Mapping reward and loss-related brain activity and effects of reward context

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Neuromatch Academy 2021

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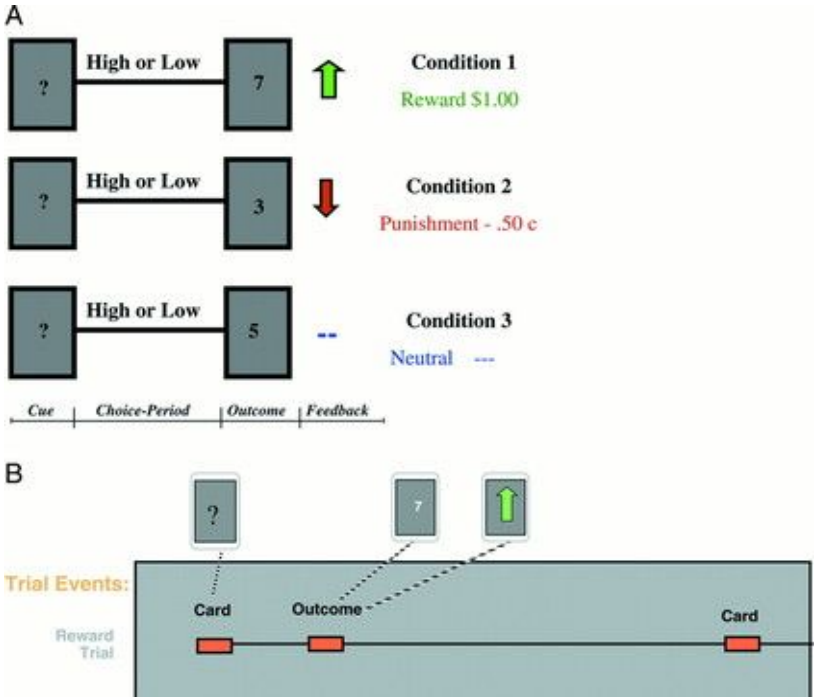
Human Connectome Project Gambling Task

- On each trial, participants (N=339) made random guesses that were correct (reward) or incorrect (loss)
- Trials were embedded into larger blocks that contained either mostly-reward trials (“reward context”) or mostly-loss trials (“loss context”)
- fMRI time series data parcellated into 360 regions



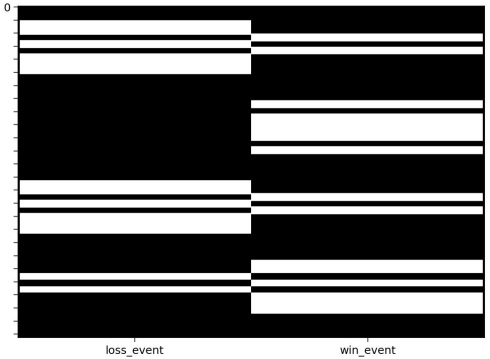
Aims & Predictions

- **Map reward and loss-related brain activation**
  - In what brain regions does activity reflect reward vs. loss?
  - Create a model which predicts the outcome of a trial (reward/loss) based on brain activity alone

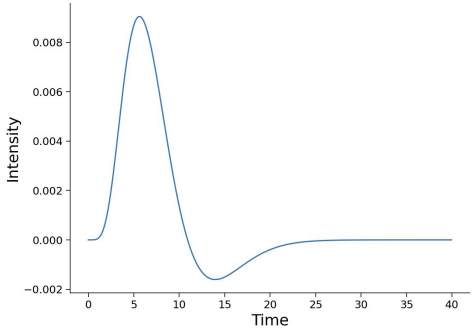
- **Probe the effect of “reward context”**
  - How does reward- and loss-related brain activity depend on “reward context” (“mostly-reward” vs. “mostly-loss” blocks)?

Approach: Mapping reward- and loss-related brain activity

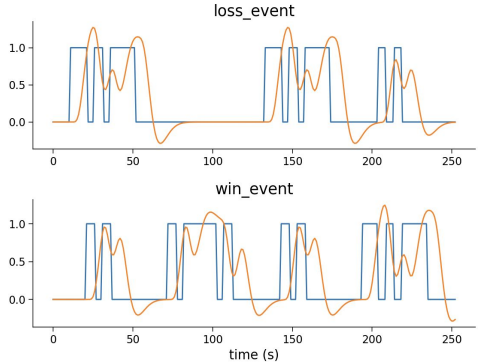
Design matrix



Hemodynamic response function



Design matrix, convolved with HRF



General linear model

$$\begin{pmatrix} X_{l,t1} & X_{r,t1} \\ X_{l,t2} & X_{r,t2} \\ X_{l,t3} & X_{r,t3} \\ X_{l,t4} & X_{r,t4} \\ X_{l,t5} & X_{r,t5} \\ X_{l,t6} & X_{r,t6} \\ \dots & \dots \end{pmatrix} \begin{pmatrix} \beta_{loss} \\ \beta_{win} \end{pmatrix} = \begin{pmatrix} BOLD_{t1} \\ BOLD_{t2} \\ BOLD_{t3} \\ BOLD_{t4} \\ BOLD_{t5} \\ BOLD_{t6} \\ \dots \end{pmatrix}$$

n_TRs, n_conditions, 1, =, n_TRs, 1

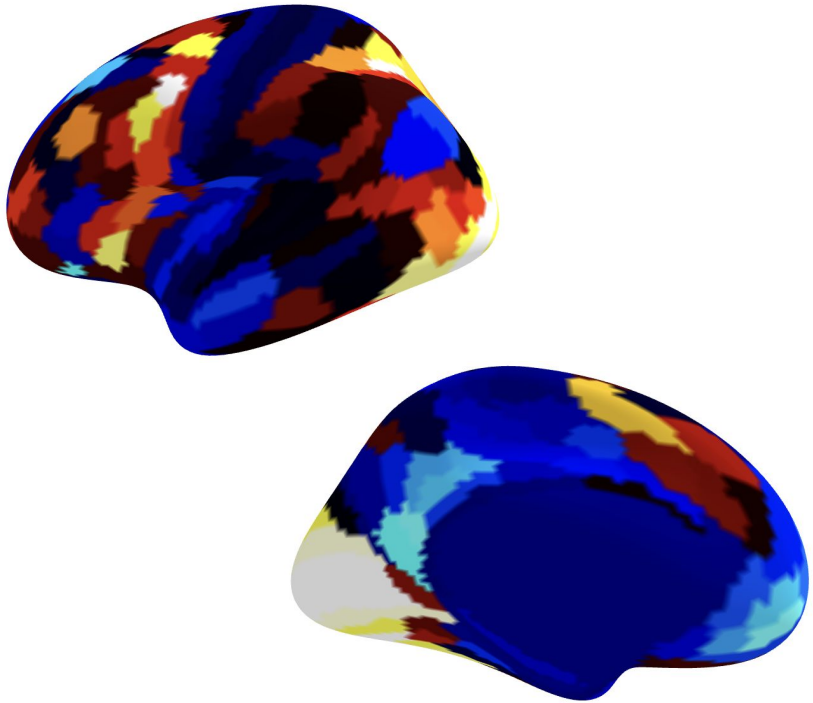
Solve for β values using ordinary least squares:

$$\boldsymbol{\beta} = (X^T X)\,(X^T y)$$

Repeat for each of 360 parcels to generate β-map for each condition

Results: Mapping reward- and loss-related brain activity

β-map depicting activation during **reward** trials

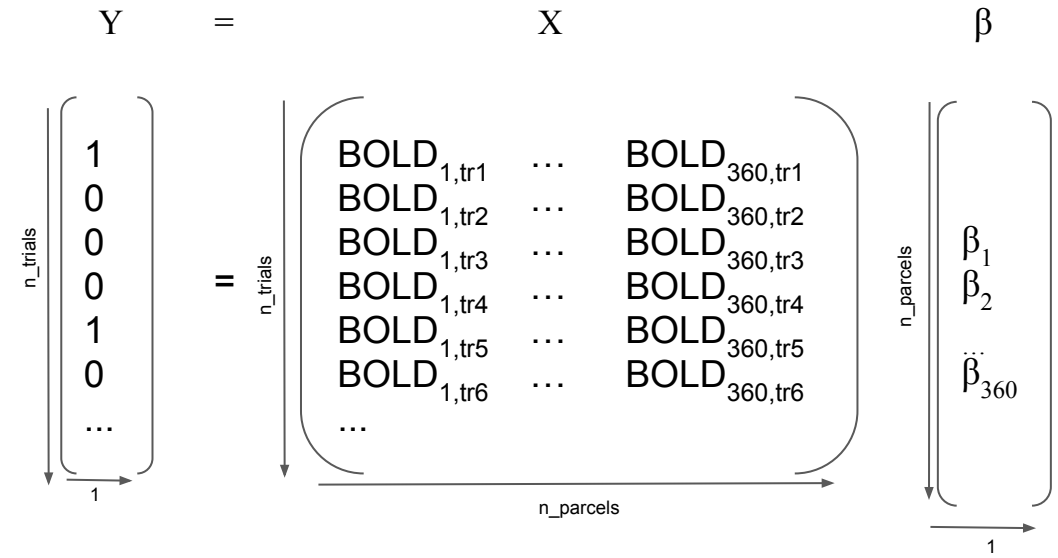


β-map depicting activation during **loss** trials

β-maps reflect average across all participants; only left hemi shown

Approach: Predicting trial type from brain activity

Logistic regression model:



calculation of prediction accuracy:

accuracy = 1 - MSE
where MSE = $(1/n) * \Sigma(y - y\_pred)^2$

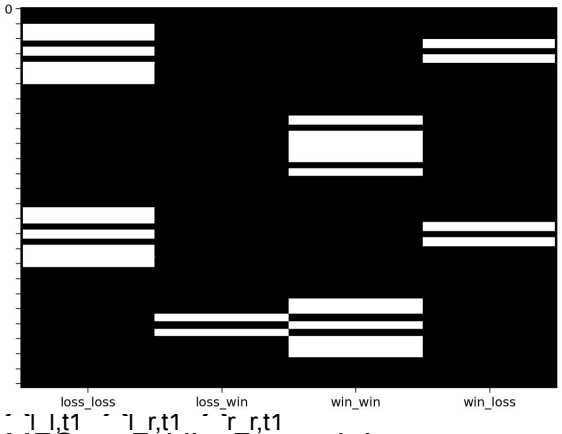
Model trained on training set (90% of participants), then tested on held-out test set (10% of participants)

Training set accuracy: **63.23 %**

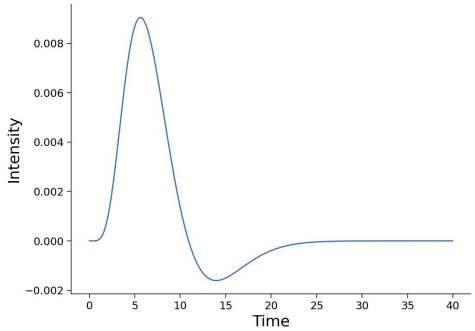
Test set accuracy: **59.99 %**

Approach: Testing the effect of reward context

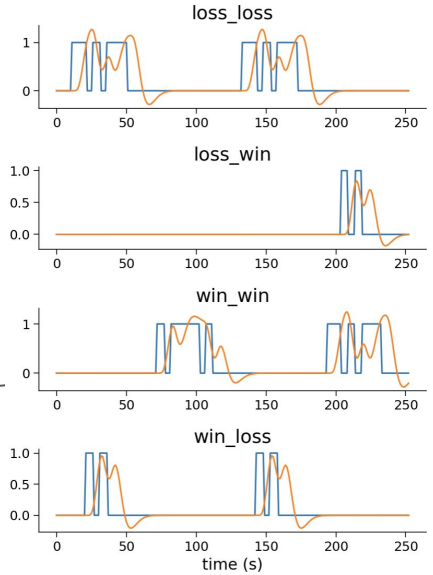
Design matrix



Hemodynamic response function



Design matrix, convolved with HRF



General linear model

$$\begin{bmatrix} X_{l\_l,t1} & X_{l\_r,t1} & X_{r\_r,t1} \\ X_{l\_l,t2} & X_{l\_r,t2} & X_{r\_r,t2} \\ X_{r\_l,t2} & & \\ X_{l\_l,t3} & X_{l\_r,t3} & X_{r\_r,t3} \\ X_{r\_l,t3} & & \\ X_{l\_l,t4} & X_{l\_r,t4} & X_{r\_r,t4} \\ X_{r\_l,t4} & & \\ X_{l\_l,t5} & X_{l\_r,t5} & X_{r\_r,t5} \\ X_{r\_l,t5} & & \\ X_{l\_l,t6} & X_{l\_r,t6} & X_{r\_r,t6} \\ X_{r\_l,t6} & & \end{bmatrix} \begin{bmatrix} \beta_{loss\_loss} \\ \beta_{loss\_win} \\ \beta_{win\_win} \\ \beta_{win\_loss} \end{bmatrix} = \begin{bmatrix} BOLD_{t1} \\ BOLD_{t2} \\ BOLD_{t3} \\ BOLD_{t4} \\ BOLD_{t5} \\ BOLD_{t6} \\ \dots \end{bmatrix}$$

n_TRs, n_conditions, 1, =, n_TRs, 1

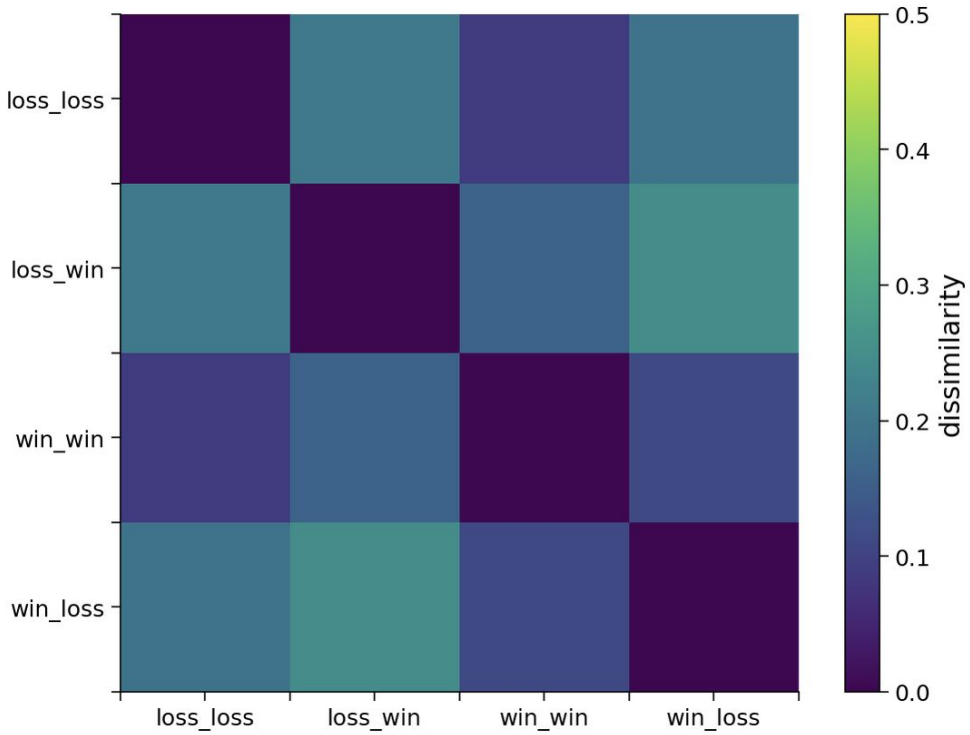
Solve for β values using OLS:

$$\boldsymbol{\beta} = (X^T X)\,(X^T y)$$

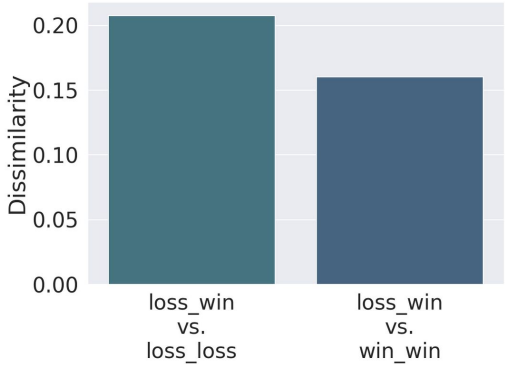
Repeat for each of 360 parcels to generate β-map for each condition

Results: Testing the effect of reward context

Representational dissimilarity matrix



Loss trials in win blocks were more similar to win trials in win blocks:



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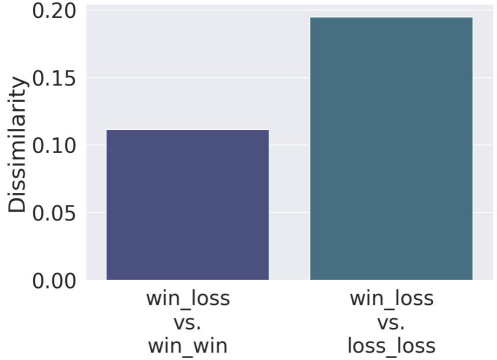
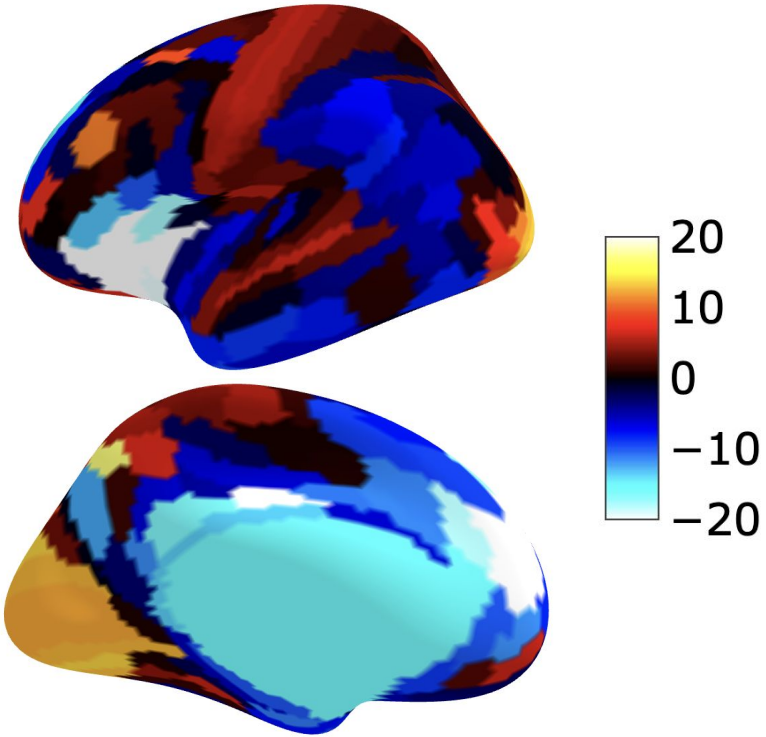
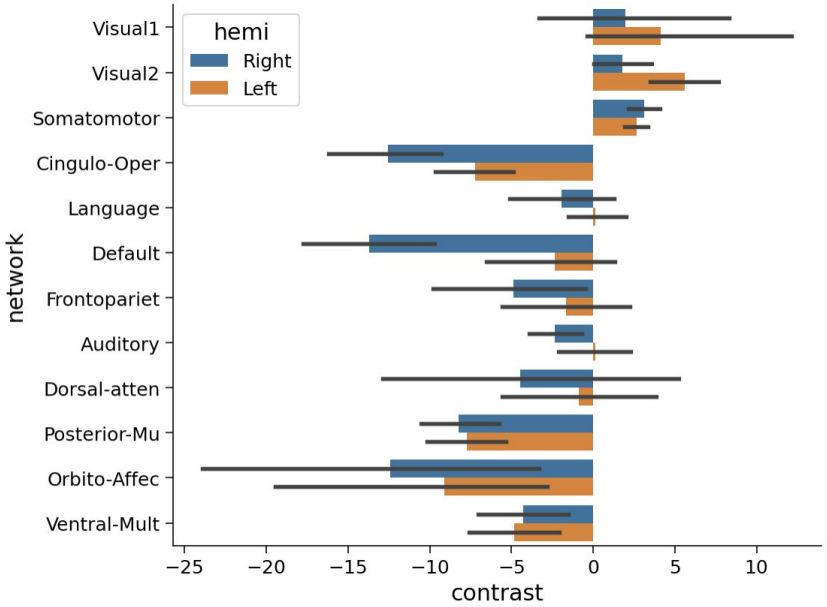


RDM reflects dissimilarity among β-maps for each condition, averaged across participants

Results: Testing the effect of reward context





β-map (only left hemi shown) depicting activation that was higher on context-incongruent vs. context-congruent trials

Summary

- Experiencing reward and loss engaged expected cortical brain regions
- We were able to predict trial type (reward, loss) using fMRI data alone
- Reward and loss context affected whole-brain activity in differing ways
- Several brain regions were selectively active on trials that differed from their context