A Computational Model of Prediction Error in a Large Sample

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Introduction

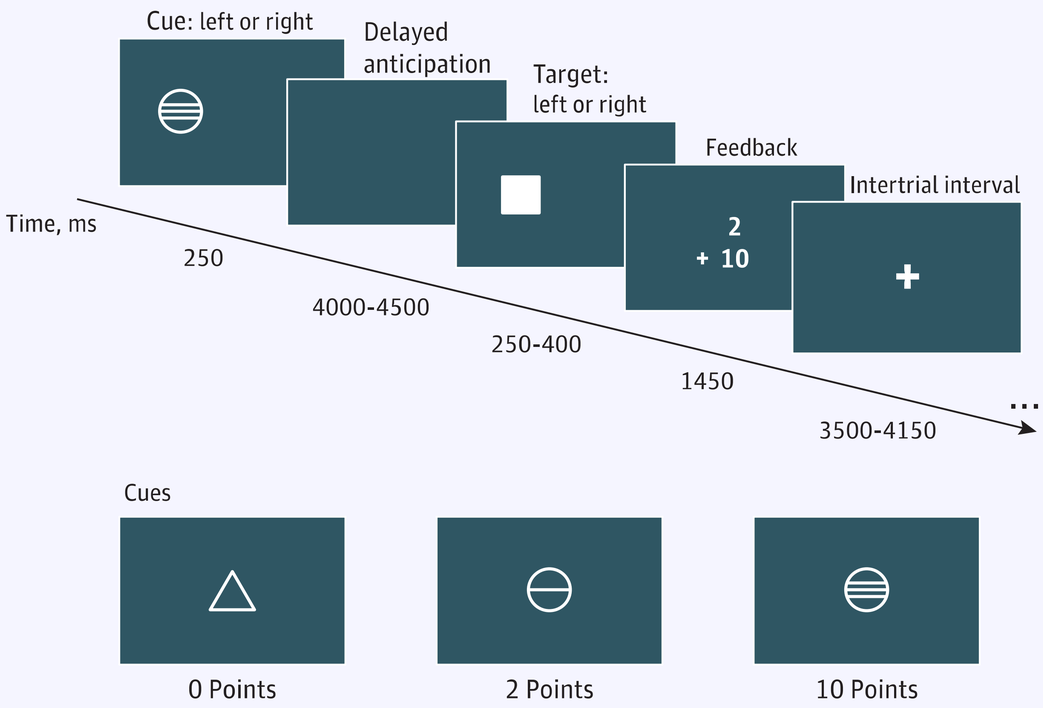
Reinforcement learning models do not presume that all trials in which a reward is obtained are equal. Instead, it is hypothesized [1] that subjects develop and update reward expectancy (*Expected Value, EV*) based on:

- their prior performance
- the magnitude of the potential reward on the current trial
- the degree to which they learn from previous trials.

Consequently, a trial's outcome reflects the deviation from expectations (i.e., a *Prediction Error; PE*)

The neurobiology of the PE may be especially relevant to *substance abuse* given the role that dopamine is thought to play in its generation and that *addiction* is often conceptualized as both *pathological decision making* driven by discrepancies between expected and received outcomes and an inability to flexibly shift behavior in light of feedback and learn from one's errors.

The Monetary Incentive Delay (MID) Task



22 trials of each type for 10 seconds each

Rescorla-Wagner Computational Model

A Rescorla-Wagner algorithm based Reinforcement Learning model [1,2] was trained on the behavioral data for MID task. The model contains two internal (unobserved) variables: Expected Value (EV) & Prediction Error (PE)

Training the model:

$$Q_t = pGain_t * C_t$$

$$\delta_t = R_t - Q_t$$

$$pGain_{(t+1)} = pGain_t + \eta * (\delta_t / C_t)$$

C_t : Possible reward at trial *t* (0, 2 or 10 points)

Q_t : Expected value (EV) at trial *t*

R_t : Actual reward at trial *t*

δ_t : Prediction error (PE) at trial *t*

pGain$_t$: Participant's subjective probability of obtaining the reward

η: Learning rate (η=.7)

References

[1] Glascher J, O'Doherty J: *Model-based approaches to neuroimaging: combining reinforcement learning theory with fMRI data*. Wiley Interdisciplinary Reviews: Cognitive Science 2010, 1:01-10

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[4] White SF *et al*: *Disrupted expected value and prediction error signaling in youths with disruptive behavior disorders during a passive avoidance task.* Am J Psychiatry 2013, 170:31-323

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Participants

Participants consisted of 1824 14-year old adolescents recruited in the IMAGEN project [3] (mean/SD age 14.5/0.4 years).

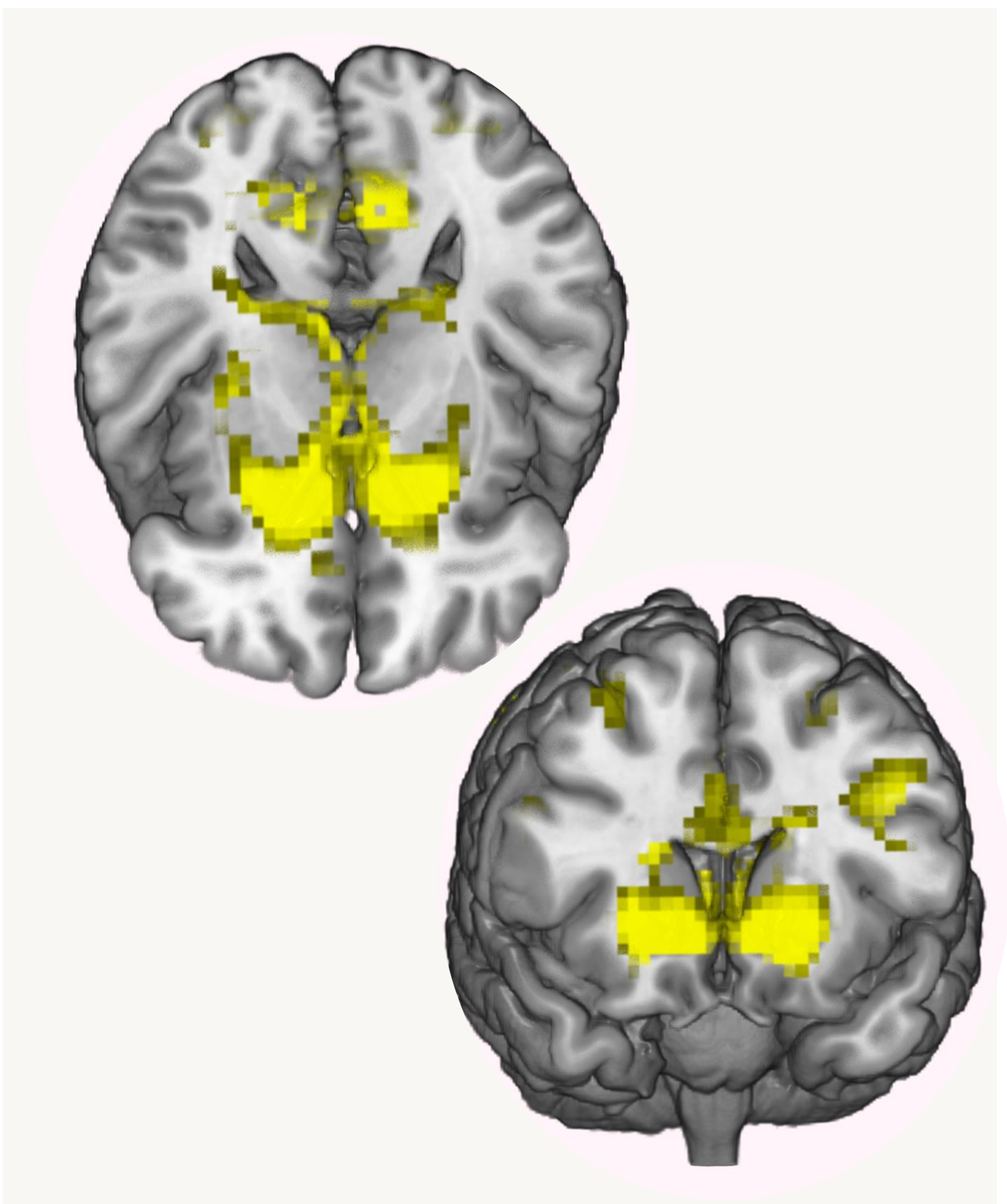
Data Analysis

First level analysis: The Prediction Error estimates from the computational model were time-locked to feedback onset and were convolved with the canonical hemodynamic response function in SPM8.

Second level analysis: The Prediction Error contrast was analysed using a 1-sample t-test with a family-wise error threshold of $p<.05$. Age, sex, handedness, pubertal developmental status, IQ and data acquisition site were entered as nuisance covariates.

Region of interest analysis: data from ventral striatum was extracted from the Prediction Error contrast. A composite measure of alcohol usage, derived from the ESPAD, was calculated. Participants with no alcohol use (n = 372) were compared with participants who scored high on the alcohol use measure (n = 423). Nuisance covariates were as above.

Results



Axial and coronal views of the 1-sample test for Prediction Error.

The region of interest analysis revealed a significant difference ($F(1,780) = 4.61$, $p<.05$) in ventral striatal activity between groups for Prediction Error, with less activity in the binge drinking group.

Conclusions

The application of the computational model to MID data produced robust and localized activity in the ventral striatum. Although PEs have been studied in adolescents [4] to our knowledge, no-one has yet to assess the PE (or any other parameters) as correlates of substance use in adolescents.

Preliminary results suggest that a computational model may prove useful for examining the neurobiology of substance misuse.