The FRN: Temporal Parameterization and Relations With Perceived Stress and Personality

Michael J. Crowley, Jia Wu, Helena J. V. Rutherford, Linda C. Mayes
Child Study Center, Yale University, New Haven, CT

Abstract

The feedback related negativity (FRN) is an event-related potential thought to reflect a reward prediction error, when an outcome is worse than expected. Few studies examine the effects of delayed outcomes on the FRN, but existing work suggests reward delay should diminish the FRN. At the same time recent work also suggests that the FRN is reduced among persons who report greater life stress, but other factors such as personality variables have not been examined in relation to the FRN. In this study we examined the FRN in a simple reward task with varying delays (800, 1600, 2400 ms). We observed a robust feedback effect for loss, but parametric delay did not reduce the FRN as expected. Stress and personality measures did related to the magnitude of the FRN difference wave and differentially over time.

Introduction

The feedback related negativity (FRN) is an event-related potential occurring at ~250-300 ms when feedback to the participant indicates that *predicted or expected* rewards will not occur (Holroyd et al., 2003). The FRN is thought to arise when the mesencephalic dopamine system relays an error signal to the anterior cingulate cortex (ACC), where it is used to improve performance. Outcomes worse than expected are thought to lead to phasic decreases in dopamine activity and large FRNs; outcomes better than expected produce the opposite effect. Animal models suggest that prediction error responses are sensitive to the time of the reward as well as its occurrence(Hollerman & Schultz, 1998). We recently showed that delayed rewards (2s vs 1s) diminish the FRN in a high-risk sample of adolescents (Crowley et al., 2009), but no other parametric work has been done with the FRN. Recent human behavioral work suggests that perceived life stress and acute stress dampen reward responsiveness (Pizzagalli, et al., 2000). Foti and Hajcak (2009) showed that perceived life stress was associated with diminished FRN. In a related line of work, with the error-related negativity (ERN), Luu et al., (2000) showed that individuals prone to negative affect show diminished ERN amplitudes over time during, a finding they interpreted to be reflective of negative affect-driven across-task disengagement (Luu et al., 2000). In the present study, we asked whether or not perceived life stress would be associated with a diminished FRN. Moreover, we reasoned that sensitivity to punishment and anxiety (negative affect driven motivations) might predictive disengagement from outcomes over the short-term, for delayed outcomes on individual trials.

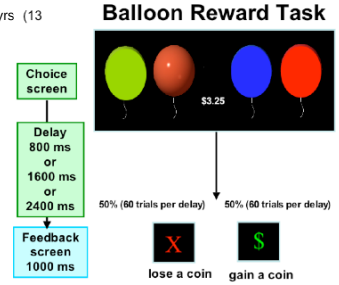
Methods

Participants: thirty undergraduate students, ages 18-22 yrs (13 female) who participated for course credit.

Balloon Reward Delay Task: Modeled after (Holroyd et al., 2003) four balloons randomly appear along a row. Feedback was rigged to have the probability 1/2 reward (gain 25 cents), 1/2 punishment (lose 25 cents) across the task at random. At the outset of each of four blocks, the participant was allowed to gain on 10-12 consecutive trials. These trials ensure that on average the participant would have a winning balance. Subsequent to balloon selection, feedback was delayed 800 ms, 1600 ms or 2400 ms. Each winning trial is worth 25 cents. A total of 360 trials (60 per condition) were administered for the purpose of computing ERPS.

Procedure: After providing informed consent, participants sat for a 128-electrode EEG recording (Electrical Geodesics, Inc.) while they played the Balloon Reward Delay Task. Stimuli appeared on a 19" LCD monitor and responses were made with a 4-button response pad.

Data Acquisition and Processing: EEG was continuously sampled at 250 Hz, with Cz reference and average reference offline. ERPs were segmented with 100 ms baseline and 600 post-baseline. Ocular Artifact Correction was used to preserve the data. The corrected data were averaged across trials for each electrode, separately for different time delays and feedbacks. Difference wave was calculated by subtracting the gain condition from the lose condition. The peak amplitudes during 200 to 350 ms after stimulus onset of difference wave ERP data were obtained and correlated with the questionnaires.



Questionnaire Measurements: Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) consists of 14 items including ''In the last week, how often have you felt that you were unable to control the important things in your life?'' or ''In the last week, how often have you found that you could not cope with all the things that you had to do?''. Items are rated on a 5-point Likert scale, 0 (never) to 4 (very often). Behavioral Inhibition System/Behavioral Activation System Scales (BIS/BAS, Carver & White, 1994). The questionnaire comprised the BIS scale (seven items;e.g., ''I worry about making mistakes,'' ''I have very few fears compared to my friends'' [reverse scored]) and the BAS Reward Responsiveness (RR; five items; e.g.,''It would excite me to win a contest,'' ''When I get something I want, I feel excited and energized''). Items are rated on a 4-point Likert scale, 1 (very true for me) to 4 (very false for me) and is thought to assess facets of Gray's personality model.

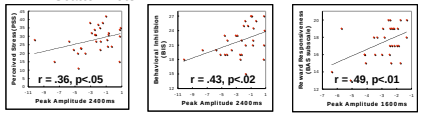
Results

First we conducted a Condition x Delay repeated measures ANOVA. Condition was significant, $F(1, 29) = 21.78$, $p < .001$, partial $\eta^2 = .43$, as was delay, $F(2, 28) = 4.21$, $p < .03$, partial $\eta^2 = .23$, but not the condition x delay interaction, $F(2, 28) = 2.53$, $p < .10$, partial $\eta^2 = .15$. Loss produced a significantly more negative peak amplitude than the gain $F(2, 28) = 10.76$, $p < .001$, -3.00 vs -1.91. The earlier delay (800 ms) produced a less negative deflection in the ERP than the next later delay (1600 ms) (-1.963 vs. -2.72, $p < .02$), the ERP negativity for 2400 ms delay (-2.68) was not significantly more negative than the early delay (800 ms), $p < .07$. A repeated measures ANOVA for the difference wave (loss - gain) was not significant, $F(2, 28)=2.53$, $p<.10$.

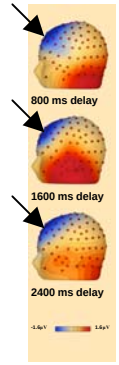
Correlation Matrix:

	Perceived Stress	Reward Responsiveness (BAS)	Behavioral Inhibition (BIS)	Peak Amplitude ↓uV 800ms delay	Peak Amplitude ↓uV 1600ms delay	Peak Amplitude ↓uV 2400ms delay
Perceived Stress	1.0	-.11 .554	.51** .004	.24 .204	.13 .508	.36* .049
Reward Responsiveness (BAS subscale)		1.0	.05 .809	.16 .398	.49* .006	-.17 .372
Behavioral Inhibition (BIS)			1.0	.15 .423	.06 .772	.43* .017
Peak Amplitude ↓uV 800ms delay				1.0	.36* .048	.16 .408
Peak Amplitude ↓uV 1600ms delay					1.0	.18 .335
Peak Amplitude ↓uV 2400ms delay						1.0

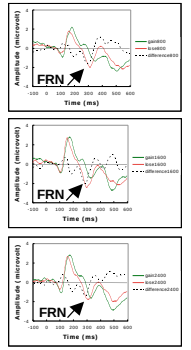
Scatter Plots:



Difference Wave Head Models:



ERP waves:



Conclusions

1) Our balloon delay task yielded a feedback-related negativity effect; **2)** However, contrary to our expectation, The FRN did not decrease over the time-span we examined (800, 1600, 2400 ms). Although our previous work suggested that the FRN was sensitive to delay, diminishing from 1000 ms to 2000 ms, this finding was not replicated. Our previous sample, different from that reported here, was younger (age ~15 yrs), had prenatal cocaine exposure, and was selected for risky behavior status; **3)** We observed time dependent relations between perceived stress, BIS score and FRN, but only at the 2400 ms delay. These two measures, which were strongly correlated themselves, suggest that stress and proneness to anxiety/negative affect may be associated with diminished reward processing when rewards are delayed; **4.** We observed that increased reward responsiveness predicted a reduced FRN, though consistent with sensation seeking models we did not anticipate this result. The feedback negativity has been proposed as a marker of reward prediction, related to risky behavior and substance abuse risk. Models that consider stress and personality in reward processing with ERPs should consider employing delayed rewards.

REFERENCES:

Crowley, M. J., Wu, J., Crutcher, C., Bailey, C. A., Lejuez, C. W., & Mayes, L. C. (2009). Risk-Taking and the Feedback Negativity Response to Loss Among At-risk Adolescents. Developmental Neuroscience, 31, 137-148.

Foti, D., & Hajcak, G. (2009). Depression and reduced sensitivity to non-rewards versus rewards: Evidence from event-related potentials. Biol Psychol, 81(1), 1-8.

Hollerman, J. R., & Schultz, W. (1998). Dopamine neurons report an error in the temporal prediction of reward during learning. Nat Neurosci, 1(4), 304-309.

Holroyd, C. B., Nieuwenhuis, S., Yeung, N., & Cohen, J. D. (2003). Errors in reward prediction are reflected in the event-related brain potential. Neuroreport, 14(18), 2481-2484.

Luu, P., Collins, P., & Tucker, D. M. (2000). Mood, personality, and self-monitoring: Negative affect and emotionality in relation to frontal lobe mechanisms of error monitoring. Journal of Experimental Psychology: General, 129(1), 43-60.

Pizzagalli, D. A., Bogdan, R., Ratner, K. G., & Jahn, A. L. (2007). Increased perceived stress is associated with blunted hedonic capacity: potential implications for depression research. Behav Res Ther, 45(11), 2742-2753.

We gratefully acknowledge the support of the NARSAD Young Investigator Award (MJC), Yale's Interdisciplinary Research Consortium on Stress, Self-Control and Addiction Pilot project funding (MJC); NIDA grants RO1-DA-06025 (LCM), DA-017863 (LCM) and KO5 (LCM), and a grant from the Pfeffer Foundation (LCM). **For questions, email** michael.crowley@yale.edu