Role of Reward Expectancy on the Generation of Feedback Related Negativity (FRN)

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Abstract

- This study examined the whether *expectations* of possible wins or losses are necessary for the generation of the FRN.
- A secondary aim of examining social factors on FRN generation, using a "cooperation" condition where participants' outcomes were yoked to the performance of "another".
- It was hypothesized that the expectation of reward was key to the production the FRN.
- A forced choice selection task was followed by an indication of monetary win or loss after a 1500ms delay (expectancy time) or simply the presentation of immediate feedback.
- Forty healthy undergraduates (25 females), ages 18-26 years of age (M=19.22, SD=1.61) were assessed.
- Losses elicited an FRN compared to winning; and more pronounced with participant's direct involvement compared to the yoked conditions.
- When participants were not able to develop expectations (immediate feedback condition), no prominent FRN was observed.
- Larger FRN amplitudes were significantly correlated with higher BAS scores, particularly the Fun-Seeking subscale.

Introduction

- The generation of the Feedback Related Negativity (FRN) is thought to indicate general negative outcome on the current task, particularly when outcomes are worse then expected (Holroyd & Coles, 2002), and the need to subsequently monitor task performance (Luu et al. 2003).
- FRN is a non-learning dependent ERP generated in the Anterior Cingulate Cortex (ACC) (van Veen & Carter, 2002) with mean peak latency at 250 ms post error.
- Observers of other's task performance elicits ERN on incorrect trials in observer's EEG as well as participants (Van Schie, Mars, Coles, & Bekkering, 2004).
- FRN has been shown to be moderated by traits such as depression, impulsivity and personality style (Tucker, Luu et al, 2003)

Hypotheses:

- Following a subject's choice, responses to loss (vs win) will generate FRN (Holroyd & Coles, 2002)
- Conditions with outcome yoked to computer choice will generate diminished FRN without direct subject involvement, but only in the presence of a delay between choice & feedback.
- The *expectation* of reward is necessary for FRN generation.

Method

Subjects:

- Forty healthy undergraduates (25 females) between ages 18 and 26 years of age (M=19.22, SD=1.61) were assessed.

Task:

- Three Conditions :
  - 1) Subject Choice + delayed (1500 ms) feedback.
  - 2) Computer Choice + delayed (1500 ms) feedback.
  - 3) Computer Choice + immediate feedback.
- Three blocks: 48 Trials per condition per block (144 per condition total). Conditions counter balanced across blocks.
- Win/lose $.25 per trial with nearly fixed probabilities of Winning (60%) Losing (40%)

Method (cont.)

Trial Structure:

- 4 ovals appear
- Subject (or computer) chooses one oval, with choice indicated by white rectangle during delay feedback conditions
- White rectangle changes to blue (win) or yellow (loss) in delay feedback conditions. In immediate feedback condition, no white rectangle appears prior to the blue or yellow rectangle.

Sample Stimulus:

Blue = Win

Yellow = Loss
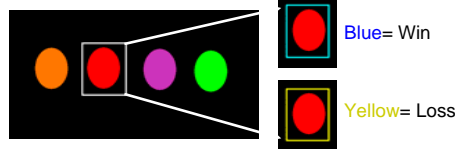
Measures:

- Behavioral Inhibition/Activation Scale (BIS/BAS)
- Positive & Negative Affect Scale (PANAS)

Data Collection:

- EEG recorded continuously using 64-channel EEG cap with 1K Hz sampling rate using online Cz reference, re-referenced offline to linked-mastoids. Ocular correction performed using the standard subtraction method. Band pass filtered from .1-8Hz. Average waveforms computed.

Results

Electrophysiology:

- FRN amplitudes for loss trials were greater (more negative) than for win trials for Subject's Choice and Computer Choice with delayed feedback Conditions. There was no mean difference between win and loss trials for the immediate feedback condition. (*See waveform plot*)
- The FRN was generated for loss trials in the first two conditions, with subject's direct task involvement generating the largest amplitudes (*See Subtraction waveforms plots*).
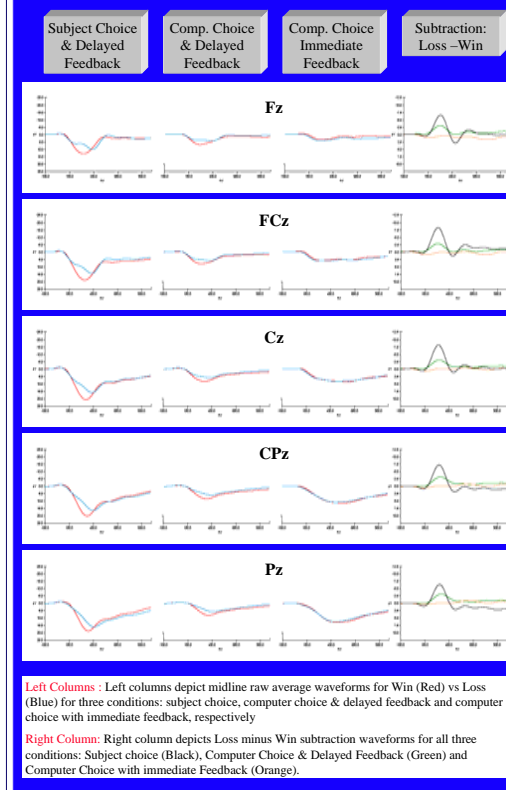
Questionnaire Responses as FRN amplitude Moderators:

- **Higher BAS scores predicted larger FRN**: Negative correlations were found for FRN amplitude during Subject's choice with: BAS total score, and the Fun-Seeking & Reward Responsiveness subscales.
- **Greater PA predicted larger FRN**: Negative correlations were found between PANAS positive subscale and delayed feedback and expectancy conditions.

Table 1: Correlations between FRN amplitudes and BAS or PA.

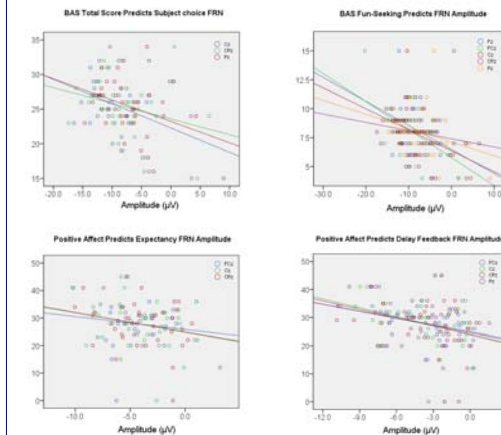| Site:	Fz	FCz	Cz	CPz	Pz
Subject Choice					
BAS Total	-.27	-.29	-.37[*]	-.38[*]	-.38[*]
BAS FS	-.38[*]	-.44[**]	-.46[**]	-.42[**]	-.41[**]
BAS RR	-.14	-.19	-.30[†]	-.29[†]	-.31[*]
Comp. Choice & Delayed Feedback					
PANAS PA	-.23	-.41[**]	-.48[**]	-.45[**]	-.38[*]
Expectation					
PANAS PA	-.26[†]	-.37[*]	-.40[**]	-.37[*]	-0.21[†]

Note: Negative correlations reflect greater BAS or PA scores associated with larger (more negative) FRN amplitudes. Scatterplots depicting these correlations are shown to the right. $† p<0.1, *p<.05, **p<.01$

Results (cont.)

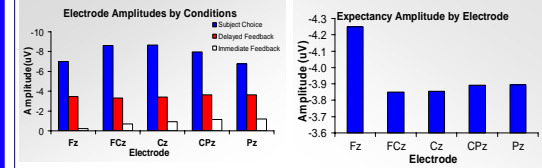| Subject Choice & Delayed Feedback	Comp. Choice & Delayed Feedback	Comp. Choice Immediate Feedback	Subtraction: Loss –Win

Fz

FCz

Cz

CPz

Pz

Left Columns : Left columns depict midline raw average waveforms for Win (Red) vs Loss (Blue) for three conditions: subject choice, computer choice & delayed feedback and computer choice with immediate feedback, respectively

Right Column: Right column depicts Loss minus Win subtraction waveforms for all three conditions: Subject choice (Black), Computer Choice & Delayed Feedback (Green) and Computer Choice with immediate Feedback (Orange).

BAS Total Score Predicts Subject choice FRN

BAS Fun-Seeking Predicts FRN Amplitude

Positive Affect Predicts Expectancy FRN Amplitude

Positive Affect Predicts Delay Feedback FRN Amplitude

Results (cont.)

Electrode Amplitudes by Conditions

Expectancy Amplitude by Electrode

Left Graph: FRN Amplitudes were largest for the Subject Choice condition, then the Delayed Feedback condition, then the Immediate Feedback condition, $F(2, 78) = 67.2$, $p<.001$, with all three conditions differing significantly from one another. There was also a main effect of site, $F(4,156)= 5.8$, $p<.01$, and a significant condition by site interaction, $F(8, 312) = 5.4$, $p<.01$, indicating conditions showed greater differentiation at more anterior sites.

Right Graph: The contribution of expectancy to the FRN effect (Delay feedback-Immediate feedback) was significantly different than zero, $F(1, 39) = 121.1$, $p<.001$, with no significant variation by site.

Discussion

- Previous findings were replicated demonstrating FRN generation to negative compared to positive outcomes.
- Observation of 3rd party's task performance using yoked outcomes generates FRNs in the observer, but smaller than during subject direct task participation.
- Without a choice-feedback delay time, no FRN was generated to negative outcome, demonstrating that expectation of a positive outcome is necessary to generate the FRN, even during observation only conditions.
- Participants who endorse greater behavioral approach motivation (BAS total) were more sensitive to negative feedback. This correlation was driven by the Fun-Seeking and Reward-Responsiveness subscales.
  - This could reflect simply greater task engagement by high BAS individuals.
  - Alternatively, the task cannot be learned, which might allow those higher in BAS to continue to have expectations of reward, and thus greater expectation violations during loss trials. The immediate feedback condition lends support for this interpretation.
- Positive affect (measured by PANAS) was predictive of FRN amplitude for the delayed feedback and expectation conditions, perhaps suggesting that negative feedback violated a positive outcome expectancy in those with greater trait positive affect
- The fact that the FRN appears only when individuals have the opportunity to develop expectations about potential outcomes suggests that the monitoring system giving rise to the FRN is not simply recruited when bad outcomes occur, but rather is recruited when outcomes are worse than expected, as an integral part of the reward learning system and allowing for subsequent alterations in task performance (Holroyd & Coles, 2002).

References

Holroyd, C., B., & Coles, M., G., H. 2002. The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review* 109: 679-709.

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