Distractors and a Primary Task in Remitted Depression

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ABSTRACT

BACKGROUND: Attentional biases, particularly difficulty inhibiting attention to negative stimuli, are implicated in risk for major depressive disorder (MDD). The current study examined a neural measure of attentional bias using a continuous index of visuocortical engagement (steady-state visual evoked potentials) before and after a negative mood induction in a population at high risk for MDD recurrence because of a recently remitted MDD (rMDD) episode. Additionally, we examined working-memory (WM) capacity as a potential moderator of the link between rMDD and visuocortical responses.

METHODS: Our sample consisted of 27 women with rMDD and 28 never-depressed women. To assess attentional inhibition to emotional stimuli, we measured frequency-tagged steady-state visual evoked potentials created from spatially superimposed task-relevant stimuli and emotional distractors (facial displays of emotion) oscillating at distinct frequencies. WM capacity was assessed during a visuospatial memory task.

RESULTS: Women with rMDD, relative to never-depressed women, displayed difficulty inhibiting attention to all emotional distractors before a negative mood induction, with the strongest effect for negative distractors (sad faces). Following the mood induction, rMDD women's attention to emotional distractors remained largely unchanged. Among women with rMDD, lower WM capacity predicted greater difficulty inhibiting attention to negative and neutral distractors.

CONCLUSIONS: By exploiting the phenomenon of oscillatory resonance in the visual cortex, we tracked competition in neural responses for spatially superimposed stimuli differing in valence. Results demonstrated that women with rMDD display impaired attentional inhibition of emotional distractors independent of state mood and that this bias is strongest among those with lower WM capacity.

Keywords: Attentional bias, Major depressive disorder, Risk and resilience, Steady-state visual evoked potentials, Visuocortical competition, Working memory

http://dx.doi.org/10.1016/j.bpsc.2016.12.007

The human visual system is exposed to more information than it can process given constraints on bandwidth and representational capacity (1). To enable adaptive behavior in complex environments, individuals display selective attention to information relevant to a certain task while inhibiting attention to task-irrelevant information (2). However, even while engrossed in a primary task (e.g., reading in a subway car), our attention can be readily captured by salient emotional distractors (e.g., the loud argument of a copassenger) (3). The neural circuitry involved in this involuntary (bottom-up) capture of attention consists of several corticolimbic regions that send projections into sensory systems. Under some circumstances, the extent of bottom-up capture of attention, particularly for negative emotional content, can become excessive, outcompeting top-down regulatory inputs from frontoparietal systems that maintain task-focused attention (2). Chronic biases in attention to distracting emotional information are central to theories of emotional disorders such as major depressive disorder (MDD) (4).

There is considerable evidence that individuals with MDD display attentional biases to depression-relevant information (5). This trait persists following remission as individuals with remitted MDD (rMDD) exhibit selective attention to negative stimuli (6–10), which predicts prospective increases in depressive symptoms (11–13) and MDD recurrence (10). Despite the strengths of previous research in this area, the majority of these studies have relied on behavioral protocols such as the dot-probe task, which uses reaction time indices to examine static "snapshots" of attentional deployment. Recent research has highlighted problems with the reliability of reaction time–based measures of attention (14–16), leading to the use of eye-tracking indices with greater reliability and precision (14). Despite the utility of having a continuous index of visual processing, eye tracking still relies on overt behavior and

 ISSN: 2451-9022

cannot capture covert shifts of attention (17). Additionally, neither reaction time nor eye-tracking indices can discriminate the focus of attention when stimuli overlap in space and time, which precludes a direct examination of attention under conditions of maximal competition (18). Depending on the amount of spatial separation between stimuli, the actual competition for neural responses may be considerably weakened or, in some situations, eliminated altogether if the visual receptive fields are nonoverlapping (1,19). Therefore, although behavioral measures have provided evidence of attentional biases (5–10) and inhibition deficits in MDD (20), there is scant evidence to specifically link difficulty inhibiting attention to emotionally salient distractors relative to concurrent task-relevant stimuli in MDD. This is concerning as attentional biases in MDD are thought to be specific to difficulties inhibiting attention to distracting depression-relevant information relative to goal-relevant information (4). To address these limitations, we used an electrophysiological measure—steady-state visual evoked potentials (SSVEPs)—that provides a continuous index of the degree to which attention is allocated to irrelevant versus goal-relevant stimuli.

In brief, SSVEPs are large-scale oscillatory field responses of the visual cortex evoked in response to rhythmic luminance modulation of a visual stimulus at a fixed frequency. The SSVEP has the same temporal frequency as the driving stimulus and its amplitude tracks fluctuations in attention to the driving stimulus (21,22). Of particular interest here is the possibility of "frequency-tagging" SSVEPs to discriminate neural responses to items that are spatiotemporally superimposed in the visual field by assigning a distinct frequency to each stimulus (23). This is particularly advantageous because competition effects are maximal in situations that involve overlap of visual receptive fields as happens with spatiotemporal superposition of stimuli (3,24,25).

The primary aim of the current study, therefore, was to use SSVEPs to evaluate how the visual system resolves the trade-off between task-relevant neutral stimuli and emotional distractors in women known to be at high risk for MDD recurrence compared to women who were never depressed. This high-risk population (i.e., women who had a fully remitted episode of MDD within the past 5 years) is at risk for two key reasons: 1) women have twice the rate of MDD than men (26–28) and 2) over 60% of individuals who develop MDD will experience at least one recurrent episode within 5 years of remission (29). Based on previous research using behavioral measures of attention (6–10), we hypothesized that rMDD women, compared with their never-depressed counterparts, would display difficulty inhibiting attention to negative distractors. Given some evidence that attentional biases in individuals with rMDD may remain latent until primed by a negative mood induction [(30,31); but see (32)], our secondary aim was to determine whether women's attention to emotional distractors changed from before to after a sad mood induction.

Finally, although there is a clear link between attention and depression, there is also a well-known heterogeneity of cognitive profiles in MDD (33). Therefore, when seeking to identify moderators of attentional bias, it is helpful to focus on neuropsychological factors known to affect the visual system. With regard to attentional inhibition, visuospatial working memory (WM) may be important because of its role in an individual's ability to filter relevant from irrelevant visual information. Research has demonstrated that WM capacity predicts activity in the visual cortex when suppressing distracting information and that individuals with lower WM capacity have difficulty inhibiting attention to task-irrelevant information (34), an effect exacerbated by dysphoria (35). Additionally, there is a well-established link between MDD and WM deficits (36) and evidence that WM training can improve dysphoric individuals' ability to filter irrelevant information from visual attention (37). Notably, WM deficits in MDD are not typically resolved with intervention or remission (38), so the identification of cognitive biases linked to WM deficits may provide novel avenues for intervention. In the current study, we predicted that rMDD women with lower WM capacity would have the greatest difficulty inhibiting attention to task-irrelevant negative distractors.

METHODS AND MATERIALS

Participants

Participants were 55 women recruited from the community. Twenty-seven women had a history of MDD currently in full remission (rMDD) and 28 women had no lifetime history of any depressive disorder. Women in the never-depressed group had no history of any Axis I DSM-IV disorder (39). The rMDD women could not have any current Axis I diagnosis, history of alcohol or substance dependence or abuse within the last 6 months, or a lifetime history of schizophrenia or bipolar disorder, and their MDD must have fully remitted within the last 5 years. Women with a lifetime history of seizures were excluded from the study given concerns that the luminance modulation used during the change-detection task could induce a seizure in these women. Similar to previous research (32), we excluded participants who experienced no change or decreases in sadness from before to after the negative mood induction ($n = 4$) to ensure that the mood induction was successful. The mean age of women in the sample was 31.80 ± 6.23 years, 76% were Caucasian, and the median annual family income was $45,001 to $50,000.

Measures

The Structured Clinical Interview for DSM-IV Disorders (40) was used to assess for lifetime histories of psychiatric disorders. Women's current depression symptoms in the past 2 weeks were assessed using the Beck Depression Inventory-II (41).

Women's attentional inhibition to emotional distractors relative to task-relevant stimuli was assessed both before and after the negative mood induction using a simple change-detection paradigm [adapted from (25); see Figure 1]. Participants sat 65 cm away from a 27-inch ASUS LCD monitor (AsusTek Computer Inc., Taipei, Taiwan) with a refresh rate of 60 Hz. On each trial, a facial stimulus was presented at the center of the screen for 5000 ms. Faces were flickered on and off (40% active duty cycle) at a frequency of 12 Hz (f^1) to evoke SSVEPs frequency-tagged to the face. A semitransparent 90º-oriented Gabor patch was superimposed over the face, flickering on and off (50% active duty cycle) at 15 Hz (f^2) to evoke SSVEPs frequency-tagged to the Gabor. Trials ended