Reward Reactivity and Impulsivity

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Introduction

This summer, I would like to examine the relationship between reward reactivity and impulsivity using unanalyzed data recently collected by graduate students in my lab. Impulsivity is the tendency towards rapid reactions to stimuli without considering negative consequences of those reactions (Moeller & Barratt, 2001). Impulsivity has consequences for our understanding of psychiatric disorder: high impulsivity has been linked to several psychiatric disorders, including substance addiction and bipolar disorder (Swann et al, 2004). Reward-reactivity represents how people engage with and process reward-related feedback. Reward-reactivity has been linked to several clinical populations: reward reactivity is decreased in depressive populations (Naranjo 2001) and increased in bipolar populations (Nusslock 2012). It is hypothesized that highly impulsive people will display enhanced reward-reactivity, because impulsive people tend to over-engage with the reward in front of them, suggesting enhanced reactivity to immediate reward (Moeller & Barratt, 2001). In sum, my research attempts to answer this question: *Does reward-reactivity related electrical activity in the brain reliably index impulsivity?*

Methods

The subject pool included 56 right-handed participants (25 female) from the Evanston area, recruited via flyer. The mean age of participants was 24.71. Data was collected over the course of one quarter, and participants were paid $35 for participation in the study. Participants completed a delay-discounting task to study impulsivity, and an ERP task to study reward-reactivity.

Impulsivity and the Delay-Discounting Paradigm: In this study I will use a reward-choice paradigm, specifically the delay-discounting paradigm, to measure impulsivity. In the delay-discounting paradigm, participants are asked to choose between a monetary sum that can be received now, and a monetary sum that can be received after a certain period of time. By incrementally increasing or decreasing the amount received now, we can find the point at which the participant will switch preference from now to later and find the "subjective value" of the later sum. For example, if data shows a participant sees 800 dollars in six months as being worth 400 dollars now, 400 dollars is the subjective value of 800 dollars with t= six months. This procedure is repeated with different values of t. See Appendix A. Highly impulsive people will tend towards selecting the "now" sum of money, and will have lower subjective values for money given later (Manuck et al, 2003). Thus, subjective values can be analyzed as an index for impulsivity. The delay-discounting paradigm is used here because it is used broadly across many fields, including social and clinical psychology, psychophysiology, and economics. This gives results from delay-discounting data greater versatility and applicability.

The Feedback-Related Negativity and the Event-Related Potential: The FRN is a negative electric potential documented in the medial prefrontal region of the brain, speculated to emanate from the anterior cingulate cortex (a reward related region) (Gehring & Willoughby, 2002). This potential is readily observed when participants receive feedback on performance, and is enhanced when feedback is negative (Hajcak, Moser, Holroyd, & Simons, 2006). This difference between the positive and negative condition will be critical during data analysis. The difference between amplitude of the FRN for positive and negative feedback is our index for reward-reactivity, as this indicates the extent to which participants "react" electrically to

feedback (Bress & Hajcak, 2013). This potential will be measured through the Event-Related Potential (ERP) Technique.

The ERP technique uses electrodes to record electrical potentials in temporal relation to "events" (in this case, positive and negative feedback). Participants have neuroelectrical activity recorded via EEG using electrodes on the scalp, and this electrical activity is examined in temporal relation to the task being performed by the participant. The study of brain potentials can provide unique insights into the cascade of subevents involved in complicated events like reward reaction. Only ERP provides the temporal resolution (down to the millisecond) to differentiate between and study individual neural potentials. This makes it an ideal tool to study subtle and microtimed electrical activity like the FRN. In the present study, participants will perform a classic gambling task while having ERP data recorded. This task involves selecting between two doors. Behind one of the doors is a +$, indicating winning money, and behind the other is a -$, indicating lost money. After choosing a door, the participant will receive feedback (whether he/she won or lost money) after two seconds. See Appendix B. This task is useful because it reliably elicits the FRN after participants receive feedback.

Data Analysis

Subjective values from the delay-discounting task will form an exponential curve. See Appendix C. This curve can be analyzed in several ways to provide a final index for impulsivity. Area under the curve, k-value in a hyperbolic regression, and k-value in an exponential regression can all be reliably used to reliably represent delay-discounting data (Reed, Kaplan, & Brewer, 2012), and will be considered in analysis as final impulsivity values.

With respect to ERP data, electrical activity will be examined in the frontocentral FCz electrode, where the FRN is generally localized (Foti, Weinberg, Dien, & Hajcak, 2011). Activity up to 500 ms post-feedback and 200 ms pre-feedback will averaged for both gain and loss conditions. After applying filters to normalize data and increase signal-to-noise ratio, the difference between "gain" and "loss" FRN amplitude will be calculated for each participant. This difference value is the final index for reward reactivity: a larger difference indicates a higher reactivity to reward-related feedback (Foti et al., 2011). See Appendix D.

If there is a negative correlation between impulsivity values and FRN gain-loss value it can be preliminarily concluded that the FRN indexes impulsivity. This will verify that, at the electrophysiological level, highly impulsive people show stronger reactivity to reward-related feedback, a connection that would refine our understanding of both impulsivity and reward reactivity. It should be noted that the correlation is negative because the FRN is a negative potential, so impulsivity will hypothetically increase with more negative FRN gain-loss value.

Conclusion

The results of this study could open the door for future studies considering further implications of the FRN (perhaps for clinical populations), or considering different methodologies for a more holistic understanding of reward-reactivity and personality variables (perhaps using fMRI for enhanced spatial resolution).

I chose to work in the ACNL because it is one of the only labs committed to multimodal, interdisciplinary study of the brain, a strategy that is probing many new frontiers in neuroscience. Through the ACNL I have been introduced to multiple techniques and ideas normally not simultaneously present in a lab, including ERP, fMRI, dMRI, and TMS. This summer, I hope to gain the skills to function as a competent ERP researcher, with competence in data collection, data analysis, research presentation, and experimental design.

Works Cited

Bress, J. N., & Hajcak, G. (2013). Self-report and behavioral measures of reward sensitivity predict the feedback negativity. *Psychophysiology*, *50*(7), 610–6. doi:10.1111/psyp.12053

Foti, D., Weinberg, A., Dien, J., & Hajcak, G. (2011). Event-related potential activity in the basal ganglia differentiates rewards from nonrewards: temporospatial principal components analysis and source localization of the feedback negativity. *Human brain mapping*, *32*(12), 2207–16. doi:10.1002/hbm.21182

Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science (New York, N.Y.)*, *295*(5563), 2279–82. doi:10.1126/science.1066893

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), 148–54. doi:10.1016/j.biopsycho.2005.04.001

Manuck SB, Flory JD, Muldoon MF, Ferrell RE (2003) A neurobiology of intertemporal choice. In: Time and decision: economic and psychological perspectives on intertemporal choi

Moeller, F., & Barratt, E. (2001). Psychiatric Aspects of Impulsivity. *American journal of Psychiatry* (November), 1783–1793. Retrieved from http://journals.psychiatryonline.org/article.aspx?articleid=175139

Naranjo, C. A., Tremblay, L. K., and Busto, U. E. (2001). The role of the brain reward system in depres- sion. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 25, 781–823.

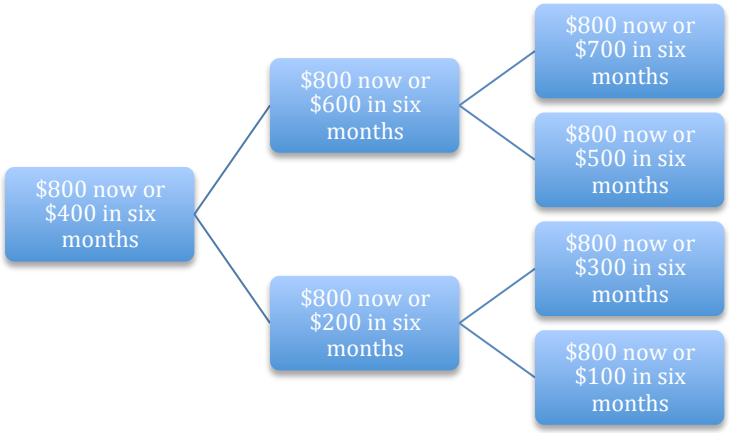
Nusslock, R., Almeida, J. R., Forbes, E. E., Versace, A., Frank, E., Labarbara, E. J., … Phillips, M. L. (2012). Waiting to win: elevated striatal and orbitofrontal cortical activity during reward anticipation in euthymic bipolar disorder adults. *Bipolar disorders*, *14*(3), 249–60.

Reed, D. D., Kaplan, B. a, & Brewer, A. T. (2012). A tutorial on the use of Excel 2010 and Excel for Mac 2011 for conducting delay-discounting analyses. *Journal of applied behavior analysis*, *45*(2), 375–86. doi:10.1901/jaba.2012.45-375

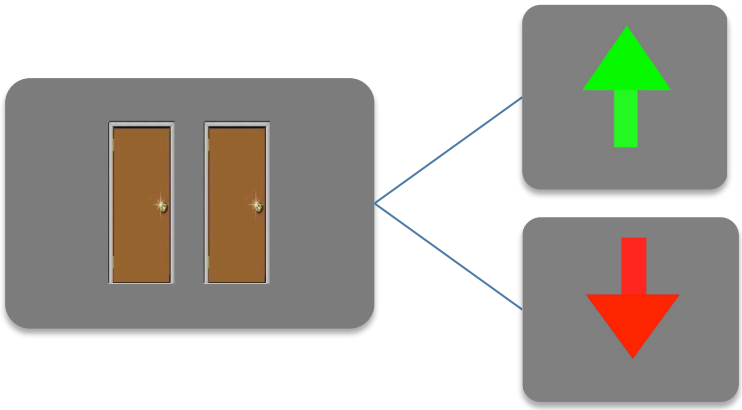
Swann, A. C., Dougherty, D. M., Pazzaglia, P. J., Pham, M., & Moeller, F. G. (2004). Impulsivity: a link between bipolar disorder and substance abuse. *Bipolar disorders*, *6*(3), 204–12. doi:10.1111/j.1399-5618.2004.00110.x

Appendices

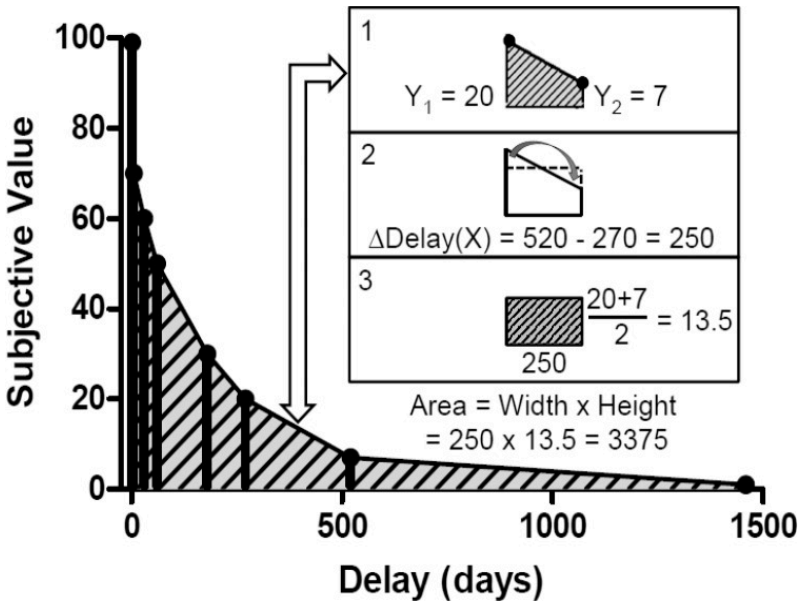
A. Delay-Discounting Task. Fixed Value=800, t=six months



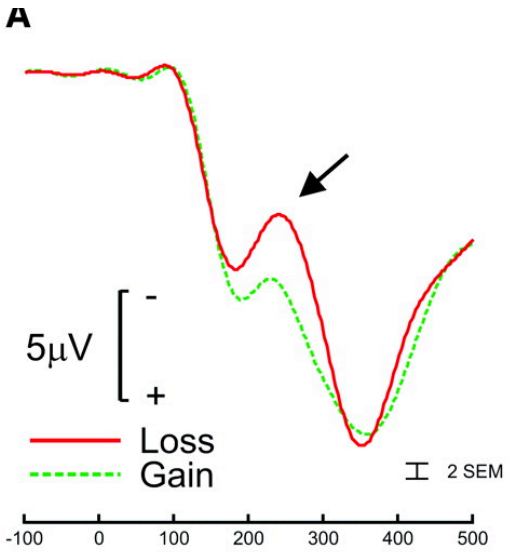
B. Gambling Task



C. Sample Impulsivity Data (Reed et al., 2012)



D. Sample FRN Data (Gehring & Willoughby, 2002). Recorded at FCz electrode. Difference between two curves at highlighted point (FRN) is final value for reward-reactivity.



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