Things Are Going Worse Than Expected:

An Examination of Neural Systems Altered By Stress

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Abstract

✦ Learning to seek reward and avoid punishment are examples of core adaptive behaviors - termed reinforcement learning - that are compromised by stress and stress-related mental illnesses.

✦ This ongoing study aims to elucidate the influence of stress reactivity on the distributed neural systems of reinforcement learning. To this end, we utilized a probabilistic reinforcement learning task with concurrent EEG recording.

✦ All participants performed one version of the learning task before being randomly assigned to take another learning task under stress (social evaluative threat) or control conditions.

✦ An increased negative prediction error would indicate that punishment feedback was 'worse than expected'. An objective correlate of the neural computation of negative prediction error, the Feedback Related Negativity, was significantly larger in the stress condition as a function of emotional reactivity.

✦ A higher learning rate for negative information would implicate greater utilization of this prediction in the ultimate integration of reinforcement cues. Negative self-evaluation correlated with an increased learning rate in stress-vulnerable individuals.

✦ These indices may be used to reveal a possible mechanism by which stress reactivity alters the neural systems of reward and punishment learning.

Methods

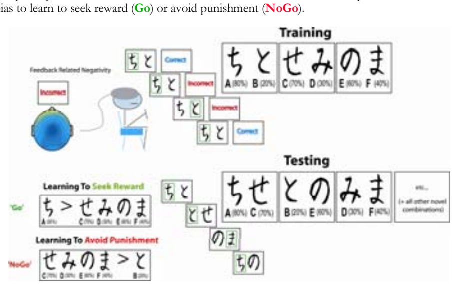
Participants

❖ Forty-seven college students have participated so far. After T1, all were randomly assigned to either stress (2/3) or control (1/3) conditions. Subjects in the stress condition were median split by a measure of stress vulnerability – **Behavioral Inhibition System (BIS)** questionnaire score (Carver & White, 1994) for the analyses reported here. This resulted in groups of: **Stress-Low BIS** (n=16, 6 female), **Stress-High BIS** (n=13, 7 female), and **Control** (n=18, 10 female).

Reinforcement Learning Task

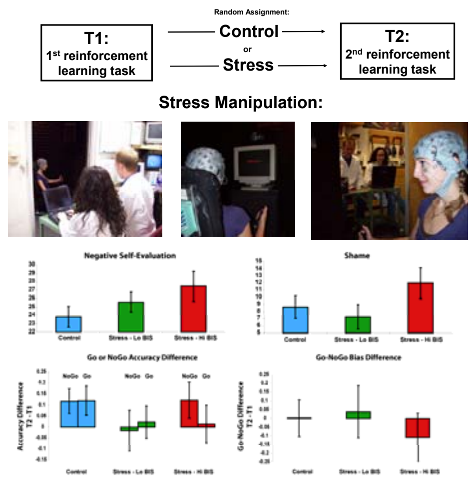
❖ A probabilistic reinforcement learning task was used (Frank et al, 2004). During the **training** phase, three pairs of symbols are learned solely by the feedback provided after each forced choice. The feedback is probabilistic and will reinforce the 'correct' choice only 80%, 70% or 60% of the time, depending on the stimulus pair.

❖ Learning is assessed in a subsequent **test** phase, where all possible stimulus pairs are presented and participants must choose the "best one", without feedback. This **test** phase revels the bias to learn to seek reward (**Go**) or avoid punishment (**NoGo**).



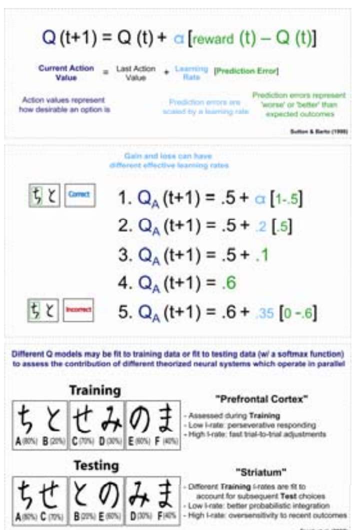
EEG Recording: NeuroScan SynAmps², 64 Channels, 500X gain, 500 Hz sample, filtered offline [1.5 -15 Hz, 96 dB/oct], re-referenced offline to linked mastoids, eyeblink corrected using a regression algorithm, and baseline corrected (-100 to 0 ms). 'Correct' and 'Incorrect' feedback trials were averaged for the **training** phase. The difference between these ERPs was computed as the dFRN (or 'difference' FRN). **All ERPs reported contained > 29 epochs**. dFRN Amplitude was defined as peak-to-peak difference between the highest negative deflection at FCz between 230 and 340 ms after the response, subtracted from the preceding trough (defined as 0 – 80 ms preceding the peak). **Thus more positive values reflect larger dFRN amplitudes.**

Stress Manipulation

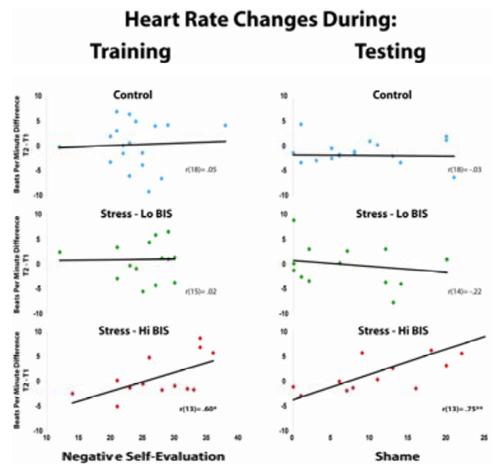


✦ The **Stress-High BIS** group showed the greatest levels of negative self evaluation, shame, and a bias to learn more from punishment (more "NoGo" as compared to "Go" learning). There were no relationships between BIS and T1 behavioral performance or Q-learning metrics.

"Q Learning"

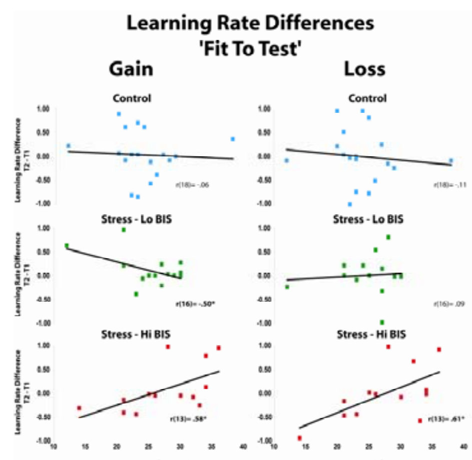


Psycho-Bio Response to Stress



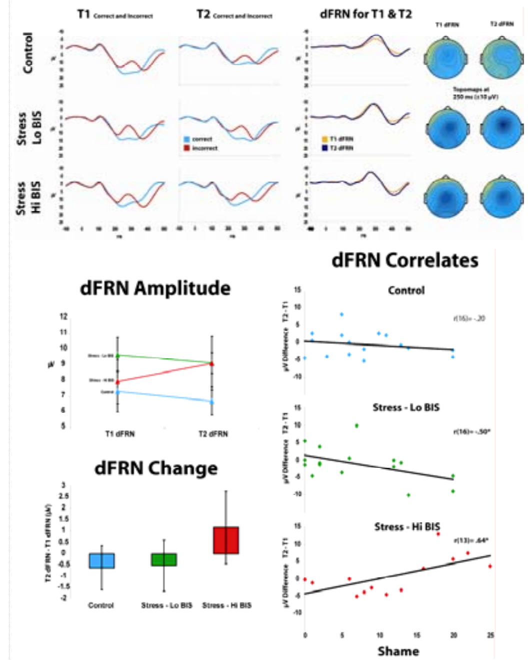
✦ The **Stress-High BIS** group showed a coordinated psychobiological reaction during stress, as indicated by the correlations between heart rate increase and negative self evaluation / shame.

Stress Affects Learning Rate



α The **Stress-High BIS** group showed a stress-related alteration of learning rate for both gain and loss. This may be maladaptive, since learning rates 'fit to test' should be low: reflecting slow integration.

FRN as Prediction Error



✦ The **Stress-High BIS** group showed an increase in dFRN amplitude, which correlated with the degree of self-reported shame. FRN amplitude may be a neural correlate of negative prediction error, indicating that events are 'worse than expected'.

Summary & Future Directions

✦ Stress **vulnerability** (high Behavioral Inhibition System scores) and **reactivity** (high negative self-evaluation, shame) interact to affect the ability to learn to seek reward and avoid punishment.

✦ **Shame** has been proposed to be a specific determinant of the **cortisol** response to social evaluative threat (Dickerson & Kemeny, 2002). This study will address the impact of shame and cortisol reactivity on reinforcement learning in the future.

✦ The use of best-fitting **action values (Q)**, **learning rates** and **prediction errors** will also be used to inform EEG measurements of reinforcement learning in the future.

Carver & White, 1994, JPSP 67(2): 319:333
Dickerson & Kemeny, 2002, Psych Bull 130 (3): 355:391
Frank et al., 2004, Science 306 (5703): 1940-1943
Frank et al., 2007, PNAS 104: 16311-16316
Sutton and Barto, 1998, Reinforcement Learning: An Introduction

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