Is model fitting necessary for model-based fMRI?

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Summary

Is model fitting necessary?

Nope!*

*depending on: number of trials, signal-to-noise ratio, task dynamics, the model under consideration

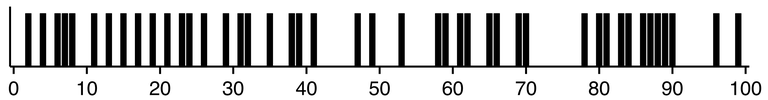
So: model-based fMRI is robust but it is also insensitive

What is model based fMRI?

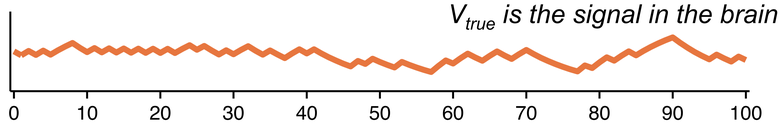
1. Fit a model (e.g. Q-learning) to human behavior
2. Estimate trial-by-trial values of variables (e.g. Q-values)
3. Look for correlates of these signals in the brain

Theory

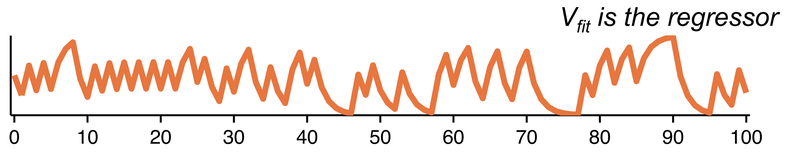
Simple example with binary rewards



Subject computes V_{true} with learning rate α_{true} (e.g. 0.1)



Experimenter computes V_{fit} with learning rate α_{fit} (e.g 0.5)



Regression coefficient, β_{fit}

Depends on true signal, β_{true}, and correlation between V_{true} and V_{fit}

$$\beta_{fit} \approx \beta_{true}\rho(V_{true}, V_{fit})$$

t-statistic

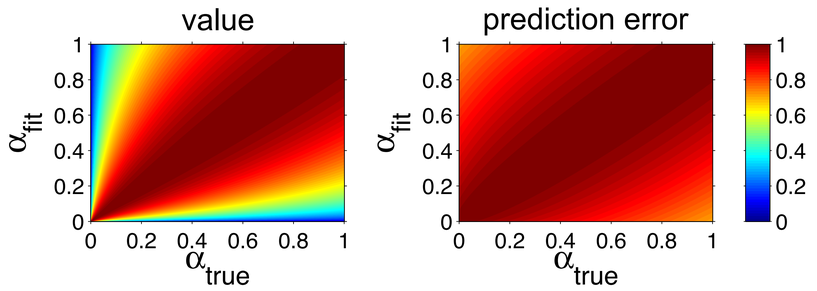
Depends on correlation, number of trials, T, and signal-to-noise ratio, SNR = β_{true} / σ_{fMRI}

$$t_{fit} = \rho(V_{true}, V_{fit})\mathrm{SNR}\sqrt{\frac{T-2}{1+\mathrm{SNR}^2(1-\rho(V_{true}, V_{fit})^2)}}$$

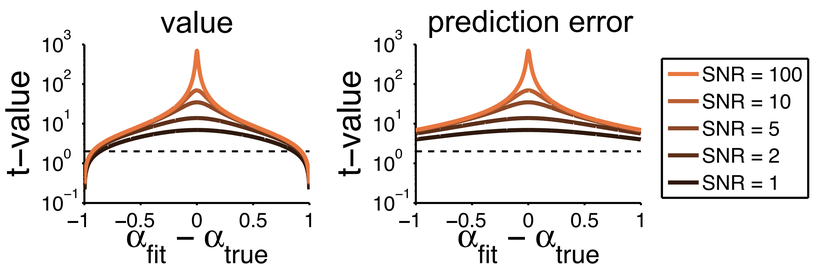
Constant reward probability

Effect of learning rate on correlations*

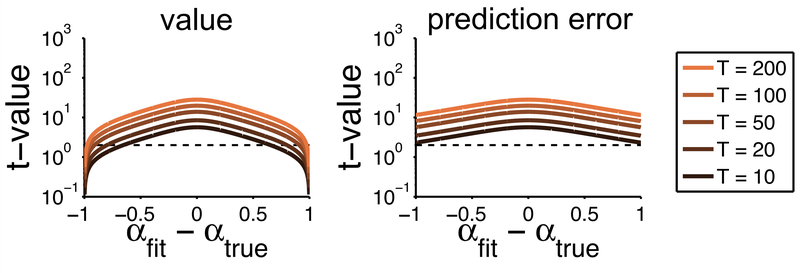
*and regression coefficients



Effect of signal-to-noise ratio on t-statistic

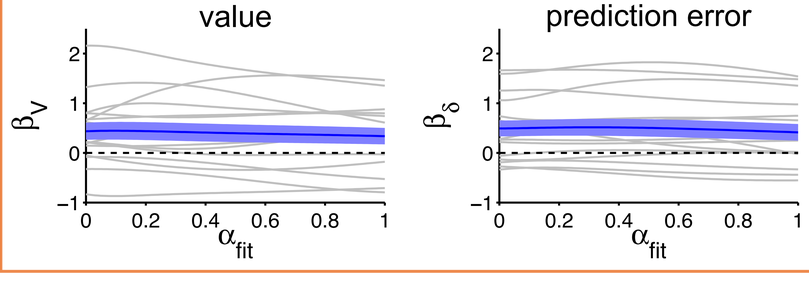


Effect of number of trials on t-statistic



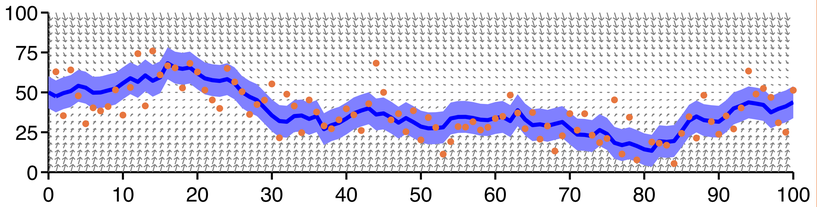
Experimental results* (nucleus accumbens ROI)

*Data from Niv et al. *J. Neurosci.* (2012)



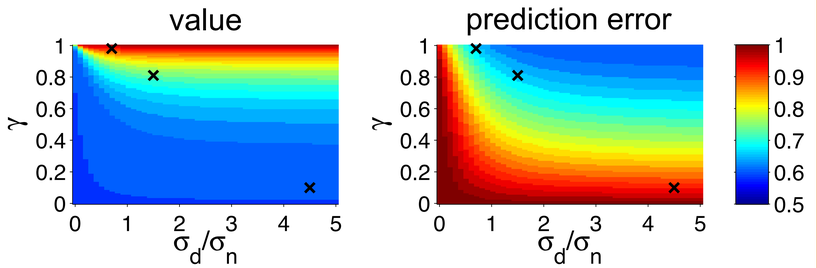
Drifting reward probability

Reward dynamics



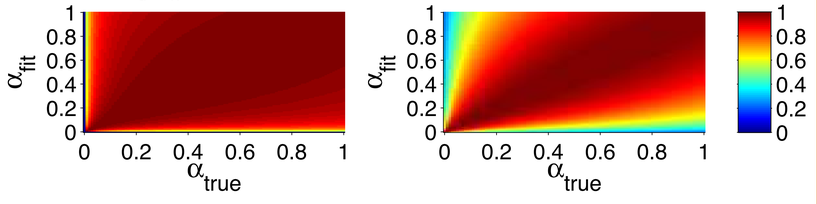
Three parameters:
drift variance, σ_d^2, noise variance, σ_n^2, and decay rate, γ

Correlations can be controlled

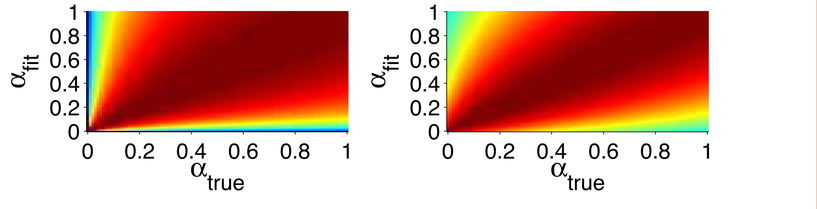


Example parameter settings

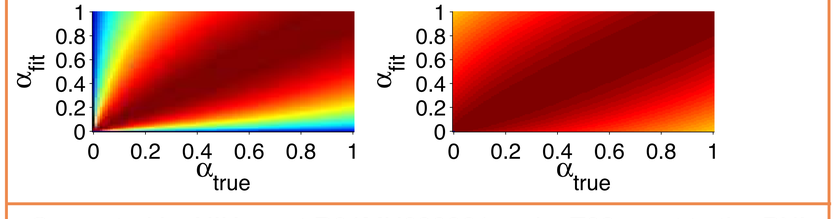
$\gamma = 0.98$, $\sigma_d/\sigma_n = 0.7$ (Daw et al. *Nature* (2006))



$\gamma = 0.81$, $\sigma_d/\sigma_n = 1.5$



$\gamma = 0.1$, $\sigma_d/\sigma_n = 4.5$



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