Distinct Behavioral Profiles of Information-Seeking for Reward in Euthymic Bipolar Disorder

Manon L. Ironside[1], Anne G. Collins[1], Luke Clark[2], Erin Michalak[3], Caden Poh[3] & Sheri L. Johnson[1]

[1] University of California Berkeley, Dept. of Psychology, [2]University of British Columbia, Dept. Of Psychology, 3 University of British Columbia, Dept. of Psychiatry

Background

Past research suggests a reward hypersensitivity profile of bipolar disorder, including increased exploratory behavior in reward-rich environments, even during euthymia.[1,2] Little research exists on the decision process during goal-pursuit within this group, which may offer greater specificity on where processes go awry as symptoms worsen. To this end, we used the Observe or Bet task to index explore-exploit decision making tendencies in a reward learning environment.[3,4] The use of this task is novel in psychiatric samples. Crucially, this task requires learners to balance seeking information about reward contingencies with making correct guesses to earn money, removing the confound of reward and information often present in bandit tasks.

Key Questions: **(1)** Will participants with bipolar disorder seek information about reward to a greater extent than psychiatric controls? **(2)** If so, can this difference be explained by a higher decision threshold and/or a higher evidence decay rate?

Participants and Methods

We recruited 38 participants with bipolar disorder and 35 psychiatrically matched controls from the community across two sites (UBC in Vancouver, British Columbia and UC Berkeley in Berkeley, CA).

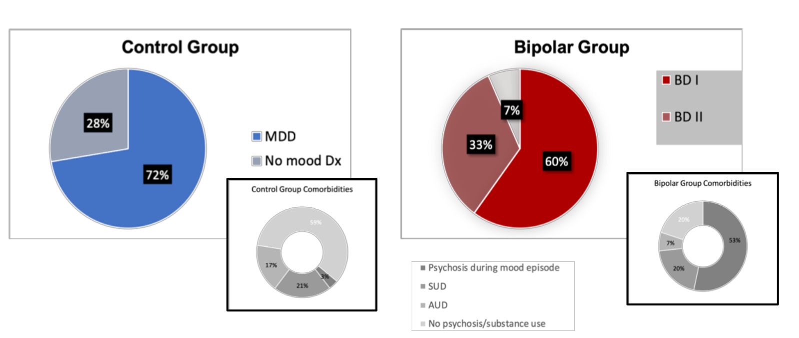

Figure 1. Primary Diagnoses and Comorbidities of Bipolar and Control Groups. Groups were matched on age, gender, and subjective SES.

Participants performed an explore-exploit decision making task in which they had to balance seeking information (explore choices) with guessing outcomes for reward (exploit choices) in a probabilistic and volatile learning environment. To model trial-by-trial behavior, we implemented an evidence accrual model proposed by Navarro & Colleagues (2016) and a Softmax choice model. This model assumes that the learner accumulates evidence on observations (which decays at rate a), and makes a bet once some decision threshold d has been reached.

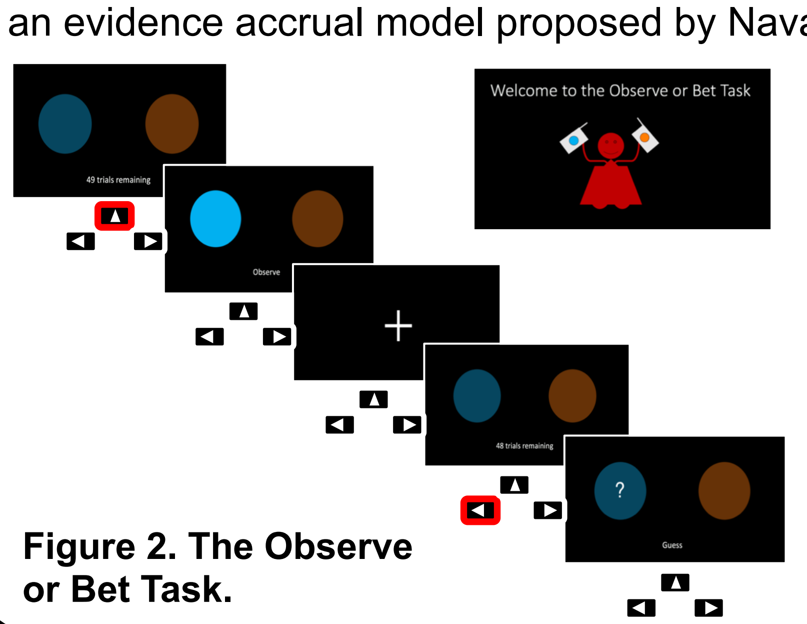

Figure 2. The Observe or Bet Task.

Participants Showed a Range of Approaches to the Explore-Exploit Dilemma

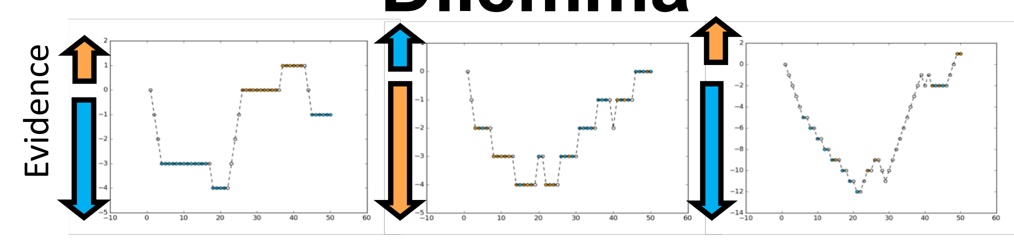

Figure 3. Individual Differences in Explore-Exploit Behavior. Example choice behavior within a block for three separate participants. White dots = observe choices, filled dots = bet choices, line shows relative information gained for blue or orange bias.

Participants with Bipolar Disorder Showed Increased Information-Seeking Behavior

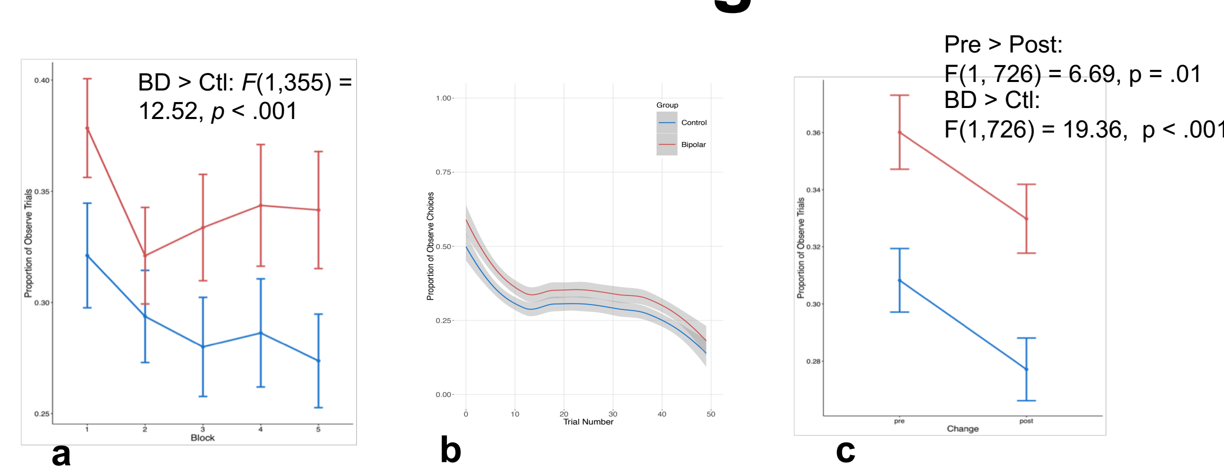

Figure 4. Group Differences in Information-Seeking Behavior. Proportion of information-seeking choices **(a)** across blocks; **(b)** across trials; **(c)** before and after the bias switch within a block.

Psychiatric Control and Bipolar Groups Showed Similar Exploit Behavior

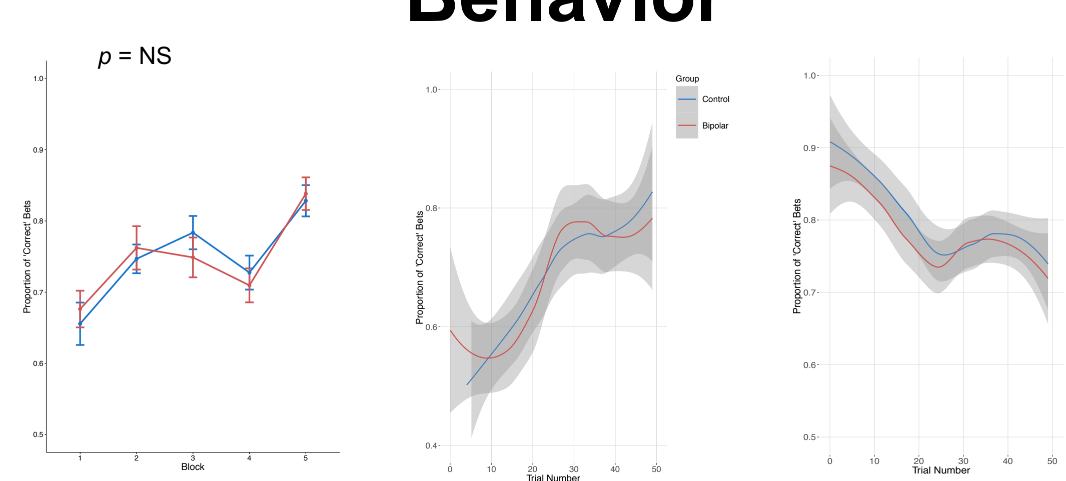

Figure 5. Groups Made Equally Profitable Exploit Choices. Proportion of bets consistent with the biased color **(a)** across blocks; **(b)** across trials during block 1, before learning the structure of the task; **(c)** across trials, averaged over blocks 2-5.

Trial-by-Trial Computational Modeling of Explore-Exploit Behavior

Evidence accrual function

$$e_t = x_t + (1 - a)e_{t-1}$$

Softmax choice function

$$p(obs) = \frac{1}{1 + exp^{\beta(|e_t| - d_t)}}$$

$$p(bet) = 1 - p(obs)$$

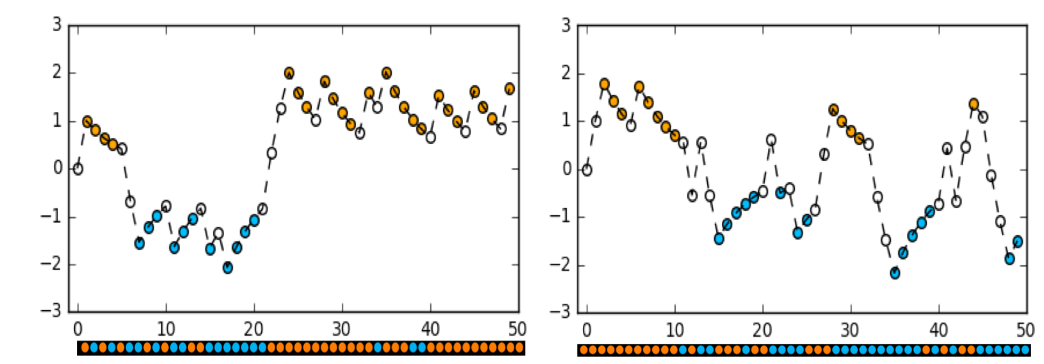

Figure 7. Example Simulation Data for 2 Blocks.

The maximizer model assumes that participants will bet for the color with more evidence after evidence accrual reaches a subjective decision threshold (Fig. 7). When the agent makes bets (filled dots) they do not gain information, and their evidence value decays at a subjective rate.

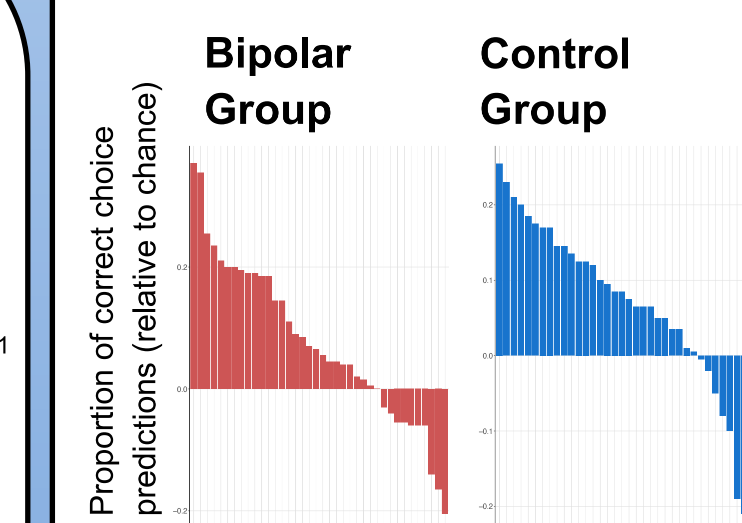

Figure 8. Proportion of Choices Predicted Above Chance Level.

To calculate model performance, we fit parameters based on a training set (80% of the data, 4 blocks) and compared generated data using the fit parameters with a test set (20% of the data, 1 block).

The model predicted trial by trial behavior above chance in the test dataset for 74% of the Bipolar group (Fig. 8, *left*) and 80% of the Control group (Fig. 8, *right*). Chance was calculated separately per participant, defined as the % maximum choice (observe, bet right, bet left) across trials in the 4-block training set.

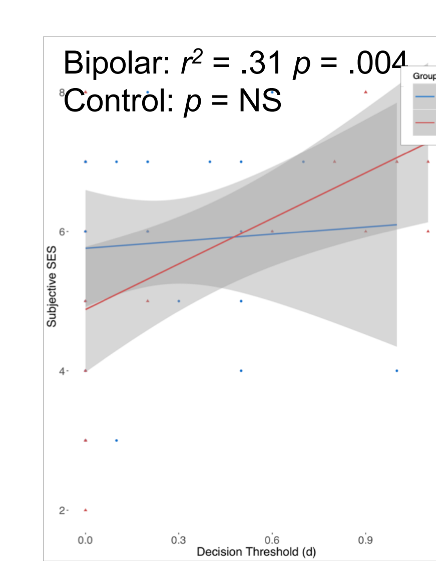

Figure 9. Modeled Decision Threshold and SES Correlations by Group

Contrary to our hypotheses, increased information seeking in the Bipolar group was **not** explained by higher decision thresholds or evidence decay rates. Exploratory correlations showed a significant association between decision threshold and subjective SES for the bipolar group, but not for the control group (Fig. 9).

References

1. Perry, W., Minassian, A., Paulus, MP.... (2009). A reverse-translational study of dysfunctional exploration in psychiatric disorders. *JAMA Psychiatry, 66*(10), 1072-1080. **2.** Henry, B. L., Minassian, A., Patt, V. M., Hua, J., Young, J. W., Geyer, M. A., & Perry, W. (2013). Inhibitory deficits in euthymic bipolar disorder patients assessed in the human behavioral pattern monitor. *J Affect Disord, 150*(3), 948-954. **3.** Navarro, D. J., Newell, B. R., & Schulze, C. (2016). Learning and choosing in an uncertain world: An investigation of the explore-exploit dilemma in static and dynamic environments. *Cogn Psychol, 85*, 43-77. **4.** Tversky, A. Edwards, W. (1966). Information versus reward in binary choices. *J Exp Psychol, 71*(5), 680-683.

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