# ENHANCED FEEDBACK-RELATED ACC ACTIVITY IN RELATION TO NEGATIVE EMOTIONALITY DURING ADOLESCENCE

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## Background

The FRN is a negative deflection in the ERP elicited by both positive and negative feedback [1], which has been localized to the ACC and other areas of the medial prefrontal cortex (mPFC) [2,3]. Recent adult studies have reported that the FRN is enhanced in the moderately depressed [4], in remitted depressed patients [5] and in high anxious individuals [6]. This suggests that depression and anxiety are associated with hyperresponsivity of the ACC and mPFC in response to feedback.

**Goal:** To see whether the extent of anxious and depressive symptoms in healthy adolescents relates to (i) neural activation associated with performance feedback as reflected in the scalp FRN, and (ii) activation within specific cortical regions (using LORETA) during the time of the FRN to positive and negative feedback.

**Hypotheses:** We expected that
(1) the FRN would be greater to negative than positive feedback in healthy adolescents,
(2) FRN amplitude would correlate with symptoms of anxiety and depression.
(3) depressive symptoms would be associated with greater activity in the ACC in response to negative stimuli.

## Monetary Incentive Delay Task



| 500 ms | 1.0-2.0 s | Variable | Response | 1.0 s | 1.0 s |
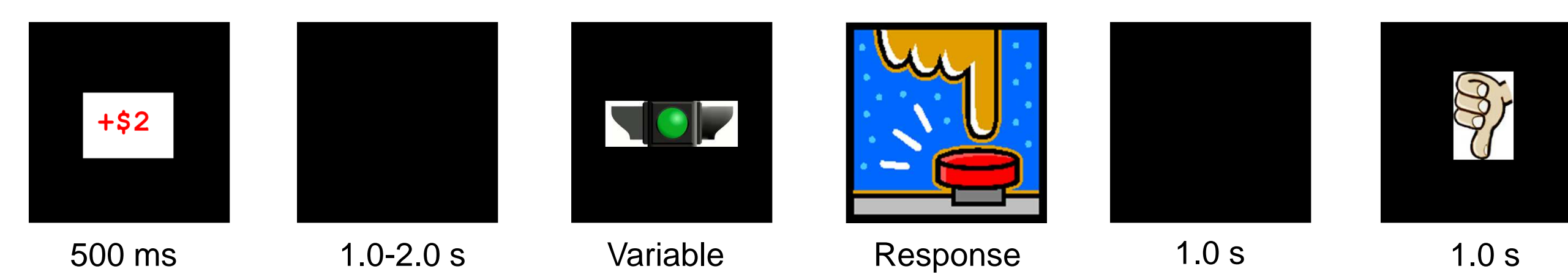
Example of a potential gain cue and loss feedback trial.

- Cues signaled trials with potential large or small monetary reward (+), loss (-) or trials with no gain or loss ($0).
- Participants pressed a key as quickly as possible to a green traffic light.
- Participants' reaction times (RTs) would determine outcome (e.g., rapid RTs led to higher probability of winning money or avoiding loss).
- Target duration was 280 ms on the first trial then adjusted +20 ms or -10 ms on subsequent trials to ensure participants won approximately one third of the time.
- Feedback indicated gain (thumbs up) or loss (thumbs down).

## Method

### Participants
- 24 boys, 21 girls, 12-15 years (Mean 13.2 years ± .80).

### Self-report measure of negative emotionality
- *Center for Epidemiologic Studies Depression* (CES-D) Scale [7].
- *The Student Life Satisfaction Scale* measured negative affect during the last several weeks [8].
- *The Symptom Checklist-90-R* (SCL-90-R) Anxiety subscale [9].

### EEG recording and reduction
- EEG recorded continuously during the task using a 128-channel sensor array.
- ERP epochs were extracted -200 to 800 ms following feedback at Fz.
- Epochs were filtered at 1-30 Hz; baseline was -200 to 0 ms pre-response.

### Low Resolution Electromagnetic Tomography (LORETA)
- Used to examine intracerebral current density underlying the FRN within a 50 ms time window post-feedback, capturing the mean latency of the FRN.
- Pearson correlations performed between current density in predefined regions of interest (ROIs) in the ACC and negative emotionality, Figure 3 [10].
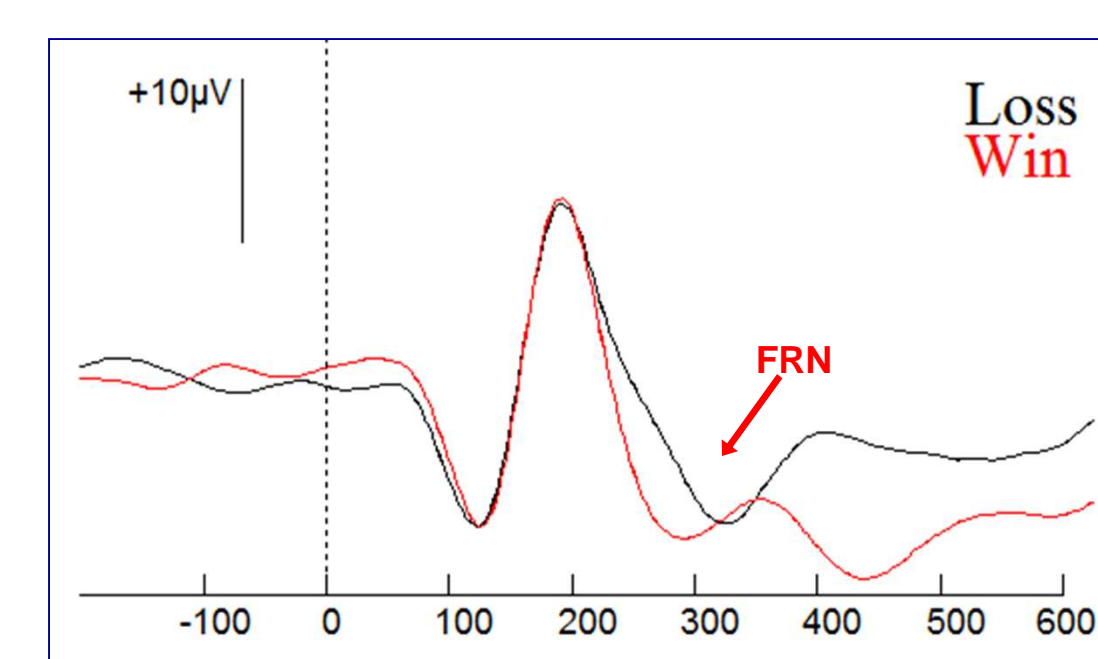
## FRN Results



Figure 1. FRN amplitude at Fz for win (blue) and loss (red) monetary feedback.

- FRNs were based on trials of both reward and loss cues, and did not differ between feedback conditions, t(44) = .24, p = .82, Figure 1.
- Thus, the adolescents did not show the adult pattern of larger FRN for negative than positive feedback.

- Loss feedback FRN related to depression (r = -.45, p = 001), negative affect (r = -.48, p =.001), and anxiety (r = -.31, p =.03), Fig 2A-C.
- Together variables accounted for 27% of the variance in the FRN (p =.003) with negative affect accounting for unique variance (8%, p = .05).
- The FRN to win feedback was unrelated to negative emotionality.



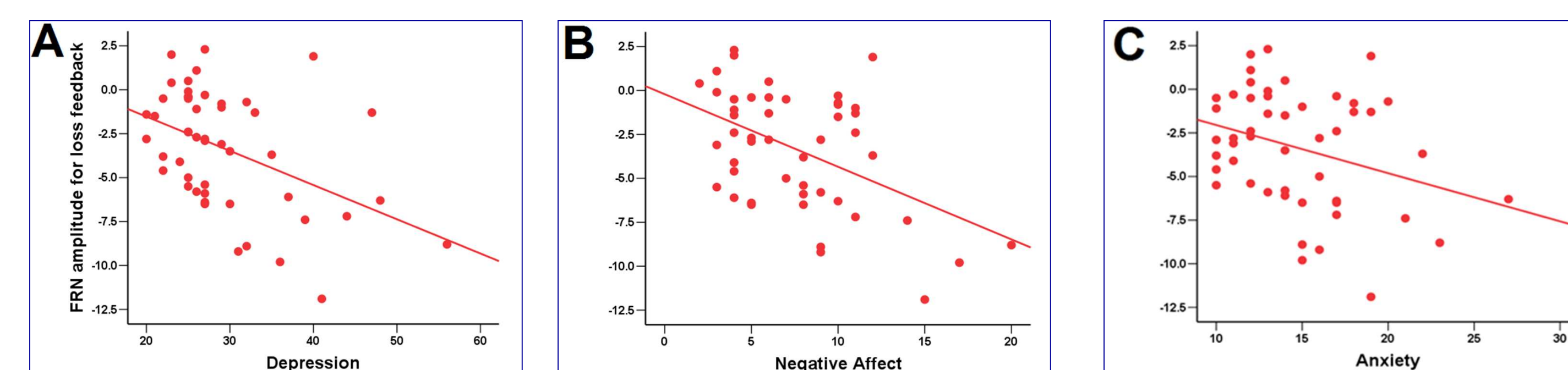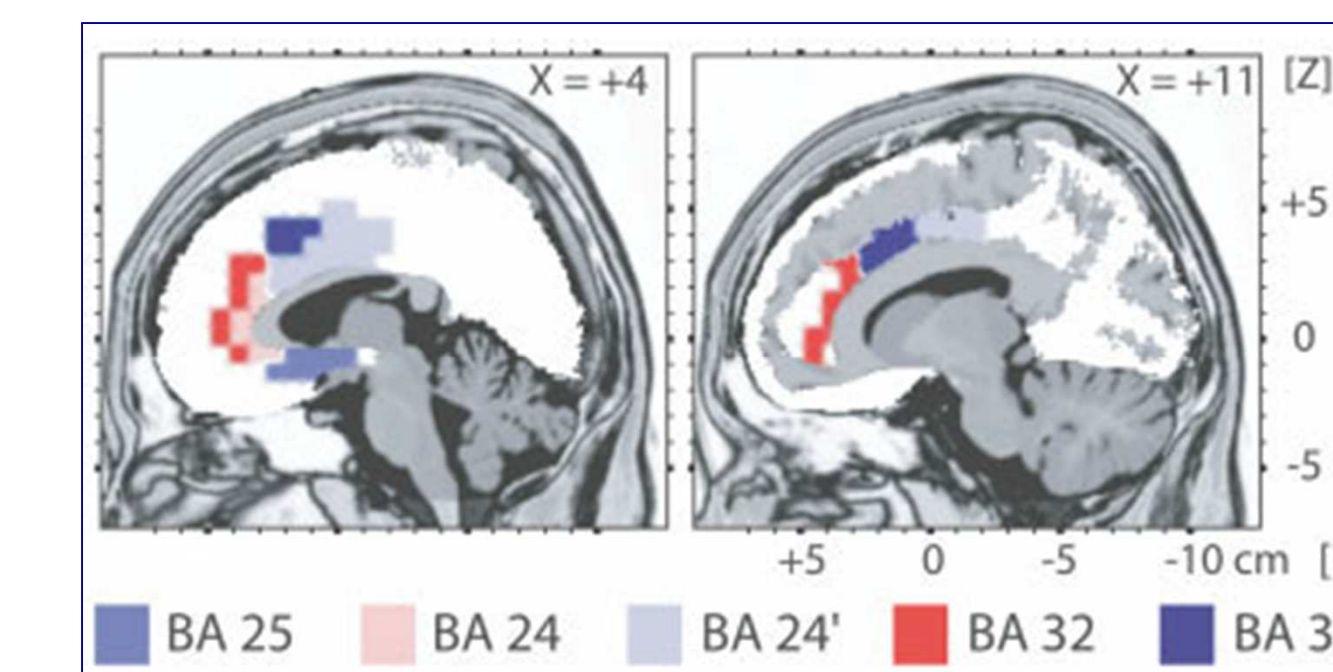Figure 2 A-C. Scatterplots for the correlation between the FRN at Fz for loss feedback and negative emotionality.

## LORETA Source Localization



Figure 3. From Pizzagalli et al. (2006): Location and extent of various ACC subdivisions as defined by the Structure-Probability Maps and displayed on the LORETA template. Coordinates in cm (MNI space).

- LORETA current source density (CSD) from the loss trials (of both cue types) was derived from five ROIs in the ACC including the rostral, dorsal and subgenual ACC, Figure 3 (averaged over left and right hemispheres).

- CSD in the rostral ACC (BA 24, indicated by pink in Figure 3) was significantly related to depression (r =.32 , p =.03) and negative affect (r =.47 , p =.001), Figure 4 A, B. Other regions were not related (rs < .05).
- Depression and negative affect accounted for 22% of the variance in rostral ACC activity (p =.006) with negative affect accounting for unique variance (11%, p =.02).
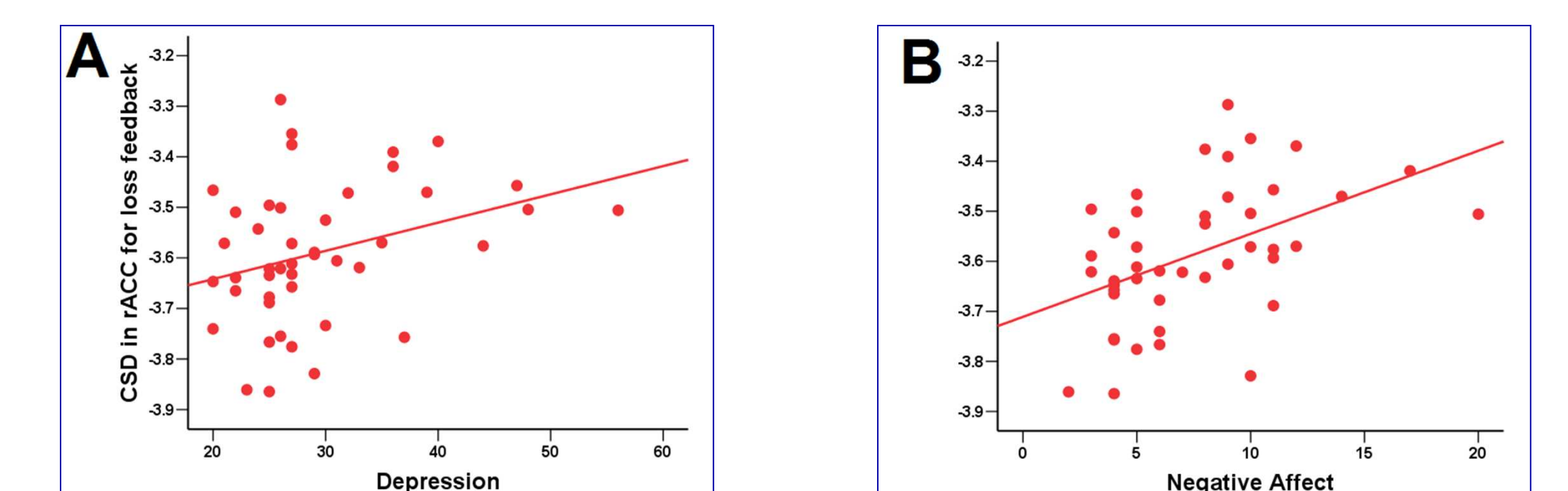


Figure 4 Scatterplots for the correlation between CSD in the rostral ACC for loss feedback with (A) depression and (B) negative affect.

## Conclusions

- The magnitude of the adolescents' FRN increased with depressive symptoms and negative affect consistent with previous reports [4,5].
- The LORETA results confirm the role of the ACC in reward processing and increased ACC response to suggest that negative feedback is related to affective symptoms [2].
- Together with other research finding depression and negative affect relate to enhanced ERNs [11], depression may be characterized by both a hypersensitivity to internal (errors) and external (feedback) cues of performance monitoring and reflected in ACC activation.

## References

[1] Gehring WJ, Willoughby AR. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. Science, 295, 2279–82.
[2] Miltner WHR, et al. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: evidence for a "generic" neural system for error detection. J Cogn Neurosci, 9, 788–98.
[3] Nieuwenhuis S, et al. (2004). Reinforcement-related brain potentials from medial frontal cortex: origins and functional significance. Neurosci Biobehav Rev 28, 441–8.
[4] Tucker DM, et al. (2003). Frontolimbic response to negative feedback in clinical depression. J Abnorm Psychol 11, 667–78.
[5] Santesso DL, et al. (2008). Enhanced negative feedback responses in remitted depression. NeuroReport, 19, 045-8.
[6] Gu R, et al. (2010). Anxiety and outcome evaluation: The good, the bad and the ambiguous. Biol Psychol.
[7] Radloff, L.S. (1977). The CES-D scale: a self-reported depression scale for research in the general population, Applied Psychol Meas, 1, 385-401.
[8] Huebner, E.S. (1994). Preliminary development and validation of a multidimensional life satisfaction scale for children, Psych Assess, 6, 149-58.
[9] Derogatis, L. & Lippman, R.. (1973). COVI L. SCL-90. An outpatient psychiatric rating scale-preliminary report, Psychopharmacol Bull, 9, 13-28.
[10] Pizzagalli, DA, et al. (2006). Resting anterior cingulate activity and abnormal responses to errors in subjects with elevated depressive symptoms: A 128-channel EEG study, Hum Brain Mapp, 27,185-201
[11] Holmes AJ, Pizzagalli DA. (2008). Spatiotemporal dynamics of error processing dysfunctions in major depressive disorder. Arch Gen Psychiatry, 65, 179–88.