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The Role of Avoidance Motivation in the Relationship Between Reward Sensitivity and Depression Symptoms in Adolescents: An ERP study

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Abstract

Blunted neural responses to reward in an EEG paradigm (RewP) are associated with vulnerability to depression, but the pathways linking this biomarker to depressive symptoms are unclear. We examined whether the relationship between reward response (RewP mean amplitude and latency) and depression was in part explained by approach-motivated behaviors in adolescents with varying levels of depression. EEG was collected during a game rigged to provide win/loss trials. Longer RewP latency was associated with depression symptoms only when scores on a measure of avoidance motivation were included. These results suggest that treatments targeting avoidance may decrease vulnerability to depressive episodes.

Keywords

reward response; depression; ERP; approach motivation

Introduction

Anhedonia—decreased motivation and reactivity toward pleasurable stimuli—is a feature of numerous psychiatric disorders, including depression (Admon and Pizzagalli, 2015; Der-Avakian and Markou, 2012). Depression onset often occurs in adolescence, the peak period for the neural development of reward circuitry (Auerbach et al., 2014; Forbes, 2009; Thapar et al., 2012). Whereas adolescence is typically marked by heightened reward sensitivity (Spear, 2000), depressed adolescents have a difficult time experiencing reward and overcoming avoidance (Forbes, 2009). Disruptions of reward circuitry in the medial prefrontal cortex and subcortical areas such as the anterior cingulate cortex (ACC) and ventral striatum (Carlson et al., 2014; Gottfried et al., 2003; Knutson et al., 2003) may increase risk for depression (Auerbach et al., 2014; Bress et al., 2013; Holroyd and Umemoto, 2016; Pizzagalli et al., 2005).

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Sensitivity to rewarding versus non-rewarding stimuli can be indexed by the reward positivity (RewP), an event-related potential (ERP) acquired with EEG. This neural response is positively correlated with activation of the ventral striatum and dorsal anterior cingulate (Becker et al., 2014; Foti et al., 2011b). The RewP is typically maximal in medial frontocentral channels and has a deflection that occurs approximately 250-550ms post reward or loss feedback and thus is considered an index of reward response. Reward responsivity, using the RewP, purportedly reflects individual differences in approach-motivated affect and behaviors (Angus et al., 2015; Proudfit, 2015; Threadgill and Gable, 2016). Approach-motivation is activated by signals of reward, whereas avoidance-motivation is activated by signals of loss/failure (Carver and Harmon-Jones, 2009; Coan and Allen, 2004). Dysregulation of the approach/avoidance-motivation system may be a mechanism involved in the association between blunted reward responses and depression (Depue and lacono, 1989; Harmon-Jones et al., 2010).

While there is clear evidence that the RewP is associated with approach-motivated states and traits, the relationship between avoidance-motivation and the RewP is less clear. Lower RewP is associated with negative emotional states (e.g., anxiety, depression), (Foti and Hajcak, 2009; Gu et al., 2010, 2010) increased depression vulnerability and more severe symptom course, (Bress et al., 2013; Foti et al., 2011a; Kujawa et al., 2014; Weinberg et al., 2015; Whitton et al., 2016) but no work exists on the RewP and avoidance-motivation.

Given that depression symptoms have been associated with the avoidance of prospective rewards (Winer and Salem, 2016), we probed whether individual differences in approach- and avoidance-motivation play a role in the relationship between blunted reward processing and depression in adolescents. We used neurophysiological measures of reward response (RewP) and self-reported approach- and avoidance-motivation (Carver and White, 1994) to understand the mechanisms through which reduced reward responsivity is associated with depressive symptoms. We explored three hypotheses: 1) Reduced RewP mean amplitude and longer peak latency would be associated with depression (Proudfit, 2015); 2) blunted reward response would be associated with avoidance-motivated affect and behavior (Winer & Salem, 2016); 3) avoidance-motivation would have a role in the relationship between the RewP and depression.

Method

Sample.

Adolescents between 12-17 years (N=20) were recruited from a mood clinic. A dimensional approach to depression resulted in varied symptom profiles of participants. The majority had a history of a mood disorder (n=15), which was not necessary for inclusion (n=5) (no mood disorder) and had additional comorbidities (see Table 1). Parents and youth provided consent prior to study procedures approved by the University of California-Los Angeles Medical Institutional Review Board. Exclusion criteria were: 1) use of psychoactive drugs; 2) psychosis, autism spectrum disorder, substance abuse; 3) serious neurological conditions or brain trauma; or 4) sensory impairments. Sample characteristics are in Table 1.

Procedure.

Following diagnostic interviewing, adolescents completed questionnaires. They were fitted with EEG electrodes and completed the computer task while continuous EEG data were collected.

Diagnostic Assessments.

The Kiddie-Schedule for Affective Disorders and Schizophrenia (K-SADS) (Chambers WJ, 1985) was administered to participants and parents by a doctoral level clinician during clinic intake or during study visit (non-clinic participants). Participants were interviewed using the *Depression Rating Scale (DRS)* (GELLER et al., 2001) to assess dimensional levels of depression symptoms over the previous week. Summary scores were derived from the parent and child responses to the DRS using best estimate consensus ratings.

Affective Posner task.

This task involved 100 trials beginning with a fixation cross (500-5000ms), followed by a cue in one of two boxes positioned side-by-side (200ms), then a target within one of the boxes. Participants respond as quickly as possible as to which box the target was presented. Feedback was adjusted where 40% of correct trials were provided true feedback and monetary reward (“You are Quick! Win 25 cents”); the remaining 60% of correct responses resulted in loss feedback (“Too Slow! Lose 25 cents”) presented on the computer screen.

BIS/BAS Scales.

Participants use a 4-point Likert scale ranging from *very true for me* to *very false for me* to indicate how much they agree with self-statements associated with approach and avoidance behaviors (Carver and White, 1994). The BIS includes items covering the anticipation of or response to punishment (Cronbach’s α=.83). The BAS subscales are Drive (α=.79), Fun-Seeking (α=.72) and Reward Responsiveness (α=.62).

Electroencephalography (EEG).

EEG utilized 40 Ag/AgCL surface electrodes using an extended international 10/20-location system (ElectroCap, Eaton, OH). MANSCAN (Sam Technology, San Francisco, CA) hardware/software was used to continuously record EEG at a rate of 256 samples per second and referenced to linked-ears. Impedance was <10 kOhms. Data were processed within Matlab (Mathworks) utilizing EEGLAB functions (Delorme and Makeig, 2004). A high-pass filter at <1Hz and low pass filter at 58Hz were used, followed by manual removal of bad channels. Data were segmented into .5 second bins, and any segment outside 5 standard deviations of overall data was removed up to a 10% maximum.

Independent Component Analysis (ICA) separated neural and artifact signals using parameters by binica in EEGLAB. ICs representing non-brain activity were removed. Data were epoched 2s before and after each feedback event. An average of 75% of trials (range 69-94) were retained after cleaning. We calculated mean ERPs using as baseline the 200ms interval prior to feedback. To calculate RewP, difference scores (win-loss) were calculated

using the Fz electrode. Mean amplitude 250-350ms after feedback (win-loss) and latency of this peak (win-loss) were used for the RewP calculation (see Figures 1 and 2).

Data Analyses

Analyses used IBM SPSS v24 software. The four steps outlined by Baron and Kenny (1986) tested direct effects and hypotheses regarding the role of approach/avoidance motivation. In step one, linear regression examined whether neural response to reward (RewP amplitude/latency) predicted depression symptoms (DRS total). In step two, linear regression models examined whether the RewP was associated with motivation-related emotions/behaviors (i.e., subscales of the BIS/BAS). Third, linear regression examined whether the approach/avoidance motivation was associated with depression symptoms, controlling for RewP. Finally, we examined whether the effect of the predictor (RewP) on the outcome variable (DRS total) remained significant, controlling for the mediator (BIS/BAS). Totals were calculated for the outcome variables. In addition to the change score used to quantify RewP (Reward – Loss), RewP-reward and RewP-loss scores were examined as independent predictors of depression. Age was excluded as a covariate; it was not associated with the RewP, our predictor variable.

Results

Preliminary Analyses.—BIS total scores were positively correlated with DRS total scores $(r(18)=.70, p<.01)$. RewP mean amplitude was not associated with depression symptoms or BIS/BAS scores, so steps 1 and 2 outlined above were not supported to do the additional analyses using mean amplitude as a predictor. BAS subscales were unrelated to RewP latency; the BIS/RewP latency relationship is described below. Table 1 displays means and standard deviations for outcome variables.

The Role of Avoidance Motivation.—Direct effects of the RewP latency on depression symptoms ($R^2=.30$, $\beta=.55$, $t=2.60$ $p=.02$) and withdrawal behaviors (BIS subscore) ($R^2=.26$, $\beta=.51$, $t=2.34$, $p=.03$) were revealed, satisfying the first two steps in the model. To demonstrate step 3, we examined whether BIS score was associated with DRS, when controlling for RewP latency. Results confirmed that BIS score remained significantly associated with depression ($R^2=.60$, $\beta=.63$, $t=3.23$, $p<.01$). This model also confirmed the final step—when the BIS score was included, the relationship between RewP latency and depression was no longer significant ($p=.25$) (see figure 3).

Follow-up analysis.—The *difference* between win/loss trials cannot identify whether this difference is due to quicker response to loss, longer response to reward, or both. To clarify whether response to loss or reward was more strongly associated with depression, we examined individual associations between RewP-loss latency and depression and RewP-reward latency and depression. Loss-latency was not associated with depression. However, longer latency of reward was associated with greater depression $(r(19)=.52, p=.02)$, but not to BIS score $(r(19)=.37, p=.13)$.

Discussion

Reduced reward response and anhedonia are negative prognostic indicators for the remission of adolescent depression (McMakin et al., 2012). The RewP is considered to be a neural correlate of reward responsiveness and is a predictor of depression vulnerability and course. Less is known, however, about the specific pathways that link dysfunctions in the brain's reward circuitry, indexed by the RewP, to depressive symptoms like anhedonia. This study suggests that avoidance-motivation can help to explain the relationship between reduced reward responsivity and depression symptoms.

A longer RewP latency of onset was associated with depression and avoidance-motivation. This latency reflected a delayed onset of the RewP to rewards, rather than a quicker processing of loss (Mulligan and Hajcak, n.d.) suggesting that adolescents who were less efficient at processing rewards had greater depression. These preliminary findings extend the current literature to consider including *both* intensity (amplitude) and processing rate (latency) as features of blunted reward (Proudfit, 2015). Results were inconsistent with work focusing on the association between the RewP amplitude and depression (Proudfit, 2015). Whether previous studies have failed to find an effect of RewP latency in mood disorders or if latency was not examined is not clear. Both should be reported to clarify whether these mechanisms play different roles in the course of depression.

While the RewP has been associated with approach-motivation (Bress and Hajcak, 2013; Lange et al., 2012), results are the first to highlight the potential import of behavioral *avoidance* of reward, in understanding the relationship between the RewP and depression. These findings suggest initial support for the theory of reward devaluation which posits that depressed individuals actively avoid positive information, not just experience blunted reward responses (Winer & Salem, 2016). Behavioral avoidance is thus a mechanistic target for intervention. These avoidance tendencies may have consequences for the adolescent that affect the clinical course depression symptoms (Auerbach et al., 2014; Lewinsohn et al., 1992).

Strengths included the use of multiple levels of assessment (electrophysiology, self-report, clinician rated indices) and the Affective Posner task. The latter allowed for the potential tapping of underlying fears that approaching prospective rewards may result in punishment, as suggested by the Reward Devaluation theory. This cross-sectional pilot study is limited by the small sample size which may be underpowered, resulting in false negatives. The small, heterogeneous sample also precludes examination of the role of concurrent psychopathology, such as anxiety, on these relationships (Dickson and MacLeod, 2004), does not consider developmental factors like pubertal status, and may not be representative of the broader population. Future research should also aim to use alternatives to the BIS that specifically distinguish between avoidance of negative/punishing situations *versus* avoidance of rewarding situations that might ultimately lead to punishment in order to more robustly support Reward Devaluation Theory. While in need of replication, they provide preliminary evidence that avoidance of reward is a potentially crucial and understudied mechanism in adolescent depression.

In summary, results highlight avoidance tendencies as a behavioral mechanism contributing to how neural response to rewards may affect depression symptoms and provide support for the use of behavioral activation (BA) (Dimidjian et al., 2011; Ekers et al., 2014) in depression treatment. BA focuses on avoidance *and* activates the BAS by engaging patients in rewarding activities, despite high BIS, and may thus be a key to improving symptoms (Ekers et al., 2008).

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Highlights

- The reduced reward positivity (RewP) has been related to greater depression symptoms and course.
- Greater RewP latency was associated with greater depression symptoms and higher behavioral avoidance-motivation, as assessed by self-report.
- Blunted reward response was associated with depression only when avoidance motivation was included in the model.
- Less efficient processing of reward in adolescents is associated with greater avoidance, which in turn, is associated with depression symptom presentation in cross-sectional analyses.
- Results support theories highlighting the role of *avoidance of reward* (e.g., Reward devaluation theory) in depression maintenance.

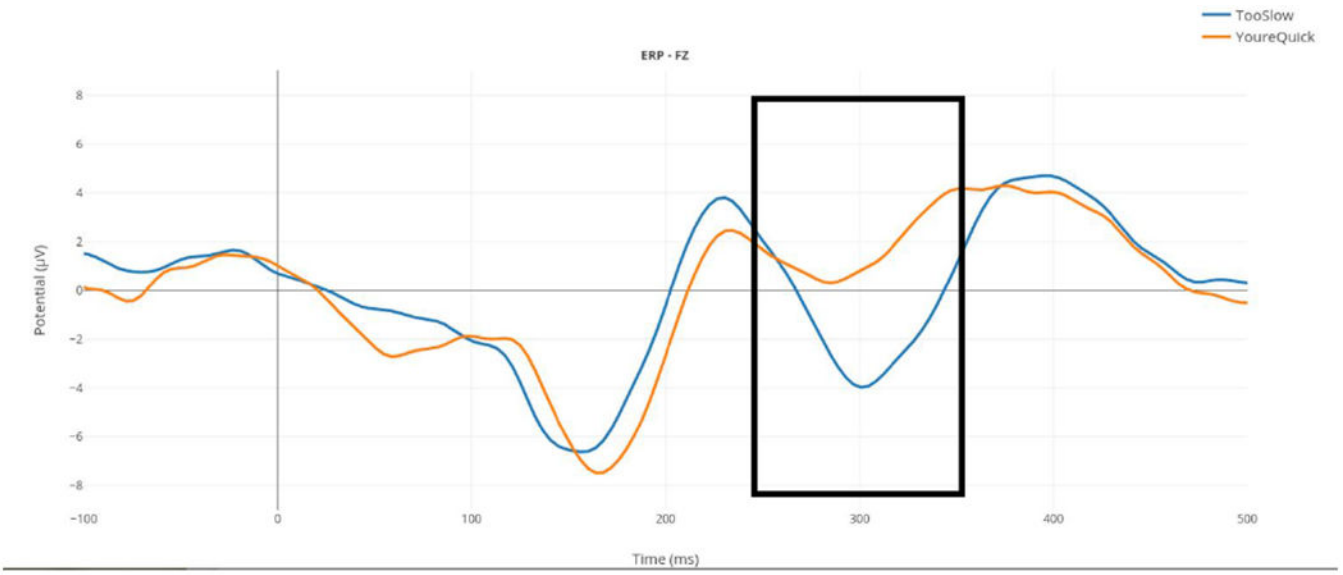

Figure 1.

ERP image from the FZ electrode during win (You're quick, orange line) and loss (Too slow, blue line) trials. Mean amplitude and latency were extracted between 250-350ms.

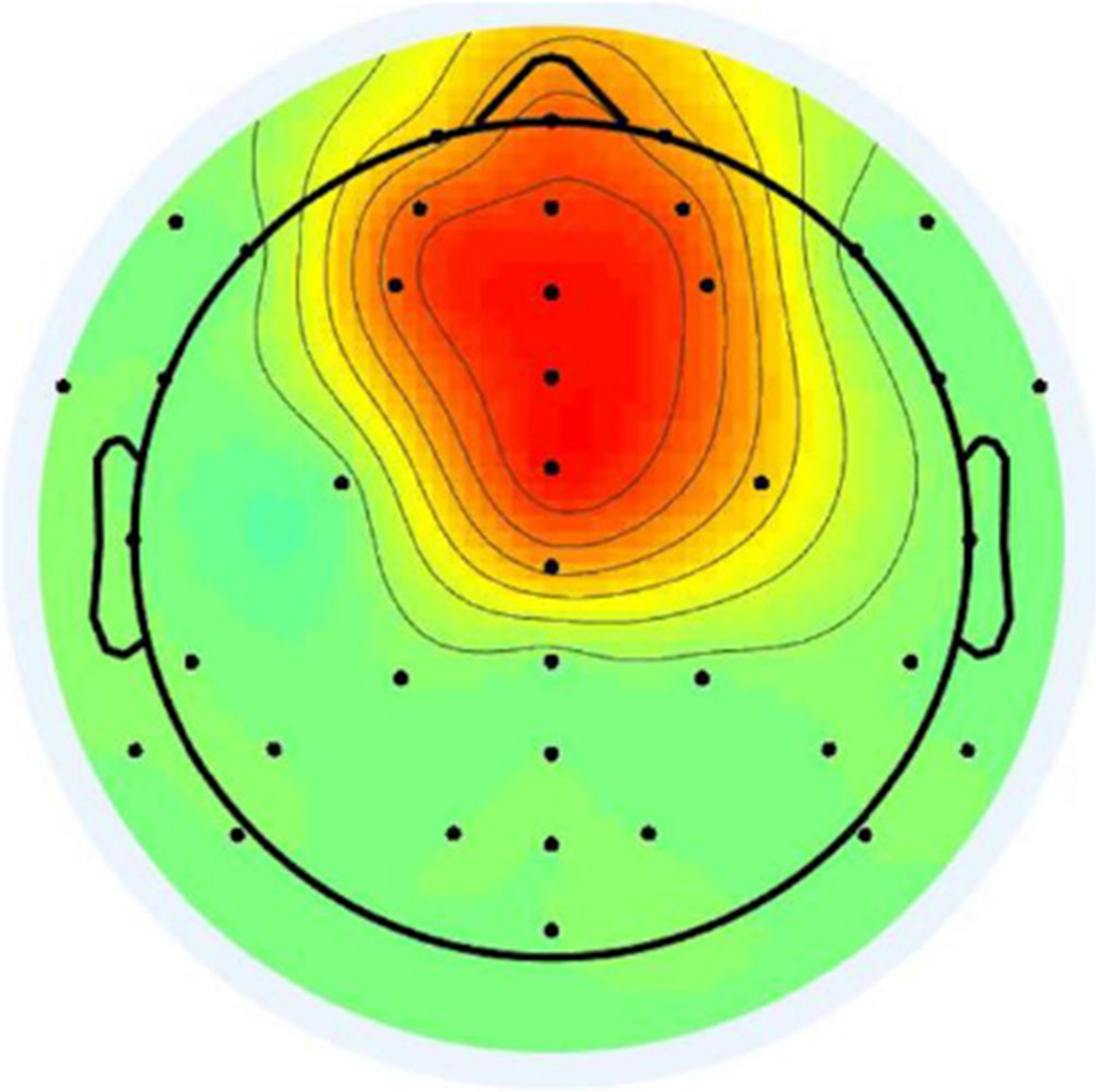

Figure 2.
Scalp distribution of the difference between win (You're quick) and loss (Too slow) trials during the 250-350ms segment used to calculate the RewP amplitude and latency.

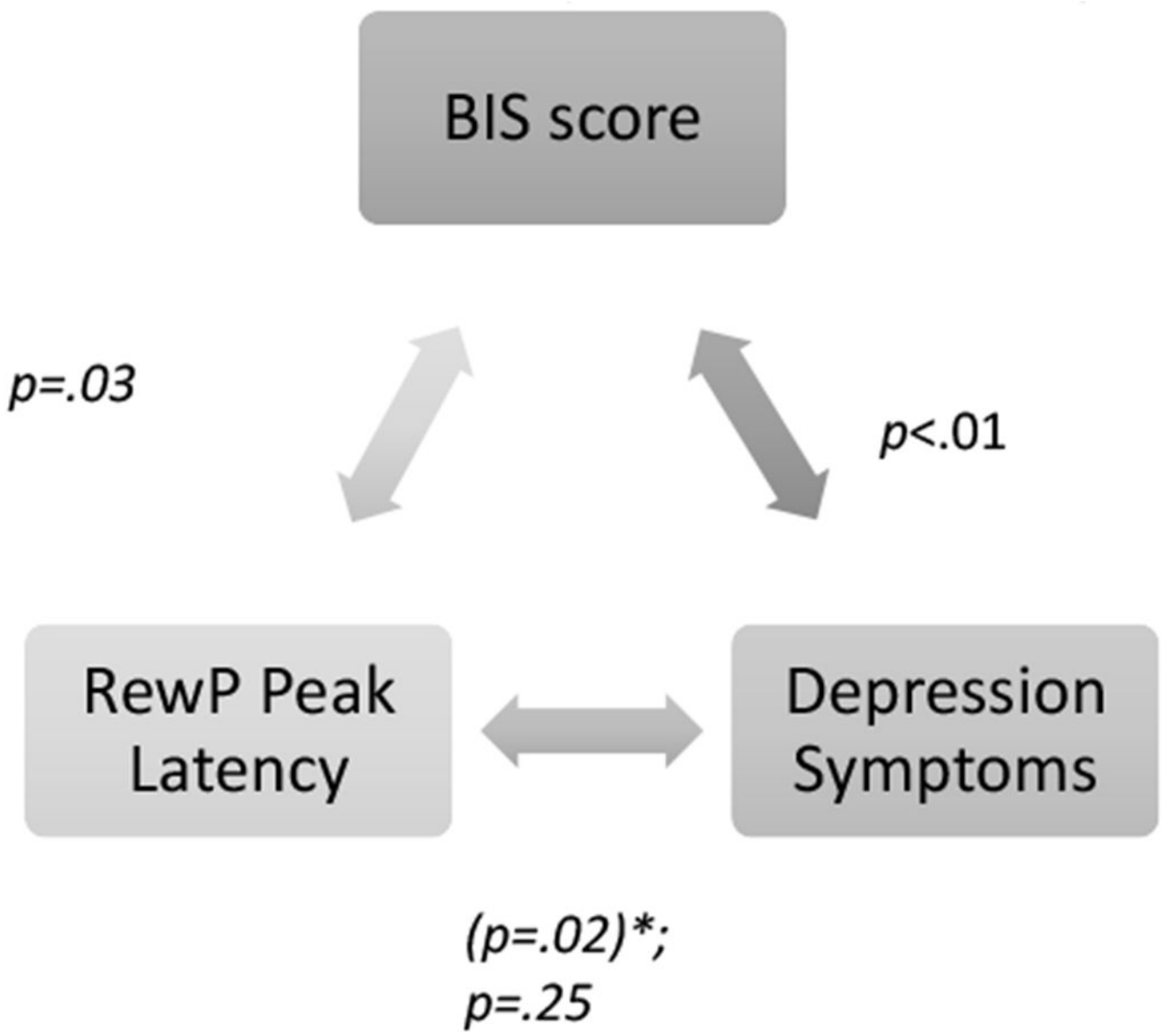

Figure 3.
The role of self-reported avoidance motivation (Behavioral Inhibition Scale [BIS]) score on the relationship between the Reward Positivity (RewP) latency and depression symptoms. *denotes the direct effect of the RewP on depressive symptoms, not including BIS in the model.

Table 1.

Demographic information and sample characteristics.

Demographics (SD)	
M/F (%)	45/55
Age (years)	14.53 (2.09)
Racial Categories (%)	
American Indian/ Alaska Native	4
Asian	0
Native Hawaiian or Other Pacific Islander	5
Black or African American	9
White	59
Other	14
Unknown or Not reported	9
Mood Disorders (n=15 with formal mood disorder diagnosis)	
Past Episode of Major Depression	5
Current Major Depression	4
Bipolar I	2
Bipolar II	2
Bipolar-NOS	2
Psychiatric Comorbidities (of those with mood disorder diagnosis)	
No comorbidities	2
Anxiety	5
Obsessive-Compulsive Disorder	2
ADHD	4
Oppositional Defiant Disorder	3
Group mean (SD) measures	
DRS (Depression Symptoms)	27.30 (11.38)
BAS-Drive	10.65 (3.03)
BAS-Fun	12.00 (2.51)
BAS-Reward	17.45 (2.26)
BIS	20.16 (3.99)
RewP latency (ms) *	−21.29 (33.71)
RewP mean amplitude (μV) *	3.18 (3.40)

DRS=Depression Rating Scale; BAS=Behavior Activation System; BIS=Behavior Inhibition System

* Represents the *difference* score derived from the RewP calculation (e.g., latency indicates a difference of 21.29ms between the win-loss conditions).