FEEDBACK-RELATED BRAIN ACTIVITY

DURING THE CHICKEN GAME

by

Emily M. Stanley

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Arts in Psychology

Spring 2011

FEEDBACK-RELATED BRAIN ACTIVITY

DURING THE CHICKEN GAME

by

Emily M. Stanley

Approved: ____
Robert F. Simons, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____
Paul C. Quinn, Ph.D.
Associate Chair for Research and Graduate Education

Approved: ____
Paul C. Quinn, Ph.D.
Interim Chair of the Department of Psychology

Approved: ____
George H. Watson, Ph.D.
Dean of the College of Arts and Sciences

Approved: ____
Charles G. Riordan, Ph.D.
Vice Provost for Graduate and Professional Education

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Robert Simons, for his guidance throughout this project, and for Dr. D. Michael Kuhlman for sharing his expertise on social decision making games with me. I am also grateful for the help and advice of the members of my lab, Jason Krompinger, Damion Grasso, Kathryn Roberts, and Christina Hong. I am very appreciative of the undergraduate research assistants who interacted assisted me with the data collection. Last, but not least, I sincerely thank parents for their unconditional encouragement, love, and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Feedback-Related Negativity (FRN) is a feedback-locked Event-Related Potential (ERP) component that is larger for losses compared with gains. The "Chicken" game is a social decision making game where both players have the choice to cooperate or compete. The most points are awarded to the player who competes when the other player cooperates, however if both players compete they each receive the worst payoff in the game. This study examines the FRN when a player receives feedback from the other player indicating how many points were won or lost on that round of the Chicken game. The FRN was larger on trials where the other player competes than when the other player cooperates which shows that this socially-complex paradigm is able to produce reliable FRNs. The FRN was also shown to be larger on trials where the participant chose the competitive choice, and that effect was strongest when there was a potential for winning points as opposed to the potential for a loss.

Chapter 1

INTRODUCTION

The feedback related negativity (FRN) is a feedback-locked component of the ERP that is observed in gambling and trial-and-error learning tasks when negative feedback stimuli are presented (Holroyd, Hajcak, & Larsen, 2006; Miltner, Braun, & Coles, 1997). It is a negative deflection of the ERP that peaks at 250ms after the presentation of feedback and it is larger for negative than positive feedback. It is also maximal over frontocentral recording sites (Gehring & Willoughby, 2002). The FRN is not sensitive to the magnitude of the loss or gain, but instead seems to reflect a binary, good or bad, appraisal of the feedback (Hajcak, Moser, Holroyd, & Simons, 2006). The FRN reflects an evaluative function in determining whether the feedback that a person received achieved the desired outcome or not (Holroyd, et al., 2006). The judgment of outcome is partially based on the predicted outcomes for that particular situation (Hajcak, Moser, Holroyd, & Simons, 2007; Moser & Simons, 2009).

The majority of research on the FRN has been conducted in the context of a person doing a task in social isolation, but many decisions in the real world happen in a complex social environment. The decisions people make effect other people, and vice versa. For example when negotiating the price of a car, the buyer and seller are both invested in the final outcome and both make decisions in the process that lead to the final outcome. In order to capture a more accurate picture of the neural processing of feedback, neural activity needs to be studied when people are faced with more complex situations than a simple gambling task can provide. Social decision making games provide an interesting opportunity to explore how social contexts effect the processing of decisions.

Some recent research has addressed this question of brain activity in a social decision making context. Hewig and colleagues (2010) used the "Ultimatum" game to investigate the psychophysiological correlates of decision making. In the Ultimatum game, the "proposer" divides a set amount of money into two shares, and the "responder" is required to decide whether or not to accept the proposer's offer. If the responder accepts the offer then the money is divided according to the proposer's offer, but if the offer is rejected then neither player receives any money. They found that the FRN predicted the participant's decision to reject unfair offers in the Ultimatum game. This shows that the FRN produced during this social decision making game was relevant for understanding the behavior of players in the game. It is promising support for the idea that the FRN might be a psychologically interesting component to measure in this context.

van den Bos and his colleagues (2009) looked at participant's fMRI activity while they played the "Trust" game. Like the Ultimatum game, two players divide a certain amount of money. The “trustor” has to decide whether to divide the money according to a predetermined scheme or to give the other player, the “trustee,” an opportunity to decide how the money should be divided. If trusted, the trustee has the option to either reciprocate the trust given by the trustor or to defect and maximize his or her own personal gain. They found that the anterior Medial Prefrontal Cortex (aMPFC) was more active when the trustee defected than when they reciprocated. The Anterior Cingulate Cortex (ACC), which is purported to produce the FRN (Miltner, et al., 1997), and the right dorsolateral prefrontal cortex were sensitive to the amount of benefit that the trustee stood to gain by reciprocating. This is further support that the ACC activity measured by the FRN represents an interesting psychological process when evaluating outcomes.

In order to continue to explore feedback-related brain activity in the context of social decision making games, we chose to examine the FRN in the “Chicken” game (Rapoport & Chammah, 1966). The Chicken game is a decision making game that has been used in social psychology and economics to understand decision making behavior. In the game, both payers have the choice to cooperate or compete. The most points are awarded to the player who competes when the other player cooperates, however if both players compete, neither receives any points. If both players cooperate, both receive an equal number of points that, while less than the maximum points available, is still larger than the number of points awarded to the cooperator when one player cooperates and the other competes. Figure 1 shows the Chicken game in its simplest two player form where one player chooses between Rows A and B and the other player chooses between Columns X and Y. The payoffs (in red for the Row player, and in green for the Column player) are such that T > R > S > P and 2R > S + T when R represents the payoff when both participants cooperate, P represents the payoff when both players choose to compete, and if one player cooperates and the other competes then the cooperator receives S and the competitor gets T. The principle of the game is that while each player prefers not to yield to the other, the outcome where neither player yields is the worst possible outcome for both players.

	Column X	Column Y
Row A	R, R	S, T
Row B	T, S	P, P

Figure 1 The Chicken Game. The payoffs must satisfy the following inequalities: T > R > S > P and 2R > S + T.

The Chicken game was chosen over more well studied decision making games such as "Prisoner's Dilemma" (PD; Sally, 1995) because unlike PD, Chicken does not have a dominating strategy (Rapoport & Chammah, 1966). The essential difference between Chicken and PD is that in Chicken the worst outcome occurs when both players are competing, while in PD, the worst outcome happens when the other player is competing when the participant cooperates. To put it in terms of the basic game structure, to make Figure 1 into PD, P would be larger than S. This makes competition the clear advantageous choice for participants in PD; whereas in Chicken, there is no clearly advantageous choice. Because of this, we assumed that participants would be more likely to switch back and forth between cooperating and competing while playing multiple iterations of the game. The multiple iterations are needed in ERP experiments to ensure an adequate number of trials to make ERP averages.

In the present study, we were interested in measuring the FRN in response to the feedback that participants received following each trial of the Chicken game. The games were presented to participants in a matrix format (see Figure 2 for the matrixes that were used in this study). Each participant was the “red” player, who chose between Row A and Row B. The participant’s partner was the “green” player who chose between Column X and Column Y. Depending on the combined choices of the two players, each receives one of four point outcomes. For example, in the top matrix, if red were to choose A (cooperation) and green chose X (cooperation), they each would receive an outcome of 7 points. However, if red chose A and green chose B (competition), then red would receive only 3 points while green received 10 points, and so on.

	Column X	Column Y
Row A	7,7	3,10
Row B	10,3	0,0

	Column X	Column Y
Row A	-3,-3	-7,0
Row B	0,-7	-10,-10

Figure 2 Positive (top) and negative (bottom) matrixes of the Chicken game used during the experiment. The participant was the Row player choosing between Rows A and B, and the other player was the Column player choosing between Columns X and Y. The values in the matrix represent the points that will be awarded to each player if that quadrant is chosen by both players. The participant receives the points in red font and the other player receives the points in green font.

A very important feature of the game used for this experiment is that decisions by the two players were made sequentially. Specifically, the red player (actual participant) went first, choosing either A or B. Once the red player's choice had been made, it was communicated to the green player (whose actions, unbeknownst to the participant, were controlled by the computer), who then chose between X or Y. In this situation, if the red player chooses A, he or she is showing trust in the green player to not take advantage of him or her by choosing Y. We are interested in measuring brain activity in response to the two types of feedback that participants receive following such a trusting move. Since the FRN has been shown to be larger for negative outcomes, we would predict that the FRN amplitude would be larger if the other player violates the participant's trust than if the other player reciprocates cooperation.

On the other hand, if the red player chose B, he or she would be challenging the green player to "chicken out", by choosing X, thereby receiving a much smaller outcome than the red player (3 points for the green player, to 10 points for red player). At the same time both players would be avoiding the worst possible outcome (0 for both players) if they were to both compete. We are also interested in measuring the FRN in response to these two types of feedback the participants receive following such a challenging/aggressive move. Again, because FRNs have been shown to be larger following negative feedback, we would expect a larger FRN when the other person meets the challenge (competes) which results in both players receiving zero points compared with when the other person chickens out. Therefore our first hypothesis is that the FRN will be larger when the other player chose to compete (Y) regardless of whether the participant cooperates (A) or competes (B).

The magnitude of the loss is larger when the green player defects after the red player had challenged him or her by picking the competitive choice (B) than it would be if the red player had picked the cooperative choice (A). Therefore, our second hypothesis was that participants would have a larger FRN amplitude overall for when the other player competes (Y) compared to when he or she cooperates (X) and that that should be largest on those trials when the participant had made the competitive choice (B) compared to when he or she had picked the cooperative choice (A). Additionally, two matrixes were used during this experiment. One, the “positive” matrix was designed so that all possible outcomes were either positive values or zero. On the second “negative” matrix, all of the available point values were 10 points less than their counterpart in the positive matrix. In that “negative” matrix, all possible outcomes were either negative or zero. According to prospect theory, people perceive losses as being more aversive than gains of the same amount (Kahneman & Tversky, 1979). Therefore, our third hypothesis was that the magnitude of the FRN would be larger when the other player competes(Y) than when the other player cooperates (X), which is largest when the participant competes (B) which will be further amplified when receiving feedback during the negative game.

Chapter 2

METHOD

Participants

Fifty-five undergraduates (35 females) at the University of Delaware participated in this experiment either as part of the research requirement of the Introduction to Psychology course in the spring semester, or for extra credit in their psychology course over the summer semester. Participants were also paid $10 for their participation that was described as their winnings from the game.

Procedure

Participants were fitted with an electrode cap and then given instructions for the Chicken game. As described above, the game was presented to participants in a matrix format (see Figure 2) that displayed all of the possible outcomes for that trial. Participants were told that they were playing against another player who was a participant in the study earlier in the semester, but unbeknownst to the participants, they were actually just playing against the computer. The participant chose between Rows A and B while the other player chose between Columns X and Y. The computer alternated randomly between choosing Column X and Column Y. Their combination of choices determined how many points each player won or lost for that trial. Participants played two different matrixes during the experiment, one was a positive game where none of the possible outcomes was negative, and one was a negative game where none of the possible outcomes was positive. Participants were given the choice on each trial between cooperative or completive options (Rows). Likewise, the other player could choose either a cooperative or a competitive option (Columns). Depending on their choice and the choice of their opponent, they received feedback about how many points they won on that trial which was communicated by a circle that appeared over the quadrant of the matrix that represented the combination of both choices. Those points were converted to bonus money. They were told that they began the study with $10.00, and points earned or lost were added or subtracted to that total at the rate of $0.10 per point. The monetary pay out was used in order to give participants more motivation to care about the results of the game.

Participants played 240 iterations of the game while seated at a computer in a room by themselves as EEG was recorded. At the conclusion of the task, the participants were paid. Since the feedback (Column player’s choice) was set so that the participants won on half of the trials and lost on the other half of the trials, all participants were paid $10.00. After they were paid, the participants were debriefed and dismissed.

Electrophysiological Recording and Processing

EEG was recorded from 32 Ag/Cl sintered electrodes embedded in an electrode cap. EEG was digitized at 512 Hz using ANT acquisition hardware (Advanced Neuro Technology, Enschede, The Netherlands) with an average electrode reference and forehead ground. The EEG was re-referenced offline to the average of the two mastoid sites. Continuous EEG was corrected for eye blinks with ASA software from ANT. A bandpass filter from 0.1 Hz to 30 Hz was used. Artifacts that exceeded a threshold of -75 µV or +75 µV were automatically rejected.

ERP averages were created with feedback-locked averages for each participant. Separate averages were made for each feedback condition at each electrode. These averages were baseline corrected by subtracting the average voltage occurring during the 200ms before the feedback from the entire average. Four frontocentral electrodes (Fz, Cz, FC1, and FC2) were averaged together to form a region of interest based on where the FRN has been found to be the largest in previous research Likewise, a time window from 230 to 300 ms after the feedback was used based on previous studies was averaged to quantify the mean amplitude of the FRN (see Figure 3; Gehring & Willoughby, 2002). Averages were only computed for conditions that had at least 13 usable ERP trials so that the averages would represent the true FRN as opposed to various other sources of noise that can appear in the raw EEG signal.

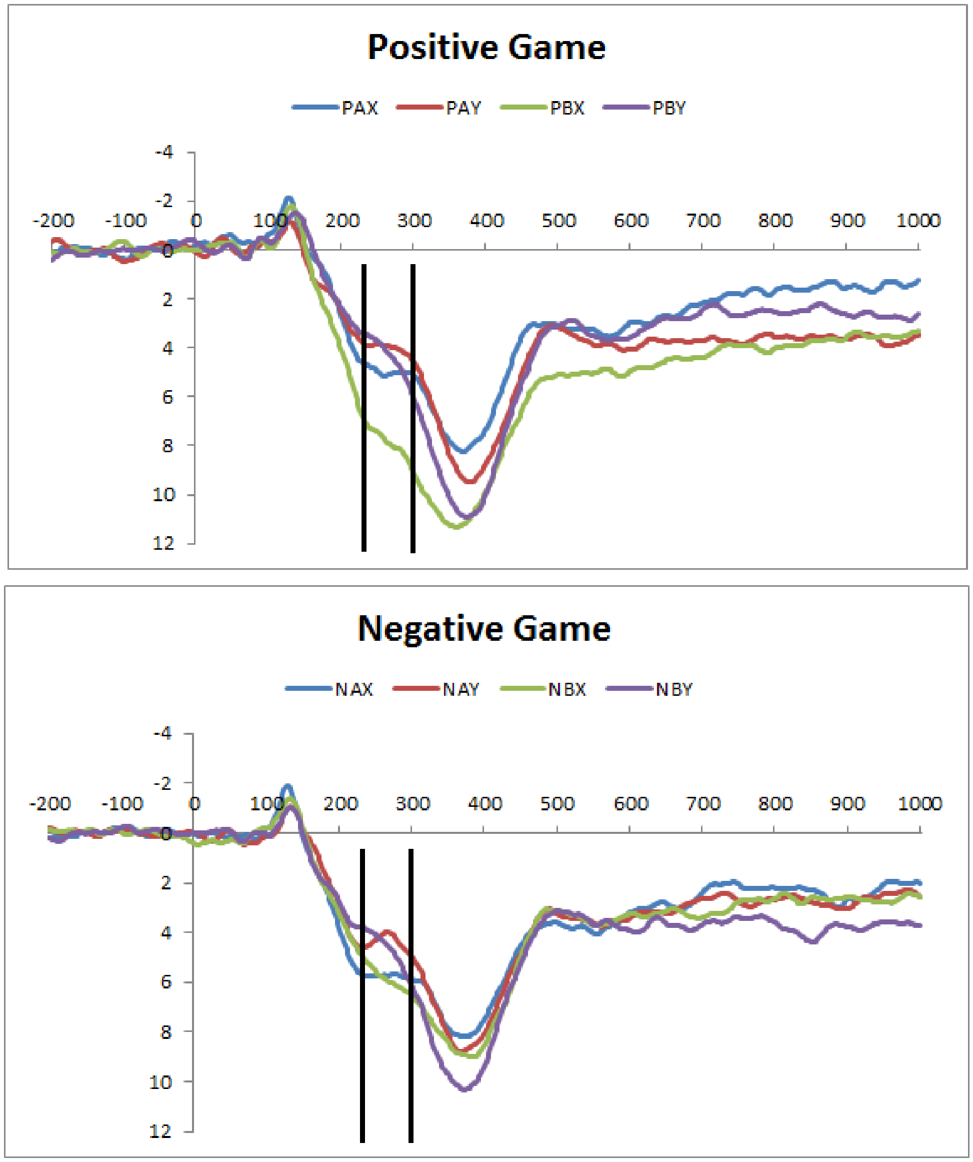

Figure 3 **ERP averages for all feedback conditions during each game averaged across the region of interest (Cz, Fz, FC1, and FC2). The black lines represent the beginning and end of the time window used to measure the FRN.**

Chapter 3

RESULTS

Data from this study conformed to a multilevel structure with repeated measures of FRN amplitude within individuals across the different levels of feedback. Additionally, because the participants were allowed to freely choose between the cooperative and competitive choices on each trial, some participants tended to respond with either cooperative or competitive choice on a majority of trials. The result was that more than half of the participants did not have enough ERP trials to produce a stable ERP waveform when they were receiving one or more of the possible levels of feedback. Since the ERP amplitude during the processing of the feedback was the dependent measure in this design, these participants did not have any usable data for some of the conditions. Traditional repeated measures analysis approaches such as Repeated Measures ANOVA are not able to include participants who don't have values of the dependent measure for all conditions (Gueorguieva & Krystal, 2004). In order to include all of the participants in the analysis, we utilized Hierarchical Linear Modeling (HLM) which can handle missing data by using maximum likelihood estimation for missing values (Schafer & Graham, 2002) and the repeated measures structure of the data (Raudenbush & Bryk, 2002).

The first hypothesis was that receiving feedback that the other player has chosen the competitive choice would produce a larger feedback related negativity (FRN) amplitude than when participants receive feedback that the other player has chosen the cooperative choice. To test that prediction, we used the other player's level of cooperativeness (X or Y) to predict the participant's FRN amplitude, allowing for both the intercept and slope to vary from participant to participant. The following HLM level-1 equation was used to test this prediction:

$$FRN_{ti} = \beta_{00} + \beta_{10}(X\_Y_{ti}) + e_{ti}$$

In this model, the β_{00} represents the intercept, which is average FRN amplitude, for trials *t* nested within individuals *i*, across all participants when the other player chose the cooperative choice (Column X). X_Y is a dummy coded variable where 0 represents cooperative feedback (Column X) and 1 represents competitive feedback (Column Y) from the other player. β_{10} represents the slope coefficient for X_Y and e_{ti} is the error term. Therefore, the mean amplitude of the FRN during Y trials could be estimated by adding the slope of X_Y to the intercept. Parameter estimates and significance tests for this HLM model are presented in Table 1. The X_Y slope indicates that the amplitude of the FRN was larger for trials where the other player responded competitively (Column Y) than on trials where the other player responded cooperatively (Column X). This supports our hypothesis that the non-optimal outcome in the Chicken game would generate a larger FRN amplitude similar to that generated by loss in gambling tasks.

Table 1 **HLM Fixed Effects Regressing Feedback Related Negativity Amplitude on the Other Player's Cooperativeness**

Fixed effects (intercept, slopes)	Estimate (SE)	t(54)	p-value
Intercept, β_{00}	0.39 (0.04)	10.47	<.001
X_Y, β_{10}	-0.12 (0.02)	-5.19	<.001

Note. HLM = Hierarchical Linear Modeling.

The second hypothesis was that the magnitude of the FRN would be larger when the other player chose the competitive choice than when the other player chose the cooperative choice, and this relationship would be magnified when the participant chose the cooperative choice. To test this prediction, we used the other player's level of cooperativeness (X or Y), the participant's level of cooperativeness (A or B) and the interaction of those two variables to predict the participant's FRN amplitude, allowing for both the intercept and slope of all variables to vary from participant to participant. The following HLM level-1 equation was used to test this prediction:

$$FRN_{ti} = \beta_{00} + \beta_{10}(A\_B_{ti}) + \beta_{20}(X\_Y_{ti}) + \beta_{30}(AB\_XY_{ti}) + e_{ti}$$

In this model, the β_{00} represents the intercept, which is average FRN amplitude, for trials t nested within individuals i, across all participants when the other player chose the cooperative choice (Column X) and the participant chooses the competitive choice (Row A). X_Y is a dummy coded variable where 0 represents cooperative feedback (Column X) and 1 represents competitive feedback (Column Y) from the other player. A_B is a dummy coded variable where 0 represents cooperative feedback (Row A) and 1 represents competitive feedback (Row B) of the participant.β_{10} - β_{30} represent the slope coefficient for X_Y, A_B, and their interaction. e_{ti} is the error term. Parameter estimates and significance tests for this HLM model are presented in Table 2.

Table 2 HLM Fixed Effects Regressing Feedback Related Negativity Amplitude on the Participant's Cooperativeness and Other Player's Cooperativeness

Fixed effects (intercept, slopes)	Estimate (SE)	t(54)	p-value
Intercept, β_{00}	0.33 (0.04)	8.72	<0.001
A_B, β_{10}	0.11 (0.03)	3.95	<0.001
X_Y, β_{20}	-0.08 (0.02)	-3.53	0.001
AB_XY, β_{30}	-0.08 (0.03)	-2.38	0.02

Note. HLM = Hierarchical Linear Modeling.

The X_Y slope indicates that the amplitude of the FRN was larger for trials where the other player responded competitively (Column Y) than on trials where the other player responded cooperatively (Column X). The A_B slope indicated that the FRN amplitude was larger for A trials overall. That relationship was qualified by the interaction coefficient which indicated that the difference between the X and the Y amplitudes when B was chosen was larger than the difference between X and Y amplitudes when A was chosen (see Figure 4).This interaction supports our hypothesis that the non-optimal outcome would generate a larger FRN amplitude when the participant chose the competitive choice (Row B).

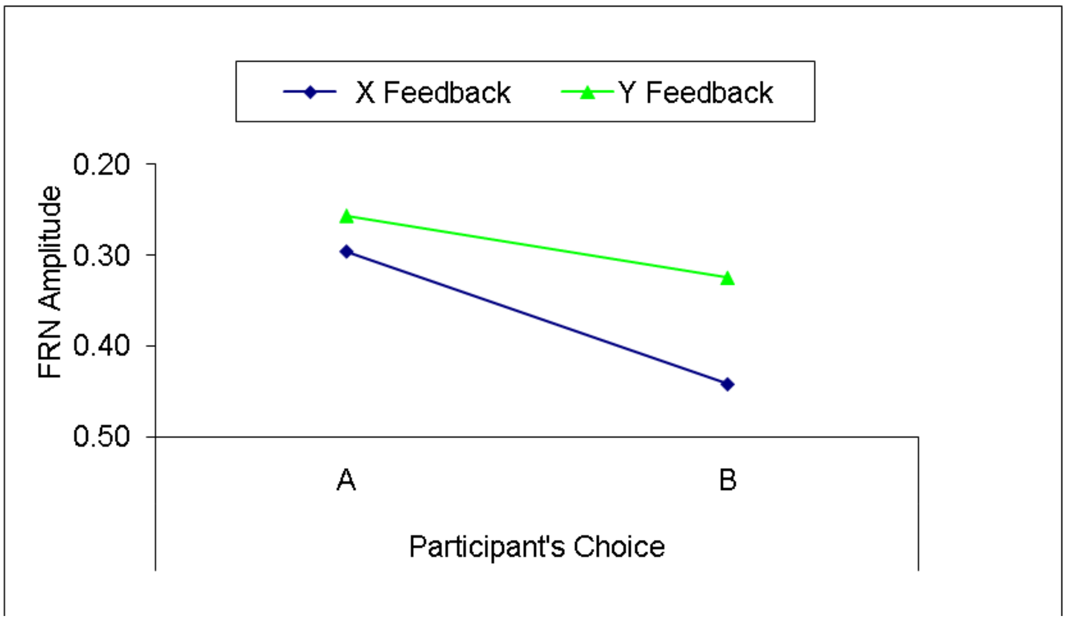

Figure 4 **Plot of the two-way interaction between the other player's feedback and the participant's choice on FRN amplitude.**

The third hypothesis was that that relationship between the participant's cooperativeness and the other player's cooperativeness would be further amplified on trials when the participant was playing the negative game. To test this prediction, we used a three-way interaction of the other player's feedback (Column X or Y), the participant's choice (Row A or B), the game (Positive or Negative), to predict the participant's FRN amplitude. We allowed for both the intercept and slope to vary from participant to participant (except for the slope of the three-way interaction, because there were not enough degrees of freedom to allow for all of the possible random effects and there was no evidence that the three-way interaction slope differed between participants). The following HLM level-1 equation was used to test this prediction:

$$FRN_{ti} = \beta_{00} + \beta_{10}(POS\_NEG_{ti}) + \beta_{20}(A\_B_{ti}) + \beta_{30}(X\_Y_{ti}) + \beta_{40}(PN\_XY_{ti}) + \beta_{50}(PN\_AB_{ti}) + \beta_{60}(AB\_XY_{ti}) + \beta_{70}(PN\_AB\_XY_{ti}) + e_{ti}$$

In this model, the intercept β_{00} represents the average FRN amplitude, for trials t nested within individuals i, across all participants for trials where the matrix was positive and both the participant and other player made cooperative choices (Row A and Column X). β_{10} though β_{70} represent the slop coefficients for each of the main effect and interaction variables and e_{ti} is the error term. POS_NEG is a dummy coded variable where 0 represents trials when the participants were making choices in a positive matrix, and 1 represents trials where the negative matrix was used. A_B is a dummy coded variable that was 0 for trials that the participant made the cooperative choice (Row A), and 1 for trials where the participant made the competitive choice (Row B). X_Y is a dummy coded variable where 0 represents cooperative feedback

(Column X) and 1 represents competitive feedback (Column Y) from the other participant. The remaining variables represent the two- and three-way interactions between the three dummy coded variables. Parameter estimates and significance tests for this HLM model are presented in Table 3.

Table 3 HLM Fixed Effects Regressing Feedback Related Negativity Amplitude on the Matrix Type, Participant's Cooperativeness, and Other Player's Cooperativeness

Fixed effects (intercept, slopes)	Estimate (SE)	t(54)[a]	p-value
Intercept, β_{00}	0.32 (0.04)	7.51	<0.001
POS_NEG, β_{10}	0.005 (0.03)	0.19	0.85
A_B, β_{20}	0.16 (0.03)	4.93	<0.001
X_Y, β_{30}	-0.08 (0.03)	-2.67	0.01
PN_XY, β_{40}	0.01 (0.03)	0.30	0.77
PN_AB, β_{50}	-0.10 (0.03)	-3.19	0.003
AB_XY, β_{60}	-0.14 (0.04)	-3.77	0.001
PN_AB_XY, β_{70}	0.13 (0.04)	3.05	0.003

Note. HLM = Hierarchical Linear Modeling. [a]Reported degrees of freedom were 54 for all calculations except the three-way interaction for which there were 318 degrees of freedom.

As in the previous model, the FRN was larger when the participant's opponent chose the competitive choice (Column Y). Additionally, in line with our second hypothesis, this effect was larger on those trials when the participant had also chosen the competitive choice (Row B). In our third hypothesis, we had predicted that this effect would be further amplified for trials that were played with the negative matrix which was tested by the three way interaction. However, the opposite was found, the FRN difference between the X and Y amplitudes for trials where the participant chose B was larger for the positive matrix (see Figure 5).

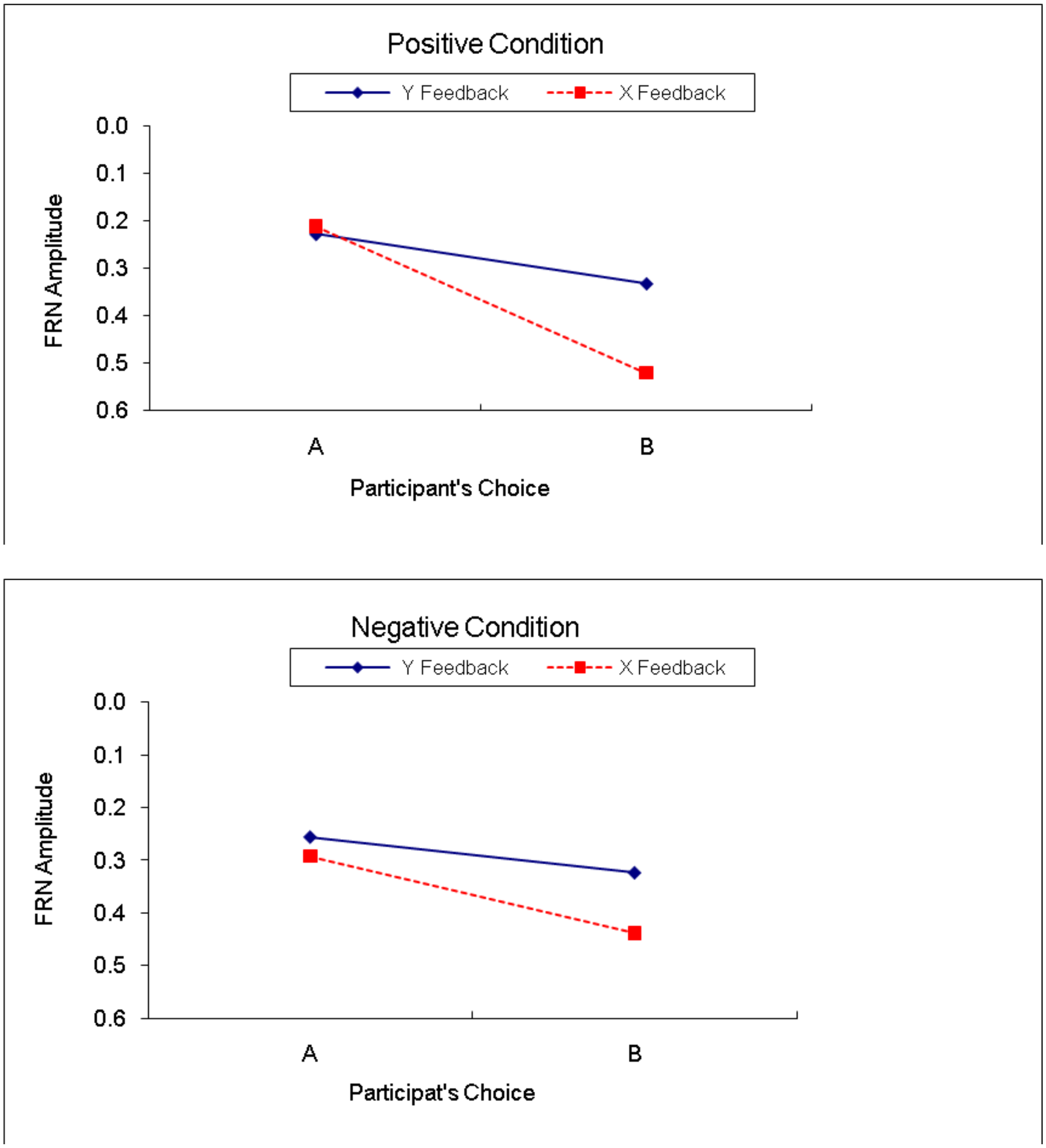

Figure 5 **Plot of the three-way interaction between the other player's feedback, the participant's choice, and matrix type on FRN amplitude.**

Chapter 4

DISCUSSION

Our first hypothesis examined the question of whether the FRN was an appropriate way to look at the processing of feedback in social decision making games. We predicted that the FRN would be larger on trials where the other player did not cooperate, and this prediction was supported. This supports the idea that the FRN is sensitive to optimal versus non-optimal outcomes in a complex social decision making situation. This proof of concept suggests that the FRN maybe an appropriate measure to compare different kinds of feedback in social situations.

Our second hypothesis looked at how the expectations related to a participant's choice to cooperate or compete would influence the FRN to the feedback that the participant received from the other player about the success of his or her choice. Specifically, we hypothesized that the FRN would be larger when the participant and the other player both chose the competitive option, which resulted in the worst possible outcome for both players. The FRN was larger when both players chose the competitive choice. This indicates that the FRN was most reactive to the condition when participants had the most to gain or lose, and ended up losing it all.

Also, it was predicted in hypothesis three that the FRN would be further amplified when participants were facing a potential loss as opposed to a lack of gain. Specifically, we predicted that the effect would be largest in the negative matrix. Surprisingly, this effect was amplified for the positive matrix, not the negative one. This result runs contrary to what would be predicted based on prospect theory (Kahneman & Tversky, 1979). Prospect theory describes the common economic phenomenon where people find loss more aversive than they find pleasure in a gain of the same size. That led us to hypothesize that the negative condition, where up to a dollar can be lost, would be more aversive, and therefore generate a larger FRN than the positive condition, where breaking even is the worst outcome.

Contrary to our prediction, the three way interaction was driven by the condition that is most favorable to the participant (BX in the positive matrix) instead of by the condition that is most negative (BY in the negative matrix). We hypothesized that the negative BY condition would cause the most negative FRN, but instead the most notable FRN amplitude was the positive BX condition, which was much less negative than the FRN in the other conditions.

This unexpected result highlights one difficulty with using the FRN as a dependent measure which is the fact that the negative going component overlaps in time with other positive components. The FRN's overlap with the much larger positive P3 component has often been accounted for when analyzing the FRN. Not only do the two components overlap in time, but also both components are sensitive to the participant's expectation on a given trial and valance of the outcome with larger P3 amplitudes for gains than non-gains (Hajcak, et al., 2007). It seems that one limitation of measuring the FRN as the mean amplitude without accounting for the P3 is that we cannot disentangle relationships between conditions that are driven by fluxuations in the FRN from relationships that are driven by fluxuations in the P3.

Also, of interest when considering this measurement problem is some recent research on the FRN that indicates that fluxuations in the so-called FRN are primarily caused from a positive component that overlaps in time with the FRN and is largest for wins relative to losses (Foti, Weinberg, Dien, & Hajcak, in press). If that is true, then we would also need to account for fluxuations in this Feedback Related Positivity (FRP) in addition to accounting for the P3 when interpreting the FRN amplitude. It seems possible that our interpretation of these findings, and particularly the three-way interaction might benefit from thinking about a small FRN as representing a large FRP and vice versa. From this perspective, it makes sense that the largest FRP would be found for the trial that produced the largest gain for participants. One future direction of for this study would be to use Principle Component Analysis (PCA) to isolate the FRN from the P3 and perhaps from the FRP so as to isolate and compare the contributions of all three components which occur during the time period being measured in this experiment.

Another future direction of this line of research would be to consider how individual difference variables might be related to the FRN during the Chicken and other social decision making games. One potentially interesting variable would be Social Value Orientation (Au & Kwong, 2004) which is a preference for a certain distribution of resources between the self and another. The three most common SVOs reflects a motivation to maximize their own and other's gain (J), to maximize their own gain (O), and to maximize the relative difference between their gain and the other's gain (R). People with these divergent sets of goals may approach the Chicken game with different expectations and therefore interpret the different levels of feedback differently.

Another potentially interesting individual differences variable to consider would be the participant's level of anxiety. Resent research has suggested that anxious participants tend to have smaller FRNs than non-anxious participants (Gu, Huang, & Luo, 2010; Stanley & Simons, 2010) during gambling tasks. Perhaps the same pattern would hold in the context of a social decision making game, but it is possible that the social context could change the interpretation the anxious person makes of the feedback. Since other ERPs generated in the ACC such as the Error-Related Negativity (ERN) are larger for anxious people (Hajcak, McDonald, & Simons, 2003), it is possible that when participants become more anxious the FRN would be larger as well.

Additionally, the FRN could be used to explore a variety of social dilemmas that have been studied by economists and psychologists for years. It could prove to be a useful tool to quantify a person’s response to feedback in these games without relying on the self-report or changes in behavior to understand the response.

REFERENCES

Au, W. T., & Kwong, J. Y. Y. (2004). Measurements and effects of social-value orientation in social dilemmas. In R. Suleiman, D. V. Budescu, I. Fischer & D. M. Messick (Eds.), Contemporary Psychological Research on Social Dilemmas (pp. 71-98). New York: Cambridge University Press.

Foti, D., Weinberg, A., Dien, J., & Hajcak, G. (in press). Event-related potential activity in the basal ganglia differentiates rewards from non-rewards: Temporospatial principal components analysis and source localization of the Feedback Negativity. Human Brain Mapping.

Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. Science, 295(5563), 2279-2282. doi: 10.1126/science.1066893

Gu, R., Huang, Y.-X., & Luo, Y.-J. (2010). Anxiety and feedback negativity. Psychophysiology, 47(5), 961-967. doi: 10.1111/j.1469-8986.2010.00997.x

Gueorguieva, R., & Krystal, J. H. (2004). Move over ANOVA: Progress in analyzing repeated-measures data and its reflection in papers published in the archives of general psychiatry. Arch Gen Psychiatry, 61(3), 310-317. doi: 10.1001/archpsyc.61.3.310

Hajcak, G., McDonald, N., & Simons, R. F. (2003). Anxiety and error-related brain activity. Biological Psychology, 64(1-2), 77-90. doi: 10.1016/s0301-0511(03)00103-0

Hajcak, G., Moser, J. S., Holroyd, C. B., & Simons, R. F. (2006). The feedback-related negativity reflects the binary evaluation of good versus bad outcomes. Biological Psychology, 71(2), 148-154. doi: 10.1016/j.biopsycho.2005.04.001

Hajcak, G., Moser, J. S., Holroyd, C. B., & Simons, R. F. (2007). It's worse than you thought: The feedback negativity and violations of reward prediction in gambling tasks. Psychophysiology, 44(6), 905-912. doi: 10.1111/j.1469-8986.2007.00567.x

Hewig, J., Kretschmer, N., Trippe, R. H., Hecht, H., Coles, M. G. H., Holroyd, C. B., & Miltner, W. H. R. (2010). Why humans deviate from rational choice. Psychophysiology, no-no. doi: 10.1111/j.1469-8986.2010.01081.x

Holroyd, C. B., Hajcak, G., & Larsen, J. T. (2006). The good, the bad and the neutral: Electrophysiological responses to feedback stimuli. Brain Research, 1105(1), 93-101. doi: 10.1016/j.brainres.2005.12.015

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. Econometrica Retrieved December 4, 2010, from http://www.jstor.org/stable/1914185

Miltner, W. H. R., Braun, C. H., & Coles, M. G. H. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a “generic” neural system for error detection. Journal of Cognitive Neuroscience, 9(6), 788-798. doi: 10.1162/jocn.1997.9.6.788

Moser, J. S., & Simons, R. F. (2009). The neural consequences of flip-flopping: The feedback-related negativity and salience of reward prediction. Psychophysiology, 46(2), 313-320. doi: 10.1111/j.1469-8986.2008.00760.x

Rapoport, A., & Chammah, A. M. (1966). The game of chicken. American Behavioral Scientist, 10(3), 10-28. doi: 10.1177/000276426601000303

Raudenbush, S. W., & Bryk, A. S. (2002). Hierarchical linear models: Applications and data analysis methods (2nd ed.). Thousand Oaks, CA: Sage Publications.

Sally, D. (1995). Conversation and cooperation in social dilemmas. Rationality and Society, 7(1), 58-92. doi: 10.1177/1043463195007001004

Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. Psychological Methods, 7(2), 147-177. doi: 10.1037//1082-989X.7.2.147

Stanley, E. M., & Simons, R. F. (2010). Error- and feedback-related negativity in obsessive-compulsive undergraduates. Manuscript in preperation.

van den Bos, W., van Dijk, E., Westenberg, M., Rombouts, S. A. R. B., & Crone, E. A. (2009). What motivates repayment? Neural correlates of reciprocity in the Trust Game. Social Cognitive and Affective Neuroscience, 4(3), 294-304. doi: 10.1093/scan/nsp009

APPENDIX – IRB APPROVAL LETTER

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE:	July 22, 2010
TO:	Emily Stanley
FROM:	University of Delaware IRB
STUDY TITLE:	[136707-3] Psychophysiological Correlates of the Chicken Game
IRB REFERENCE #:	
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	July 22, 2010
EXPIRATION DATE:	April 25, 2011
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # 7

Thank you for your submission of Amendment/Modification materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Elizabeth Peloso at 302-831-8619 or epeloso@udel.edu. Please include your study title and reference number in all correspondence with this office.