Threat of Punishment and Model-Based Learning in Late-Life Depression and Suicidal Behavior

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Introduction

Declines in learning and decision-making ability are associated with aging and suicidality. Older adults with suicidal behavior have difficulty navigating stressful and complicated situations.[1]

In particular, suicide attempters have difficulty exploiting desirable outcomes and avoid tasks requiring deliberation or cognitive demands. [2]

Model-Based learning (MBL) is a form of learning that relies on a cognitive map of the environment, rather than a history of rewards. MBL is more cognitively demanding than model-free learning and is reduced under acute stress. [3]

In the present study, we assessed MBL and the effects of a stress/threat manipulation on MBL in older adults with and without a history of suicide attempts.

H1: All groups will show altered model-based learning during the with threat condition.

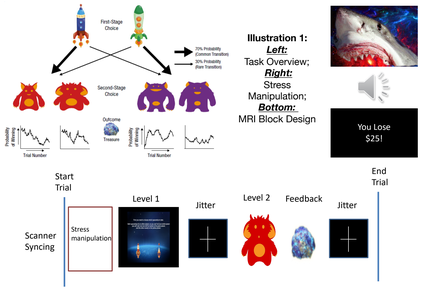
H2: Compared to healthy control participants, ideators and attempters but not depressed controls will show lower MBL.

H3: Attempters will show additional decreases in MBL under the threat condition.

Method

Sample: N=84, age 50+, suicide attempters (ATT, n = 28), ideatiors (IDE, 20), depression without suicidal behavior (DEP, 14), and controls (HC, 22). MDD assessed with SCID. 3 subjects did not complete MRI scan.

Two-Step Decision Task: Learning task assessing model-based versus model-free learning (Illustration 1). Each first stage choice (spaceships) is more likely to lead to one of two second stage states (planets). Outcome (reward/no reward) occurs probabilistically after selecting a second stage option (aliens).



Blocks of trials (total blocks = 2) alternated between non-threat and threat of punishment conditions. A visual cue signals the threat condition. Participants are told that a punishment may occur at any time during the threat block, but punishment (monetary loss [-$25], fearful image, and fearful auditory stimulus of a 'shark attack') only occurs once, during the first threat block.

Analysis: We analyzed behavioral data with:

1) Logistic mixed effects regression predicting first stage choice staying as a function of reinforcement, transition type (common/rare), and interaction;
2) Linear mixed effects regression predicting first stage reaction times (RT) with reinforcement, transition type, group and interactions; and
3) By fitting a reinforcement learning model to choices.

Regressors entered into the first level fMRI GLM included: at the first stage decision, reward prediction error, presence of reinforcement (reward/omission), transition type (common/rare), and reinforcement by transition type from previous trial ; at second stage onset, current trial's transition type. Unpaired t-tests assessed differences between groups.

Results

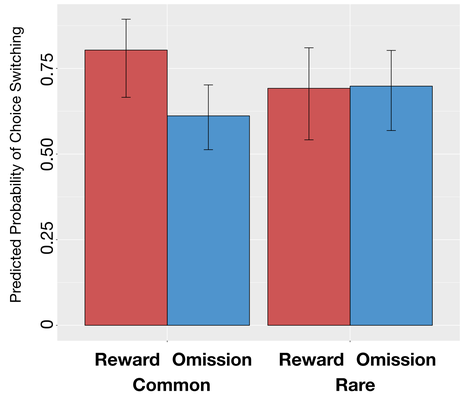


Figure 1: Effect of previous transition type * reward type interaction on first stage choice

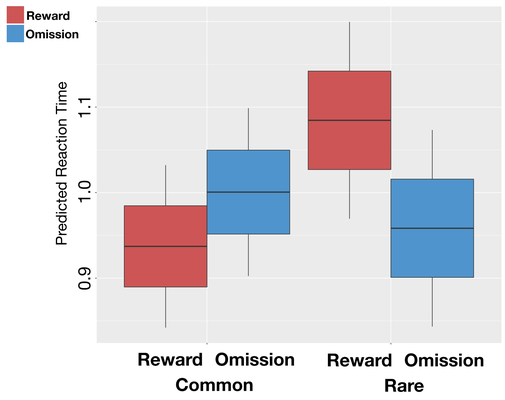


Figure 2: Effect of previous transition type * reward type on first stage RT

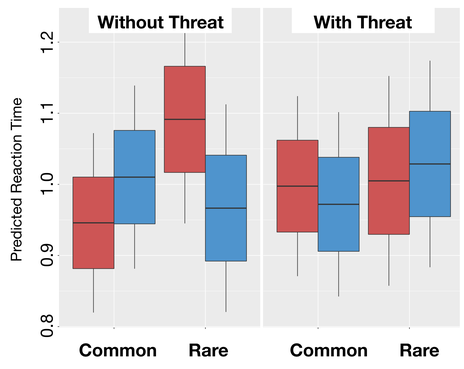


Figure 3: Effect of the transition type * reward type * block type on first stage RT

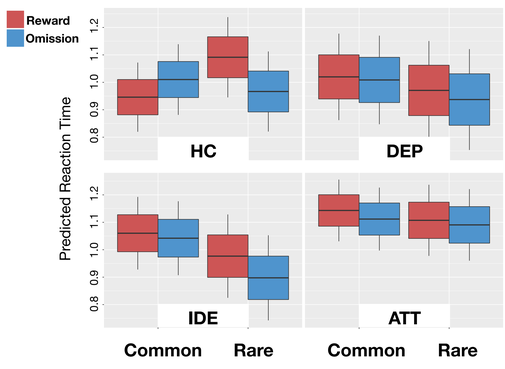


Figure 4: Effect of the previous transition type * reward type * group on first stage RT

Figure 5: Neural effect of threat of punishment (With Threat > Without Threat) in healthy control

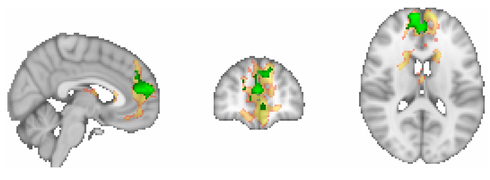


Figure 6: Neural effect of previous reward type at first decision time (Reward > No Reward)

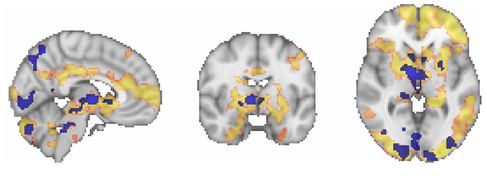


Figure 7a: Neural effect of the second stage prediction error with Control > Depressed contrast

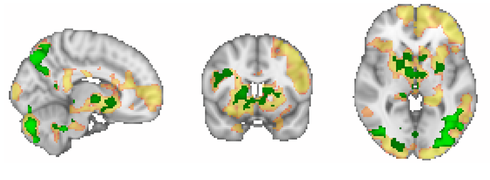
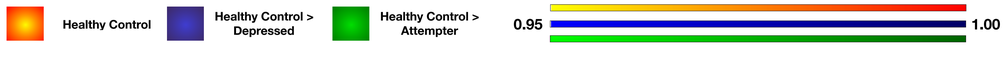
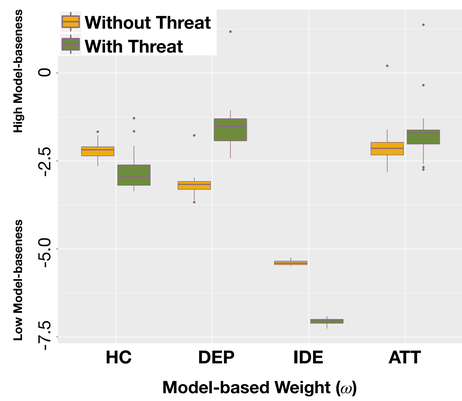
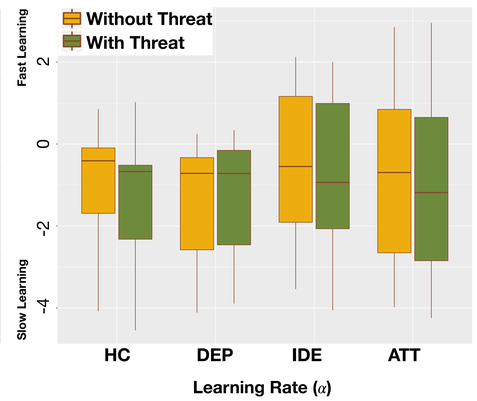


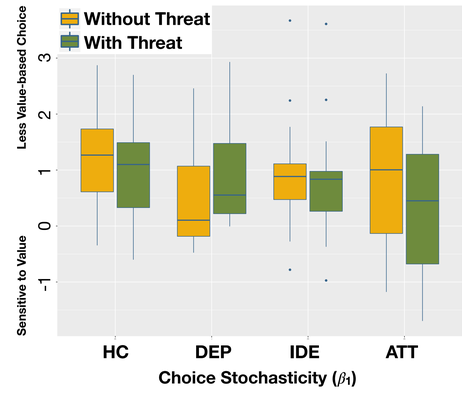
Figure 7b: Neural effect of the second stage prediction error with Control > Attempter contrast



Cluster method: threshold free cluster enhancement (tfce), 1-P > 0.95







$$Q_{MF}(s_{i,t+1},a_{i,t+1}) = Q_{MF}(s_{i,t},a_{i,t}) + \alpha^{*}\delta_i + \lambda^{*}\delta_{i+1}; \quad \text{where } \delta_i = [r_{i,t} + Q_{MF}(s_{i+1,t},a_{i+1,t})] - Q_{MF}(s_{i,t},a_{i,t})$$

$$Q_{MB}(s_{1,t},a_j) = P(s_{2B}|s_{1,}a_j) * max\ Q_{MF}(s_{2B},a) + P(s_{2C}|s_{1,}a_j) * max\ Q_{MF}(s_{2C},a)$$

$$P(s_{2B}|s_{1,}a_j) = 1\text{-}P(s_{2C}|s_{1,}a_j) = \mu_{PTransition_i}, \text{where } P_{transition_i} \sim Beta(\alpha,\beta)$$

$$Q_{unchosen}(s_{i,t+1},a_{i,t+1}) = (1\text{-}\alpha)^{*}\ Q_{unchosen}(s_{i,t},a_{i,t})$$

$$P(a_{i,t} = a|s_{i,t}) = \frac{\exp\left[\beta_{1MB}{}^{*}Q_{MB}(s_{1,t},a) + \beta_{1MF}{}^{*}Q_{MF}(s_{1,t},a) + \rho_{choice}{}^{*}choice\ rep(a) + \rho_{motor}{}^{*}motor\ rep(a)\right]}{\sum_{a'}\exp\left[\beta_{1MB}{}^{*}Q_{MB}(s_{1,t},a') + \beta_{1MF}{}^{*}Q_{MF}(s_{1,t},a') + \rho_{choice}{}^{*}choice\ rep(a') + \rho_{motor}{}^{*}motor\ rep(a')\right]};$$

where $\beta_{1MB}\ (s_i,a_j) = \omega^{*}\beta_1$ & $\beta_{1MF} = (1\text{-}\omega)^{*}\beta_1$

Figure 8 (Top Left): Posterior of model-based weight (ω) parameter in Gaussian space.

Figure 9 (Top Right): Posterior of learning rate (α) parameter in Gaussian space.

Figure 10 (Bottom Left): Posterior of choice stochasticity (β_1) parameter in Gaussian space.

Figure 11 (Bottom Right): Model Equations

Conclusion

Our sample overall showed evidence for MBL, but to a lower extent than samples assessed by previous studies. This could be due to older age of our participant and a more demanding paradigm.

In healthy controls, threat of punishment decreased MBL. This effect was abolished in suicide attempters. This pattern was only found in decision time analyses, not in choice analyses, congruent with previous studies showing that decision times are more sensitive to cognitive demands.

Both MBL and the effect of threat of punishment on MBL are blunted behaviorally and neurally in suicide attempters, possibly reflecting failure to mobilize cognitive resources.

Next steps: we will refine the reinforcement learning model, examine neural signals in regions of interest, and examine how neural signals predict choices. We will also investigate whether model-baseness is related to personality traits and age of onset of suicidal behavior.

References

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