Escape and Negative Reinforcement: ERP Response to Escape Behavior

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Abstract

One of the many ways humans regulate emotions is through escape from and avoidance of aversive stimulation. In an EEG study of 34 undergraduates, we measured and classified avoidance ERPs in a task called the Cue Avoidance Task (CAT). In this task, participants had the opportunity to press a button to stop an aversive sound after a duration of 2 seconds or 10 seconds, compared to a cue requiring a response but not associated with an aversive sound. We hypothesized that subjects would report differences in degree of relief following the different conditions, and that subjects' brain responses would correlate with self-reported emotion regulation scores.

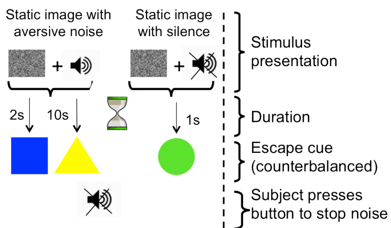
Introduction

In the scope of emotion regulation, behaviors that minimize or eliminate aversive states are said to be *negatively reinforced.* These behaviors have been linked to anxiety disorders and substance abuse. Emerging work neuroimaging work exists on brain responses to aversive stimuli, as they are thought to reveal negative reinforcement mechanisms (Delgado, et al.2008; Schiller et al., 2008). However, little work exists on ERP brain responses during an escape action. Here, we elicit escape behavior in the Cue Avoidance Task (CAT), in which a subject can stop an annoying noise after varying duration 2 s, 10 s or no noise. We derived ERPs for the escape action (button press to terminate the noise). Based on previous work in which anticipation of various arousing stimuli, including aversive noise (Crowley, Wu, Bailey, & Mayes,2009; Regan & Howard, 1995) and shocks (Baas, Kenemans, Bocker, & Verbaten, 2002) modulated frontal slow wave activity, we expected frontal slow waves would be modulated by escape. We further expected that individual differences in emotion regulation behaviors would track neural response to emotion regulation processes the Emotion Regulation Questionnaire (Gross & John 2003).

Methods

Participants: 34 undergraduate students, aged 18-22.

Trial Layout



Cue Avoidance Task (CAT): For 135 trials, one of three conditions (a 1-second silence, 2-second aversive noise, or 10-second aversive noise) precedes one of three escape cues (a blue square, a yellow triangle, or a green circle). For each subject, a particular condition always precedes a particular escape cue. The noise is selected randomly from choices of white noise, an alarm, or a baby cry. A blank screen begins each trial. A grey visual static image appears on screen while the noise plays for the assigned duration (1-second, 2-second or 10-second). The escape cue (colored shape) appears and the participant can click the image to escape the noise. Upon the participant's click, the noise and the cue image remain for 750 ms and then disappear, and the screen goes blank for 1000 ms.

Participant Feedback: At random points throughout the session, the participant is asked, "How relieved were you, just now, after you pressed the button?" The participant responds on a scale of 0-10, where 0 is "Didn't bother me" and 10 is "Extremely relieved." At the end, participants are asked to "Please rate how relieved you feel when you see the following image" for each of the three cue images, on the same scale as previously mentioned. The pairing of images with sound durations was counterbalanced across all subjects.

Electrophysiological Methods: ERPs were derived for all trials, time-locked to the escape cue (45 trials for each of the three cues). Data was gathered with high-density array Geodesic Sensor Net (GSN) of 128 Ag/AgCL electrodes (EGI, Inc.). Data were recorded through the Nestation v.4.0 software package (EGI, Inc.) E-prime v.1.2 (PST, Inc.) software packages controlled the stimulus presentation. Each 900 ms post-stimulus epoch was baseline-corrected by subtracting the average microvolt value across a 100 msec prestimulus interval. Artifact rejection was carried out to eliminate ERPs contaminated by movement and eye artifacts.

Questionnaires: Emotion Regulation Questionnaire. Developed by J. J. Gross and O. P. John in 2003. 10 items on a Likert scale of 1 (strongly disagree) to 7 (strongly agree). Designed to assess differences in two emotion regulation strategies: cognitive reappraisal and expressive suppression. 2 month test-retest reliability of about 0.7.

Results

ERP: Data was segmented to 100 ms pre response baseline and 750 ms post response epochs. (see below with error bars around ERPs).

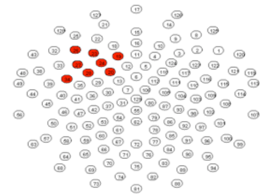
FDR: Paired samples t test on each data point and each channel were conducted. The total number of tests was 187 * 39 = 7293. 1624 tests were significant without FDR. 555 tests were significant at a false discovery rate of 0.050000 (independent or positively dependent tests) after FDR. The adjusted alpha (critical p) is 0.0038.

Significance: 8 channels [19, 20, 23, 24, 26, 27, 28, 34] have at least 200-250 ms period being significant in the late slow-wave region. These channels were averaged and during the effective time range (384-748 ms), a paired samples t test was conducted, $t(33) = -5.38, p < 0.001$.

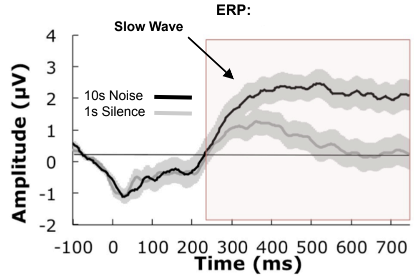
Correlations: Pearson correlation for ERQ x ERP Difference was .325, $p=.074$.

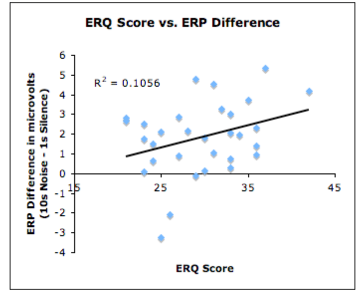
Degree of Relief: Paired sample t-test revealed a significant difference for average rating after 1s Silence compared to 10s Noise. $t(33) = -6.843$, $p<0.001$.

Post FDR Channels of Significance:



ERP:





Conclusions

1) Our ERP data implicates frontal negative slow waves, previously observed in anticipation of various arousing stimuli, including aversive noise (Crowley, Wu, Bailey, & Mayes,2009; Regan & Howard, 1995) and shocks (Baas, Kenemans, Bocker, & Verbaten, 2002). This response is thought to reflect engagement of evaluative processes. Here termination of the 10s noise clearly produces a larger frontal slow wave that that for silence.

2) We observed an association between the tendency to report using reappraisal emotion regulation strategies and differentiation at the neural level between an action in the context of escape from an aversive and a comparable behavior in a benign context. These data suggest that differentiation at the neural level predicts a greater tendency to rely on reappraisal ER strategies.

Clinical Relevance: Understanding the negatively reinforcing properties of an escape cue may illuminate aspects of avoidance behavior that, when present in an extreme, support the persistence of anxiety disorders and phobias. We are following this work with studies of avoidance in anxiety and substance use risk.

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