Towards a computational understanding of how the brain learns to predict pain

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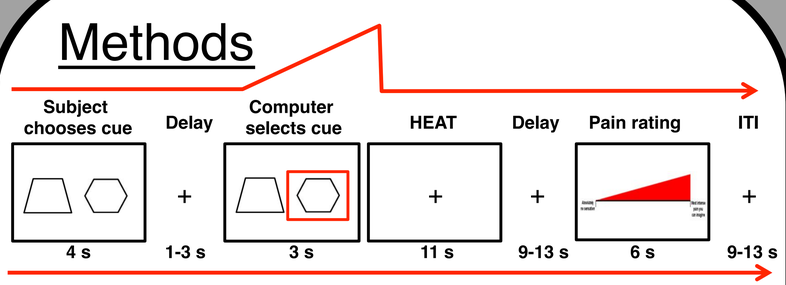
Introduction

Understanding the neural computations underlying how expectancies are developed has received surprisingly little attention, despite their central role in theories of learning, behavior, and value.

Although many studies have used reinforcement learning models to localize brain regions that correlate with learned value, they do not typically treat the brain as a learner and model the learning process in different brain systems. Thus, they cannot capture differences in learning rates across the brain[1,2].

Here, we were interested in modeling the dynamics of how expectations of pain "value" are represented in the brain. We utilized a novel method of estimating model parameters by treating brain regions as learners and directly fitting reinforcement learning models to fMRI data.

Methods

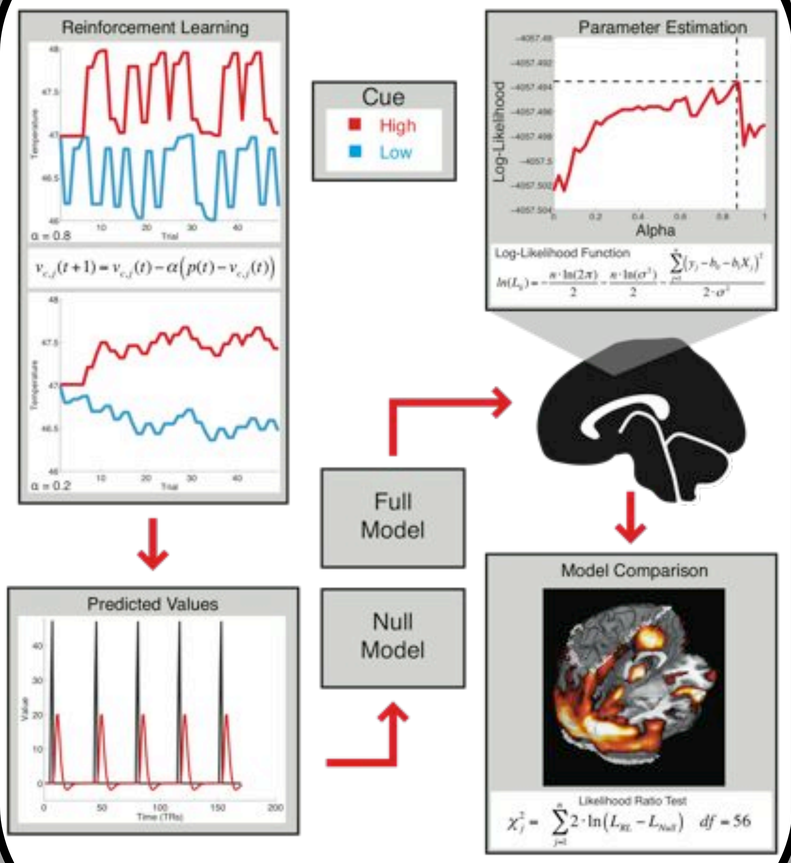


Design: Participants (n=28) received 48 trials of thermal pain applied to right forearm [46, 47,48 C], while undergoing fMRI. Each pain trial was preceded by a cue which predicted the magnitude of the pain stimulation.

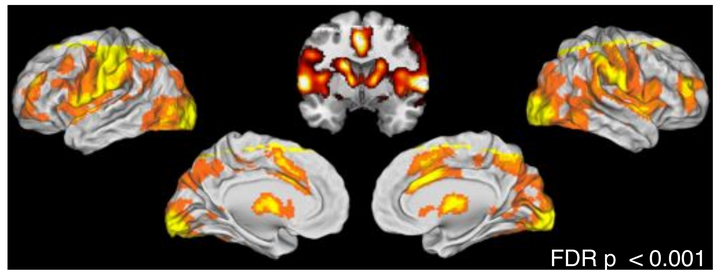
Analysis:

1) Modeled value of pain associated with cue using standard Rescorla-Wagner reinforcement learning model.
2) Created value predictors using RL model convolved with HRF.
3) Fit Full/Null model to brain data using OLS with task regressors and covariates
4) Estimated learning rate for nonlinear function RL function for each voxel by selecting the maximum log likelihood in a grid search of 25 different alphas [0,1] from linear regression.
5) Performed Likelihood Ratio Test comparing Full Model to Null Model
6) Pain value (grouped into quartiles) was determined by fitting a new model using best fitting alphas from parameter estimation procedure for each ROI .

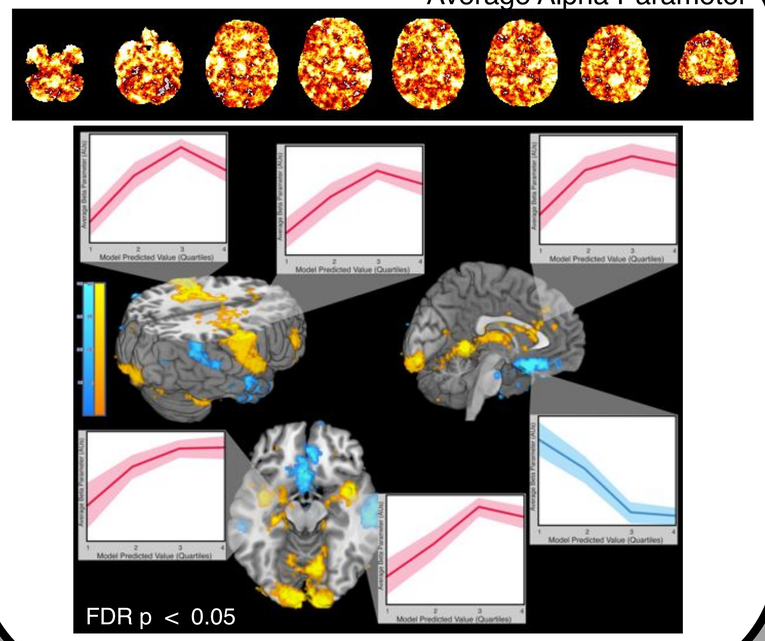
Analysis



Model Comparison



Results



Areas in the brain tracking model predicted value

Conclusion

Abstract reinforcement learning models can be directly fit to the brain to reveal regions presumably involved in the learning computation.

Neural representations of pain 'value' can be revealed using model predictions.

Anticipating greater pain is processed in the somatosensory cortex, insula, amygdala, and ACC.

Interestingly, the vmPFC which has been widely implicated in processing value decreases as greater pain is anticipated.

References

[1] Glascher & Buchel. (2005). Neuron, 47, 295-306.
[2] Seymour et al. (2004). Nature, 429, 664-667.

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