

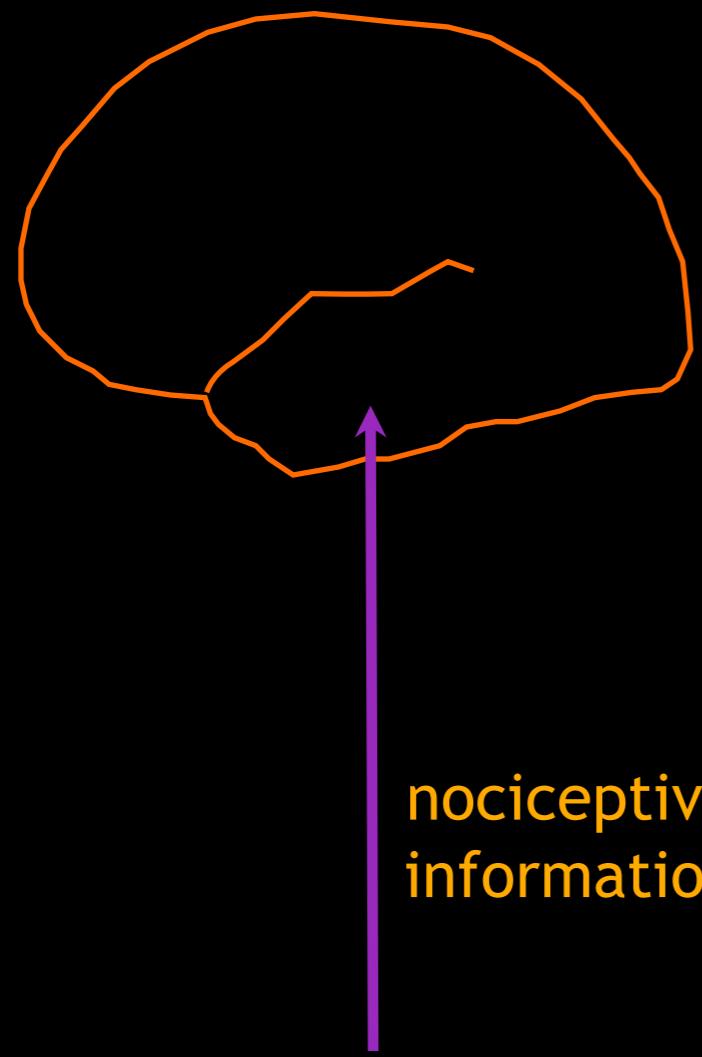


USING COMPUTATIONAL MODELLING TO UNDERSTAND PAIN

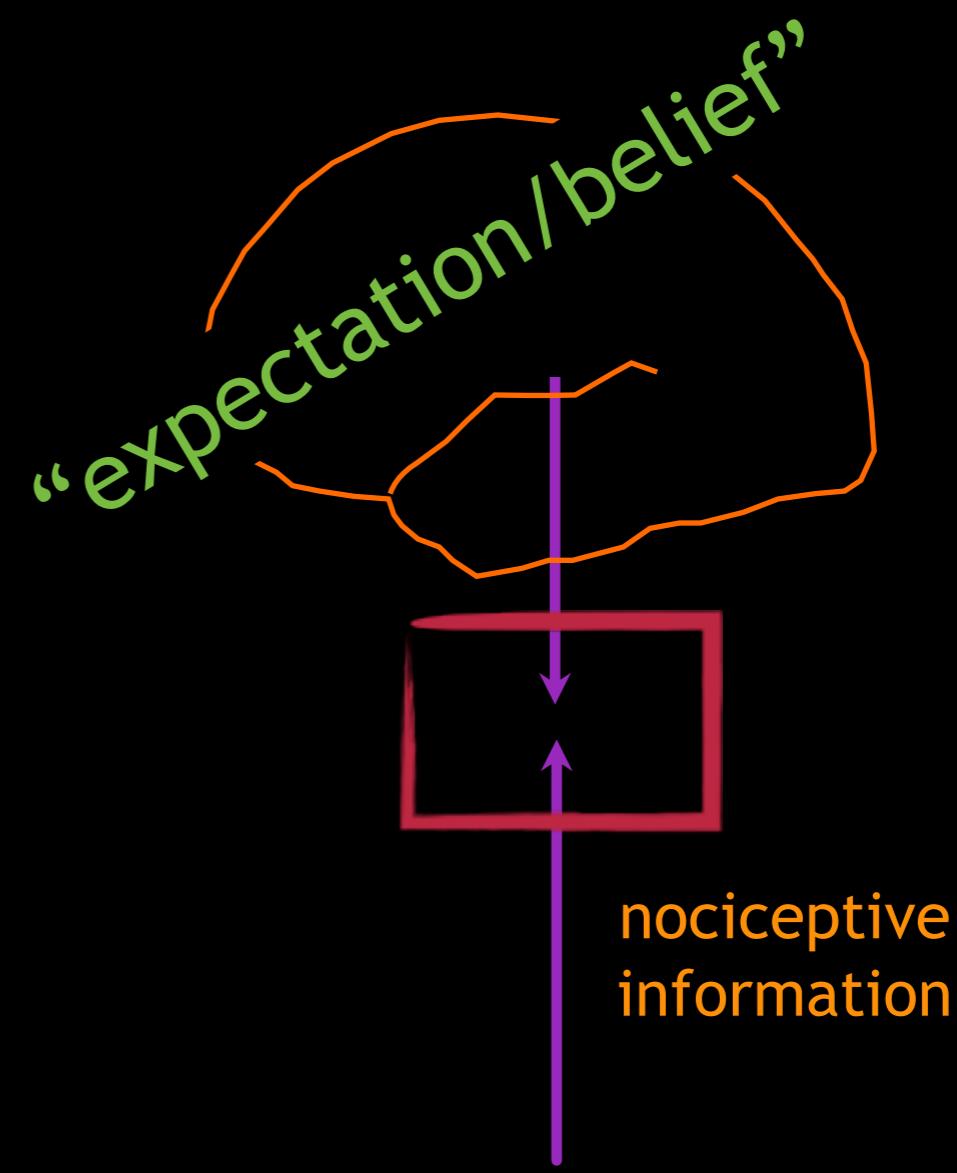
KATJA WIECH

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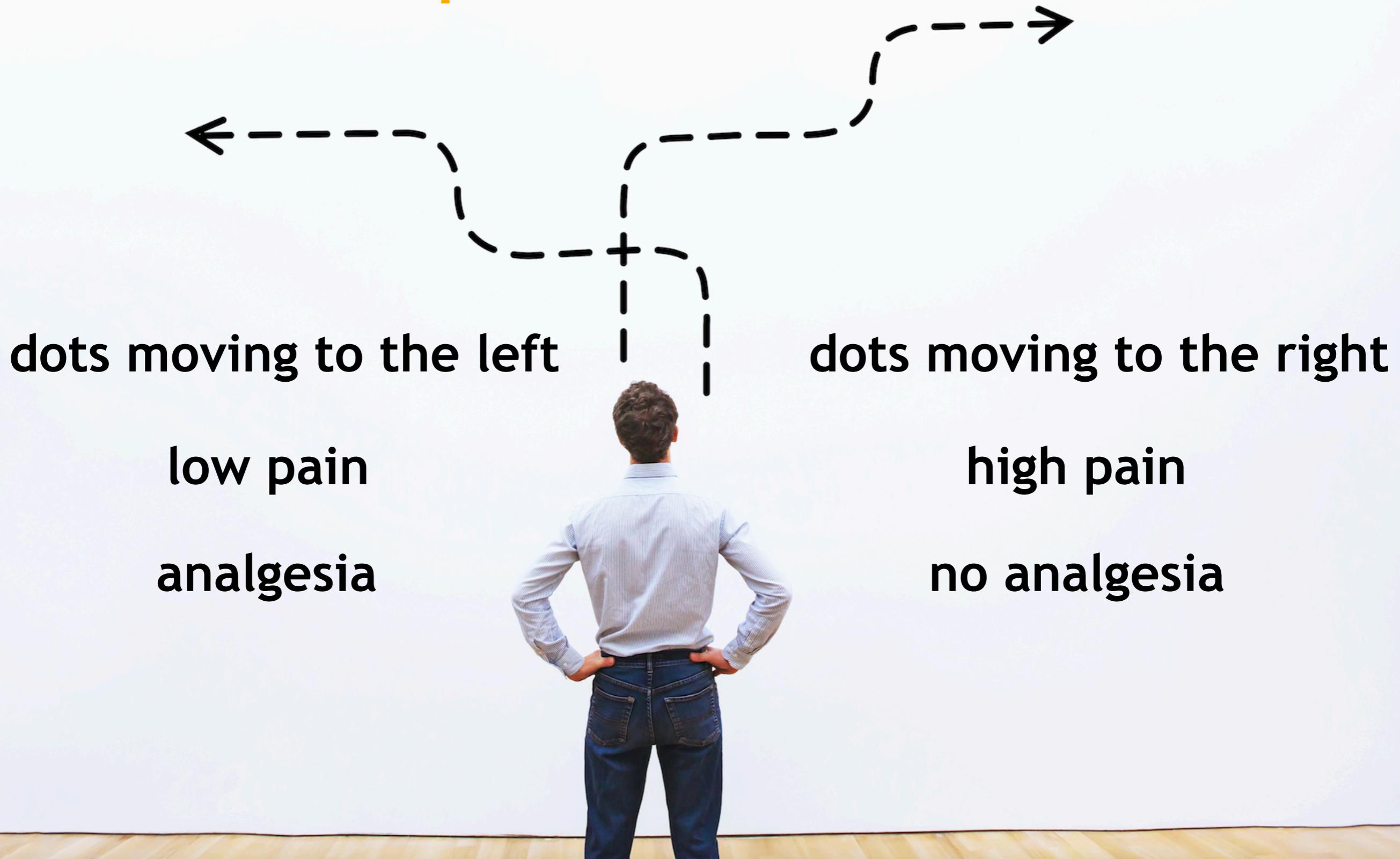
tissue damage



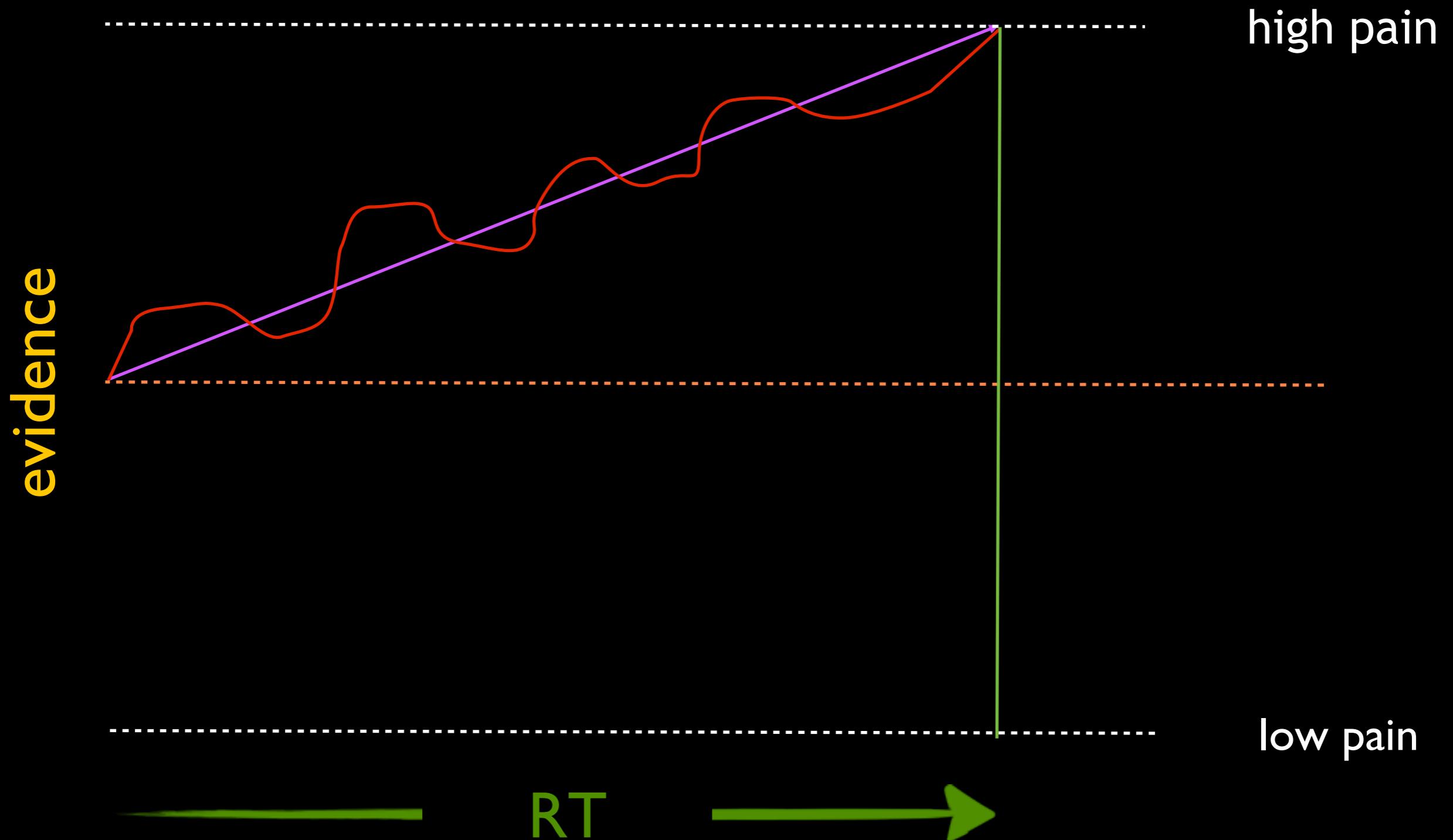
tissue damage

- The interface between beliefs and perception
- Changes in pain-related beliefs: learning and updating
- Role of beliefs in pain treatment

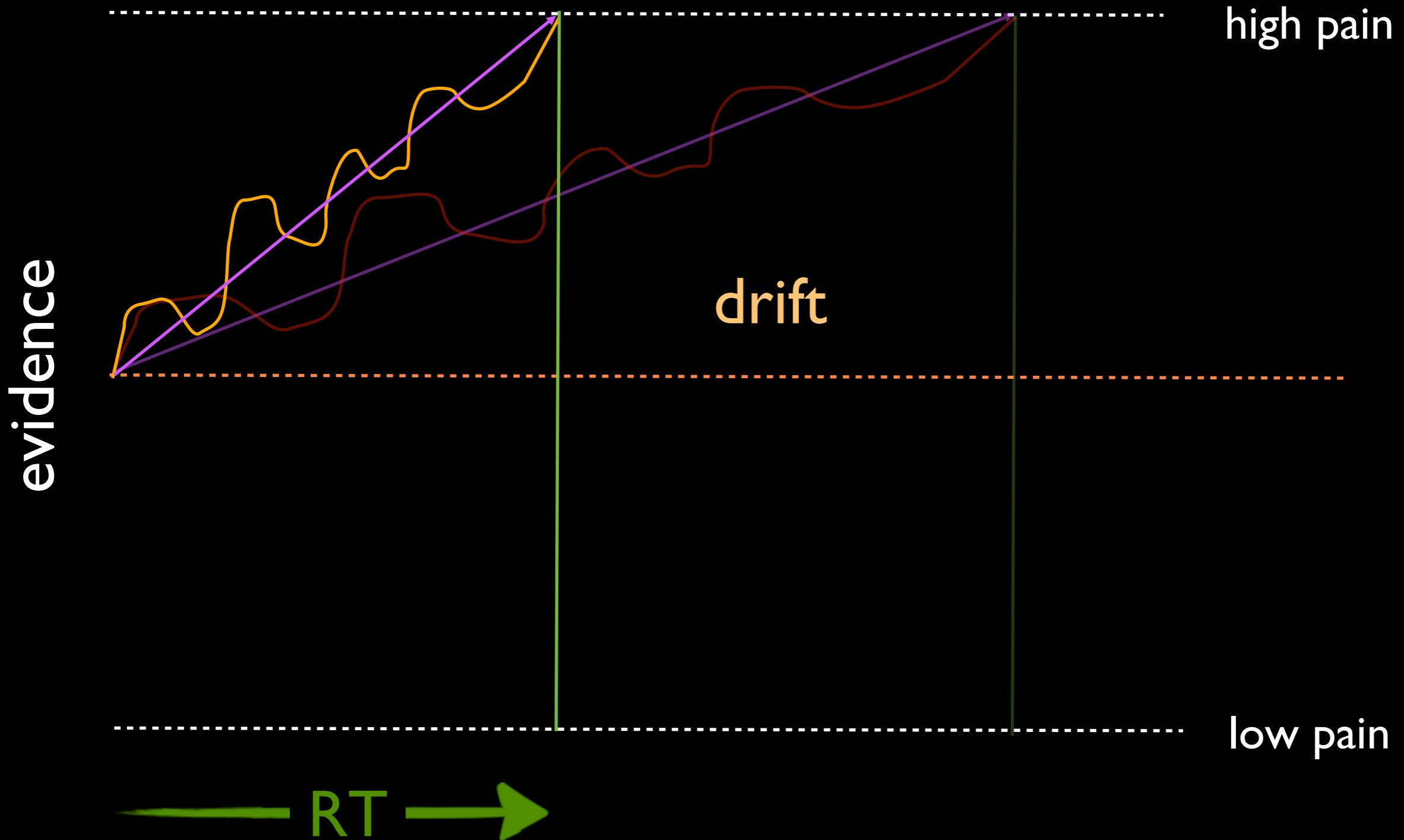
‘Perception as inference’



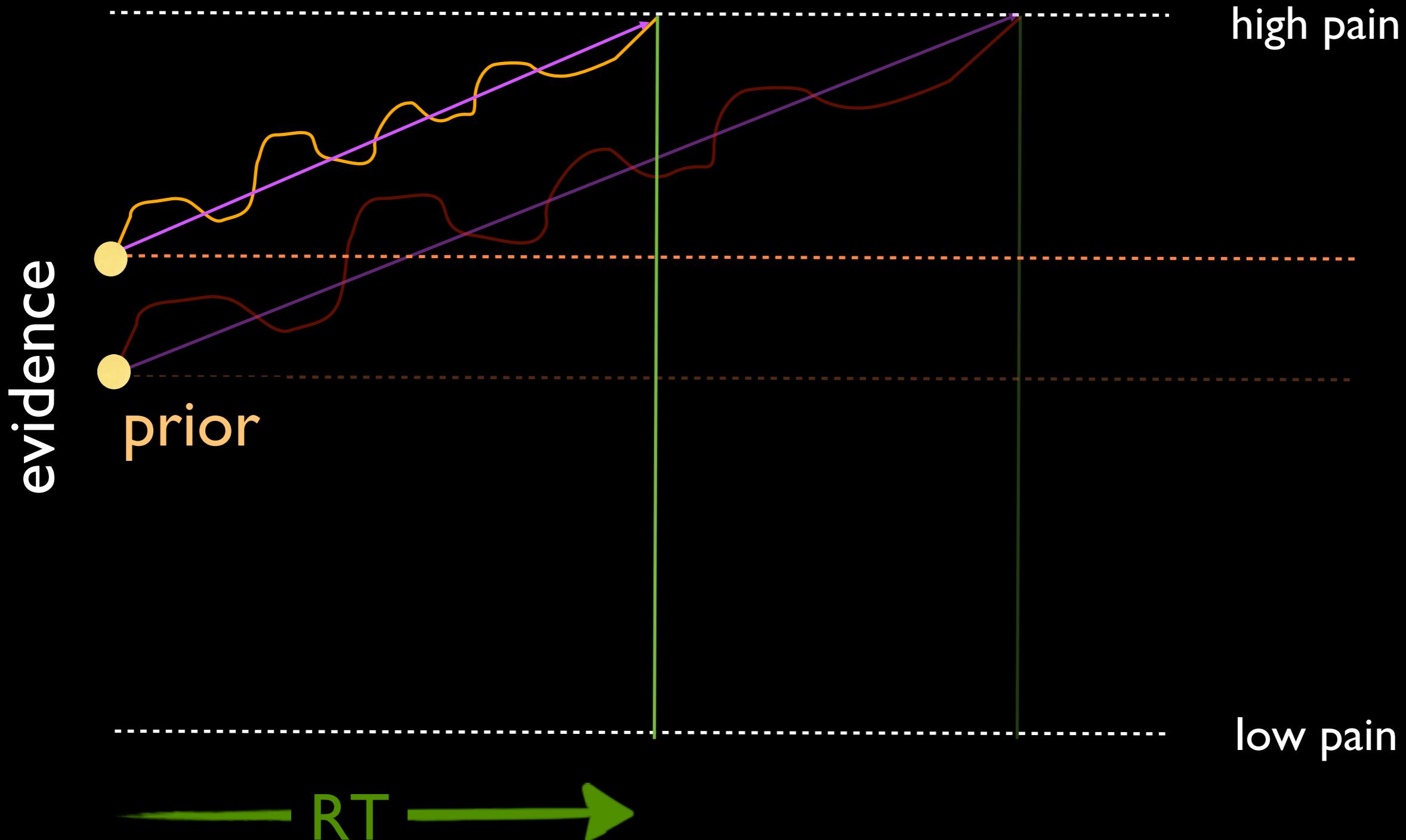
‘Perception as inference’



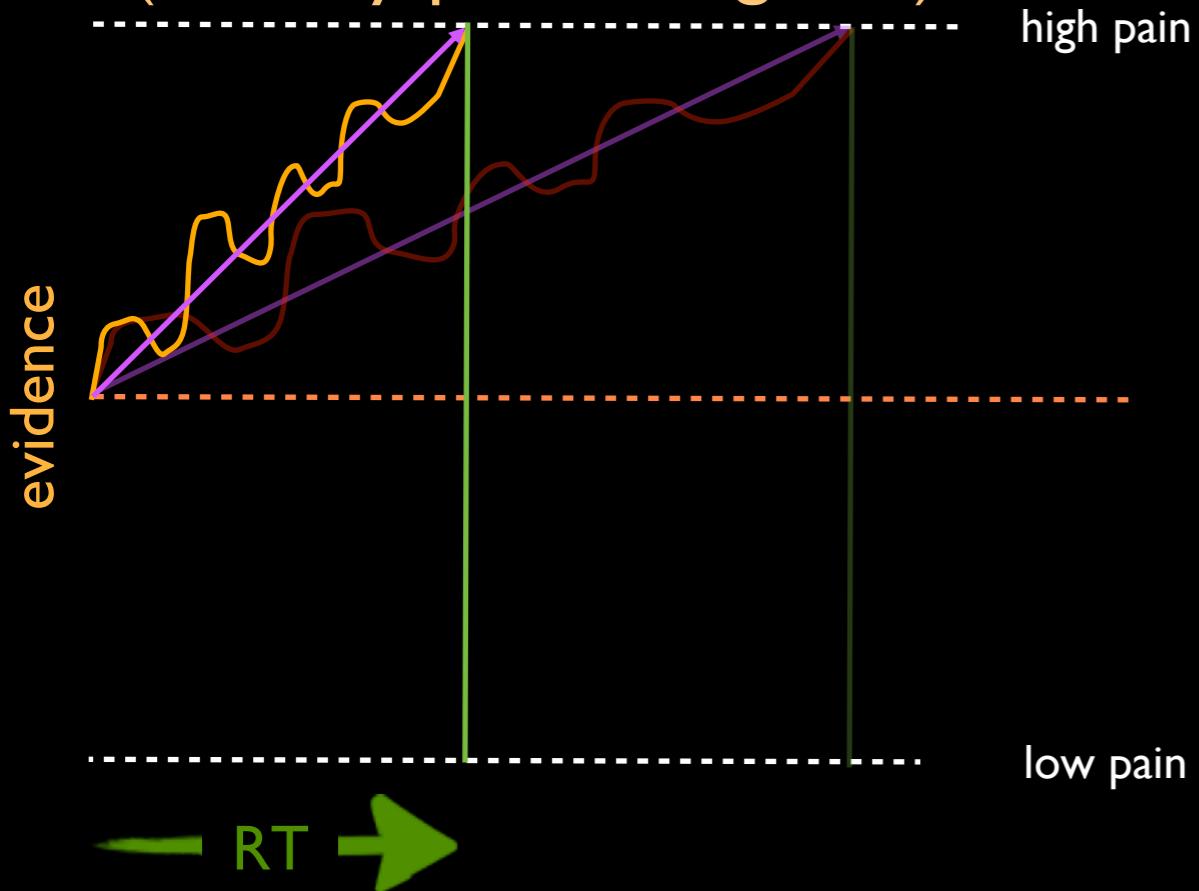
Drift model: gain control



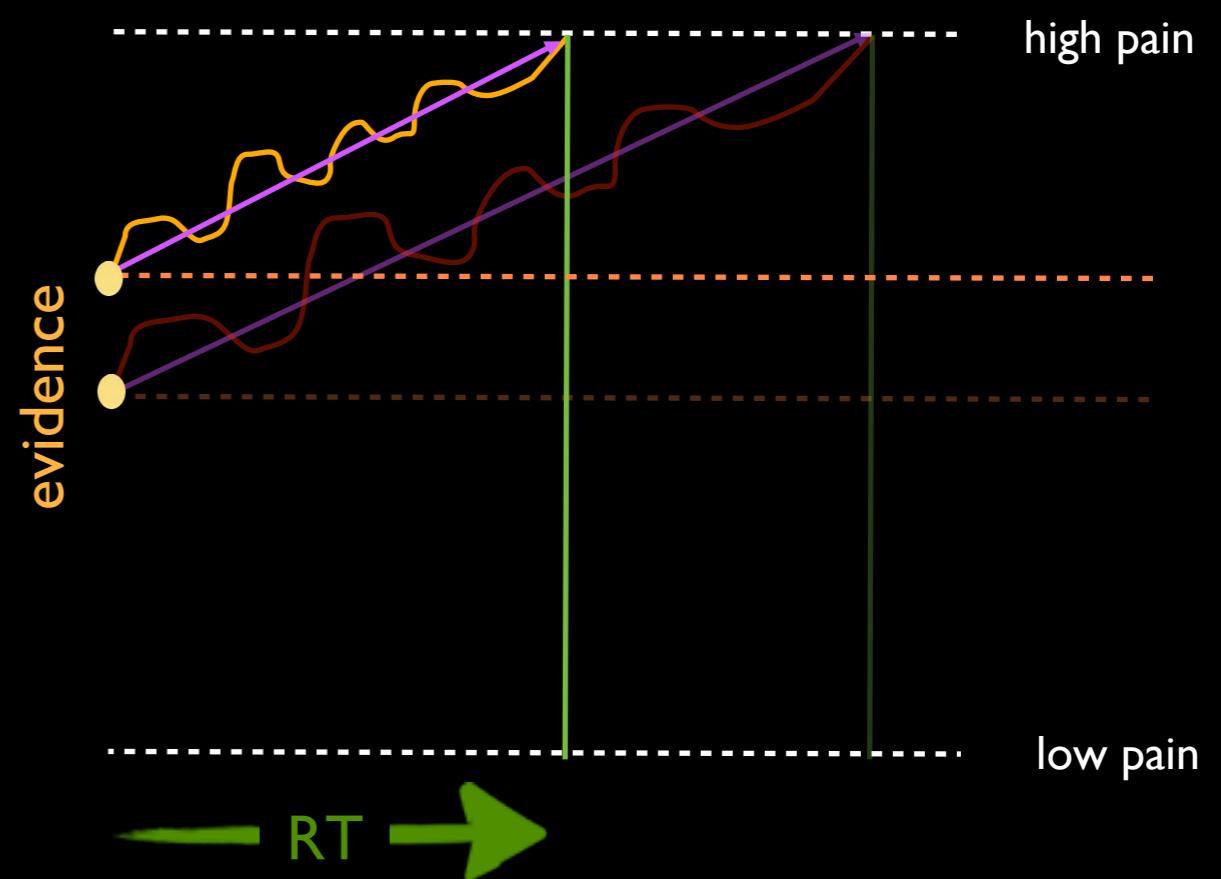
Prior model: decision-making bias



Drift model: gain control (sensory processing bias)

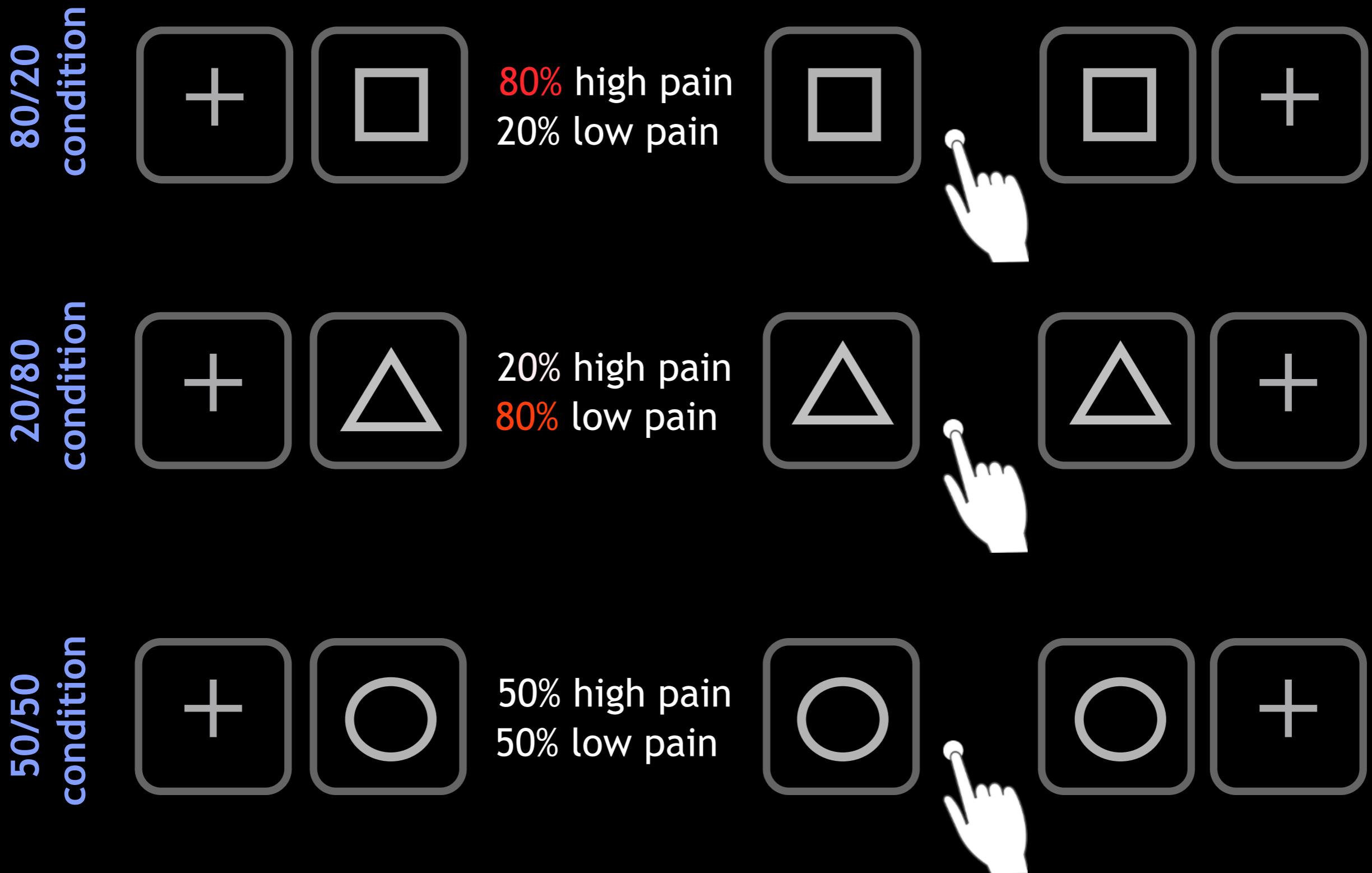


Prior model: decision-making bias

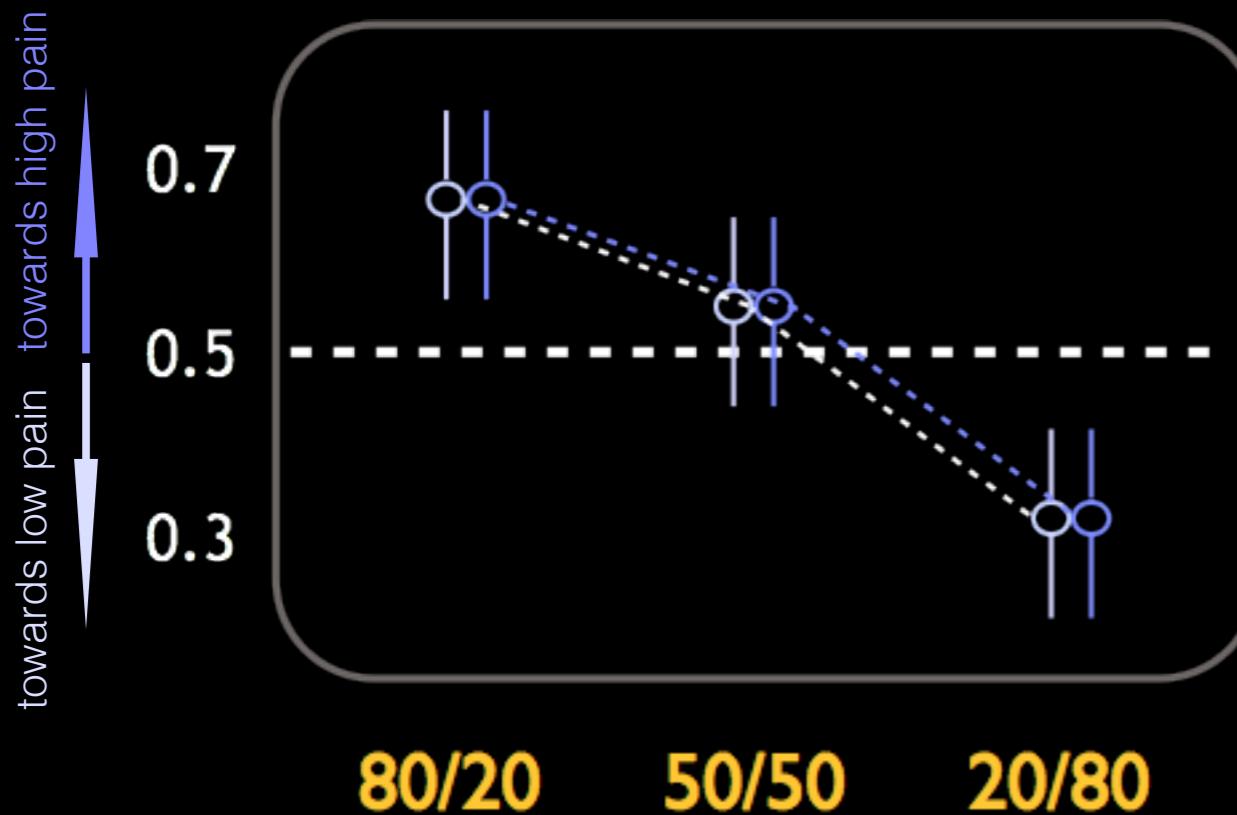


Wiech et al., Curr Biol, 2014

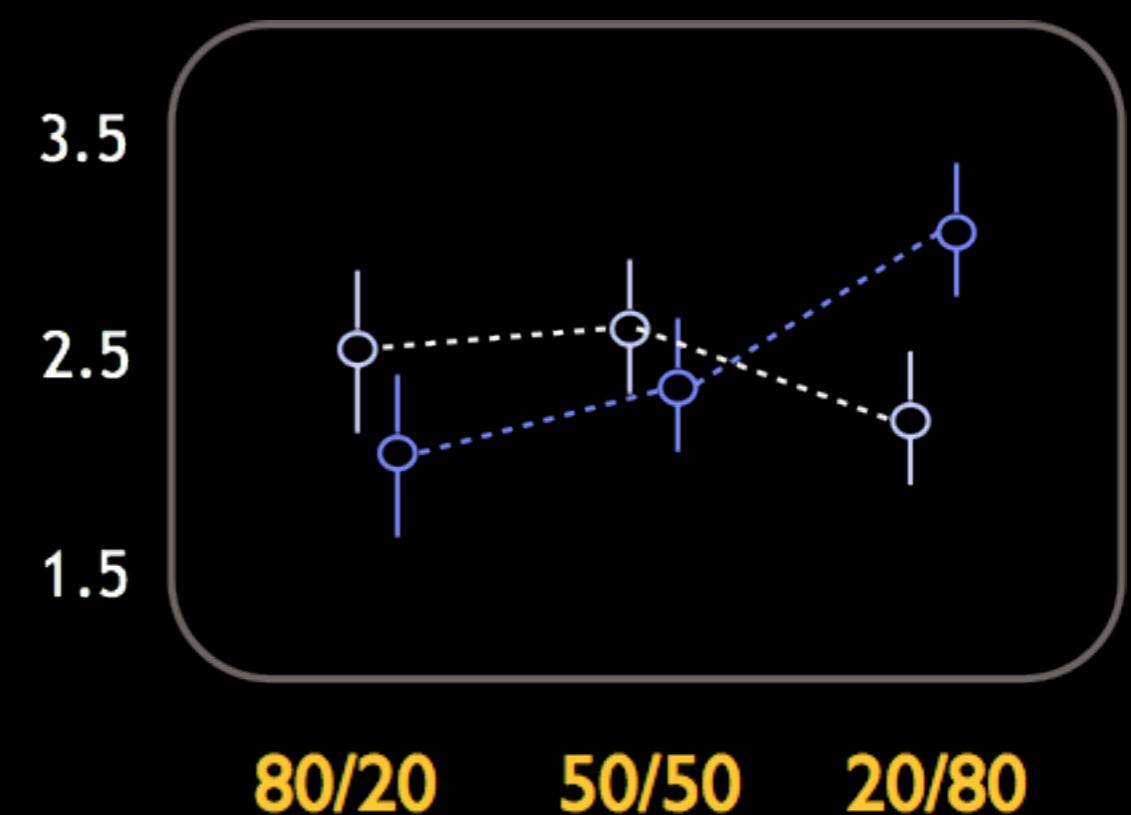
Design



change in prior

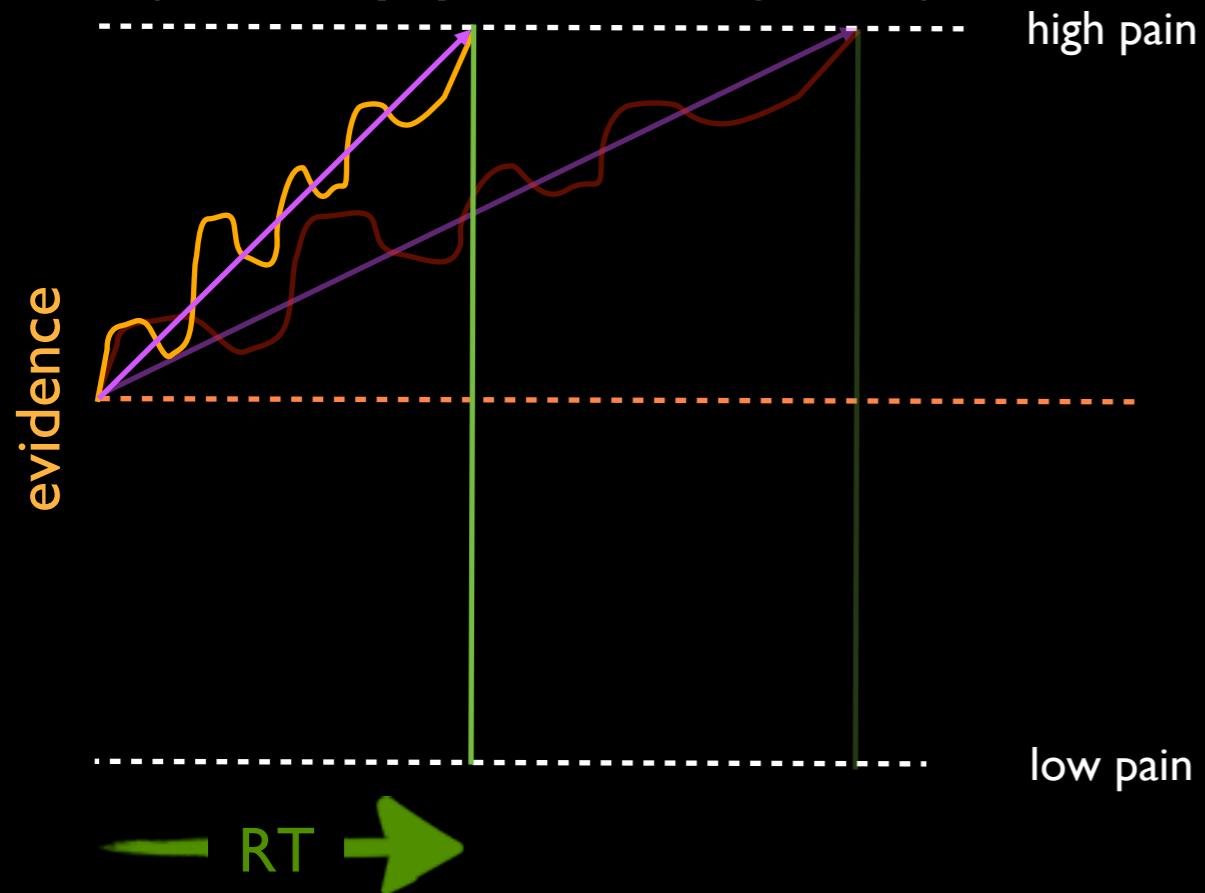


change in drift rate

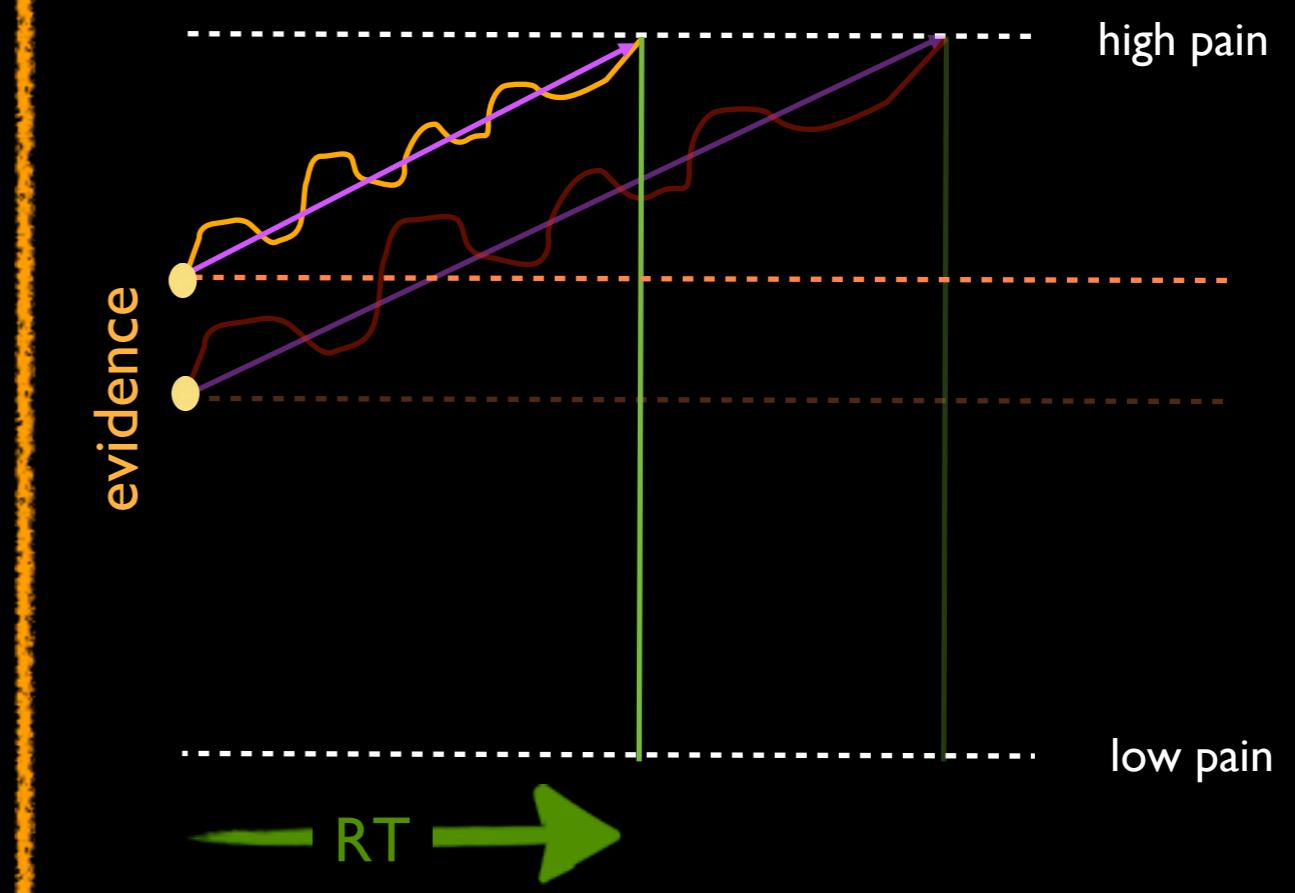


- low intensity stimulation
- high intensity stimulation

drift model: gain control
(sensory processing bias)

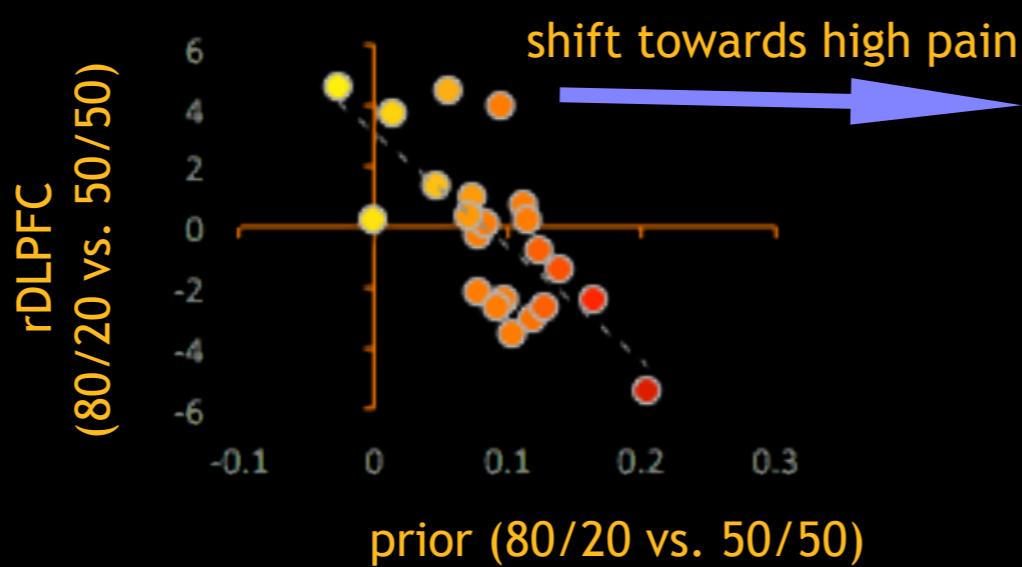
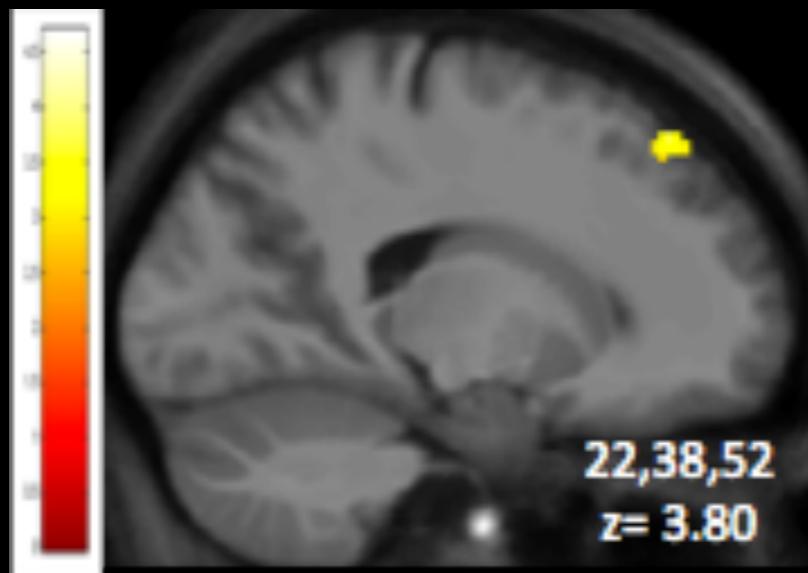
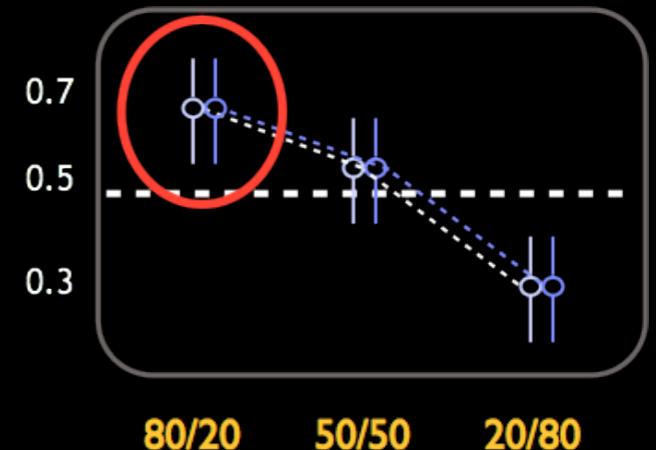


prior model: decision-making bias

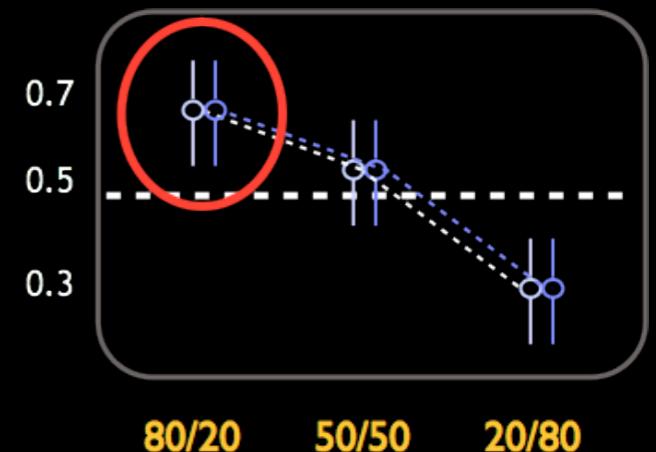


Wiech et al., Curr Biol, 2014

Decision-making bias towards high pain: anticipation phase

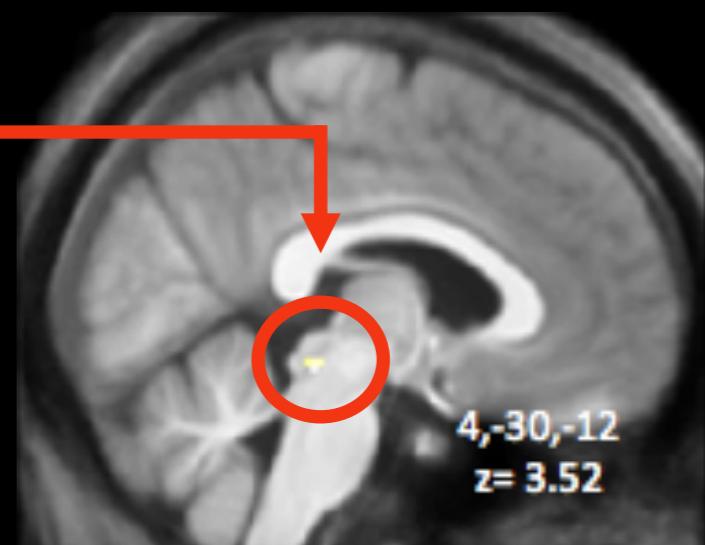
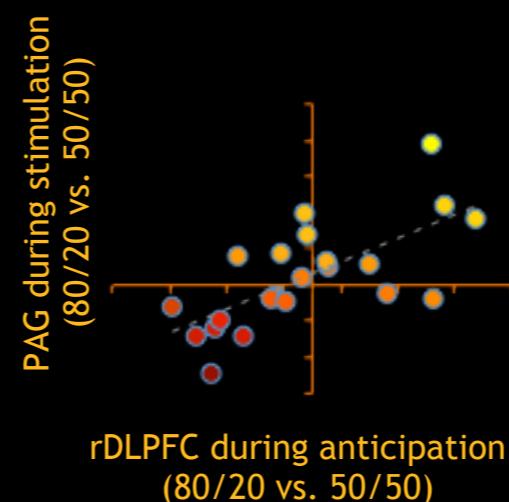
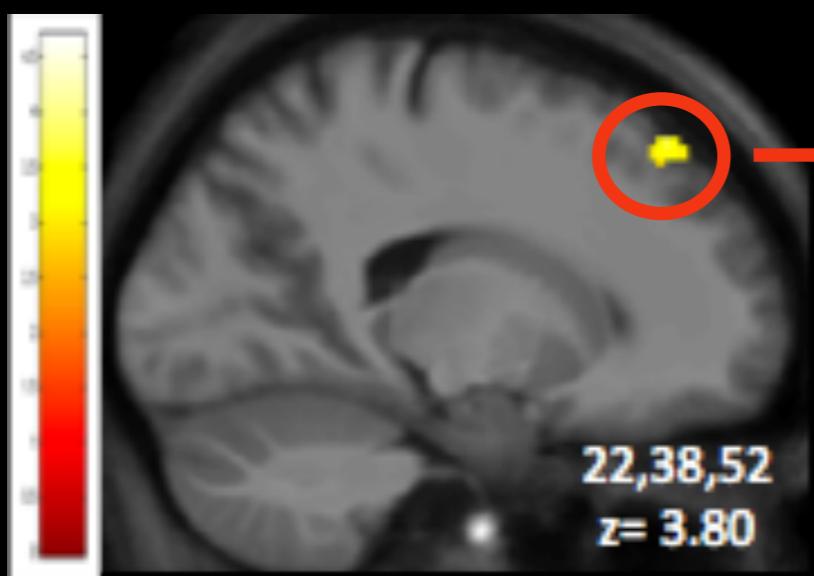


Decision-making bias towards high pain: stimulation phase

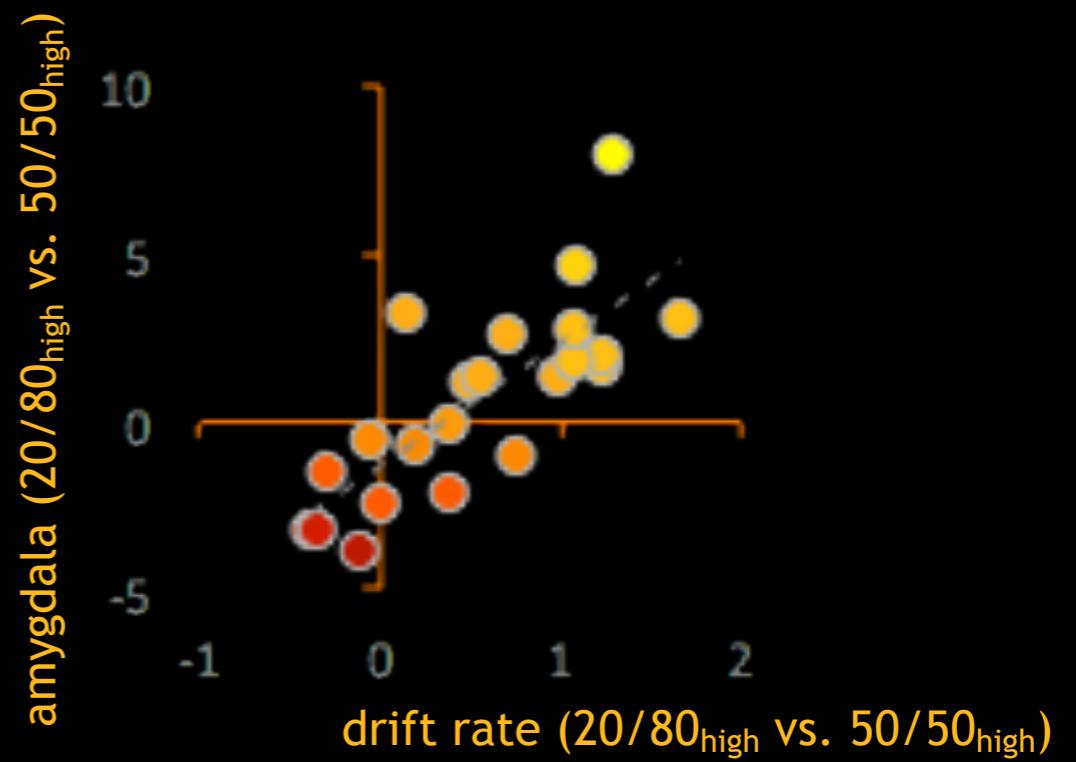
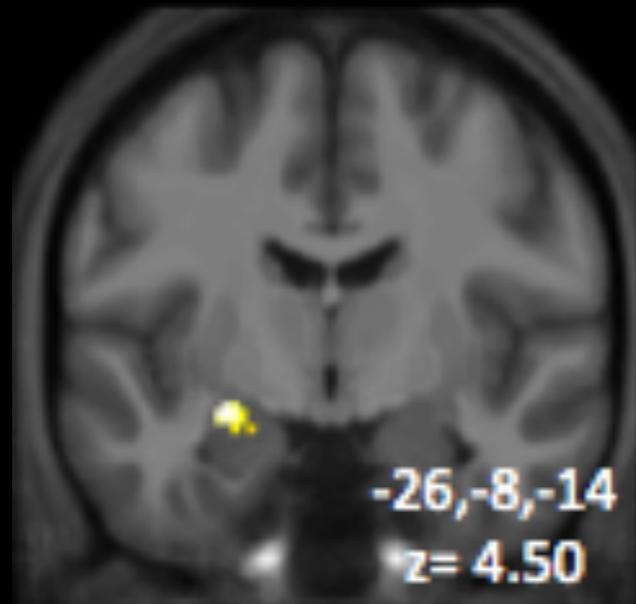


during anticipation

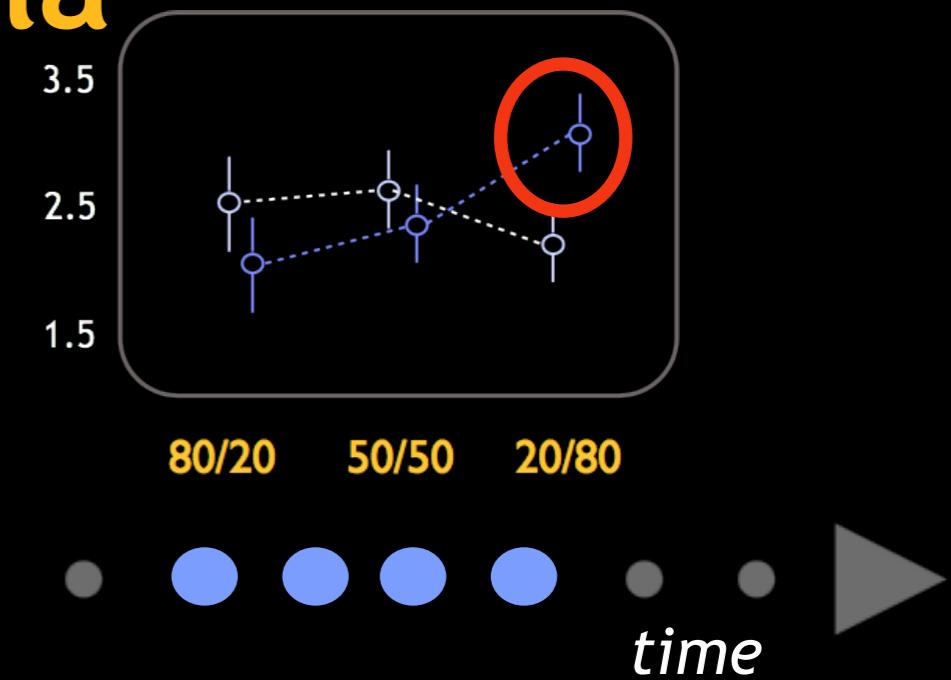
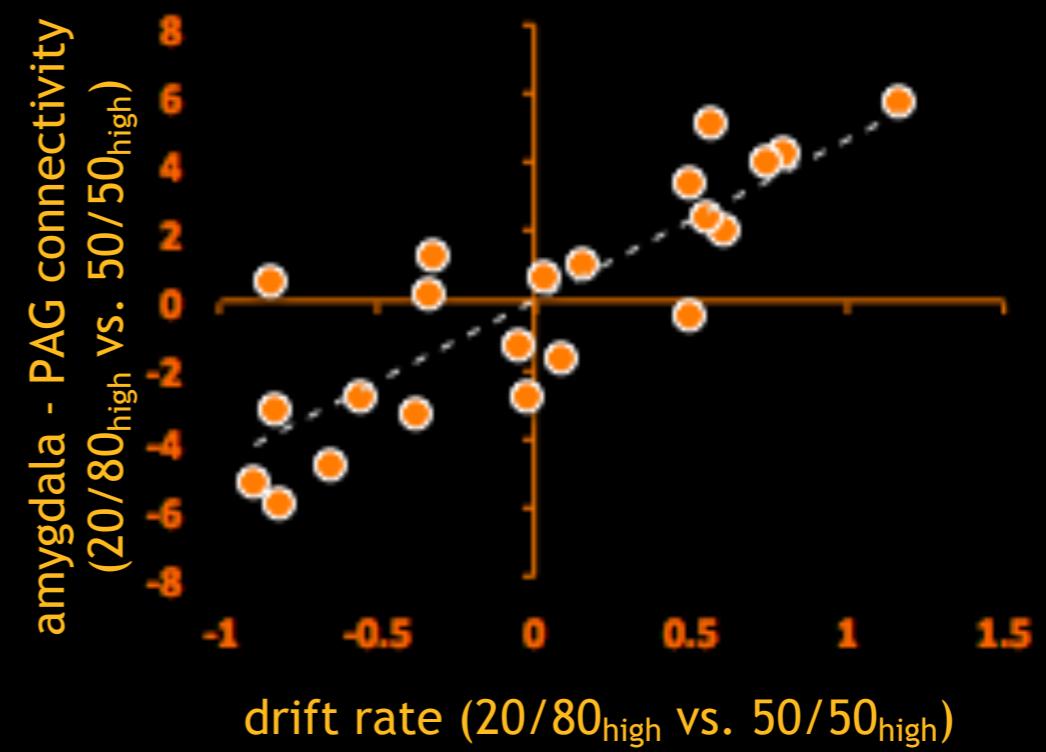
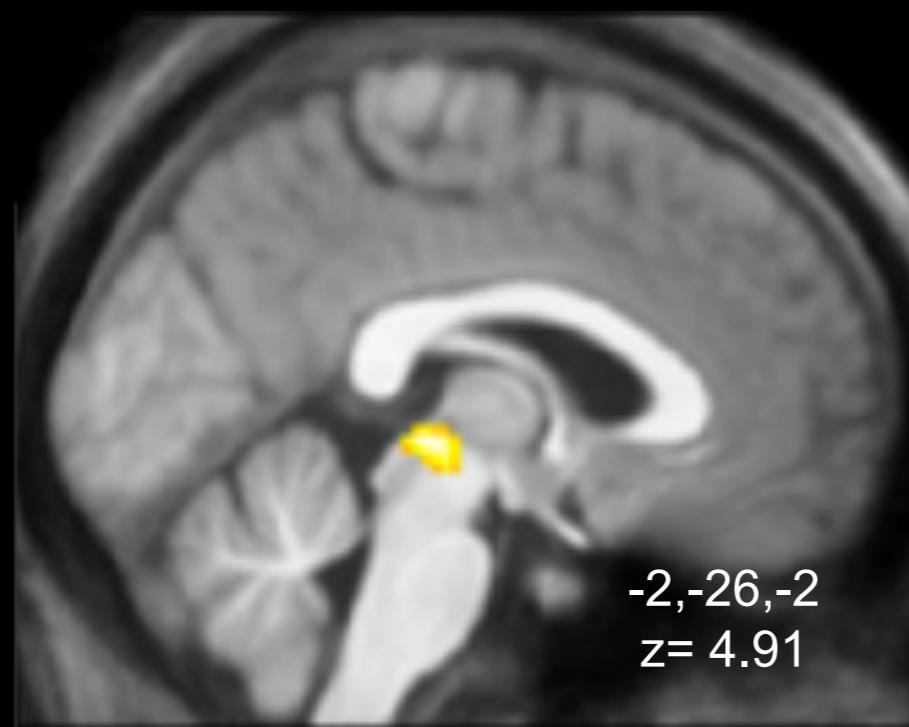
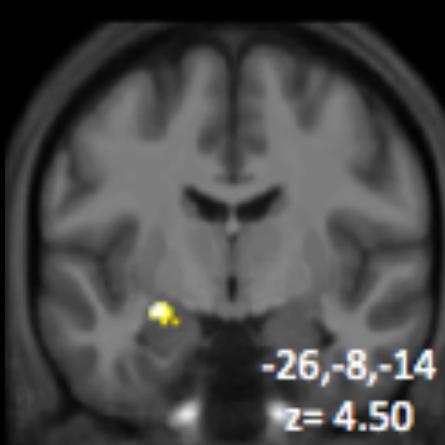
during stimulation



Increase in drift rate during unexpected high intensity stimulation: stimulation phase



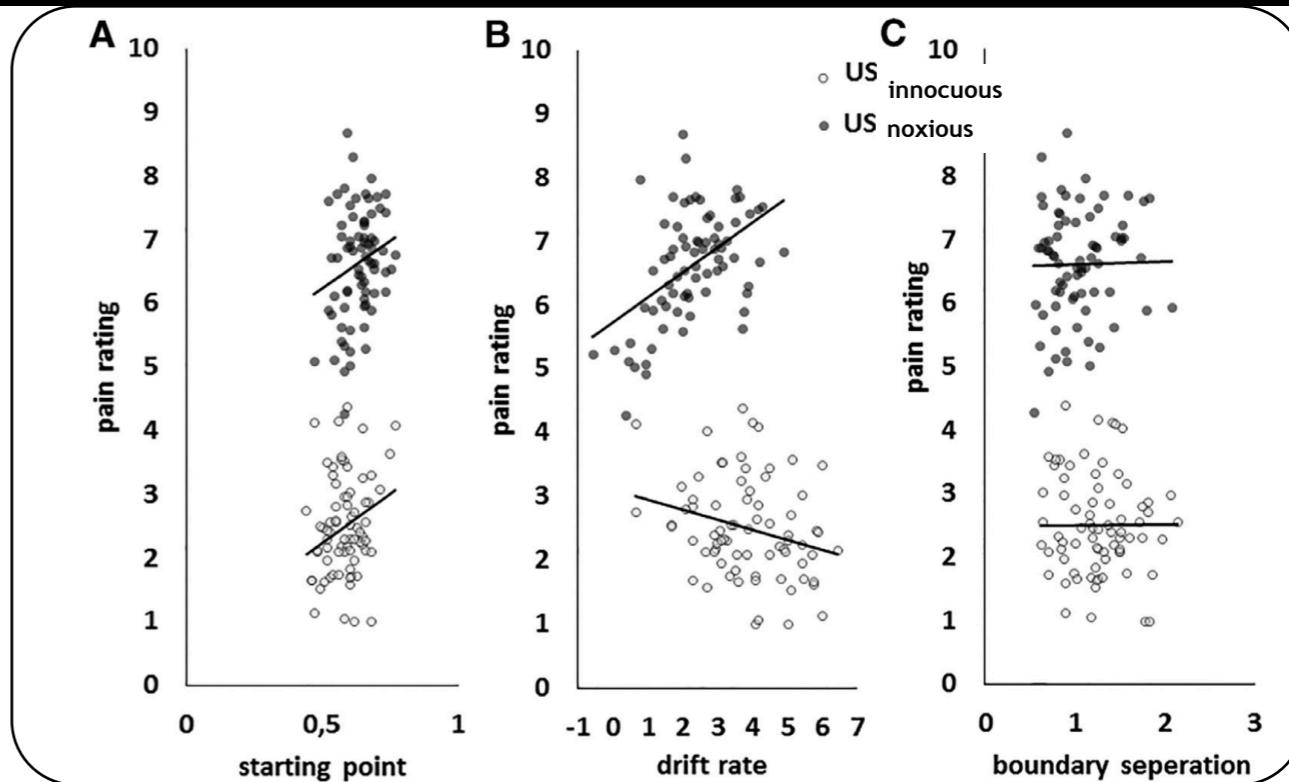
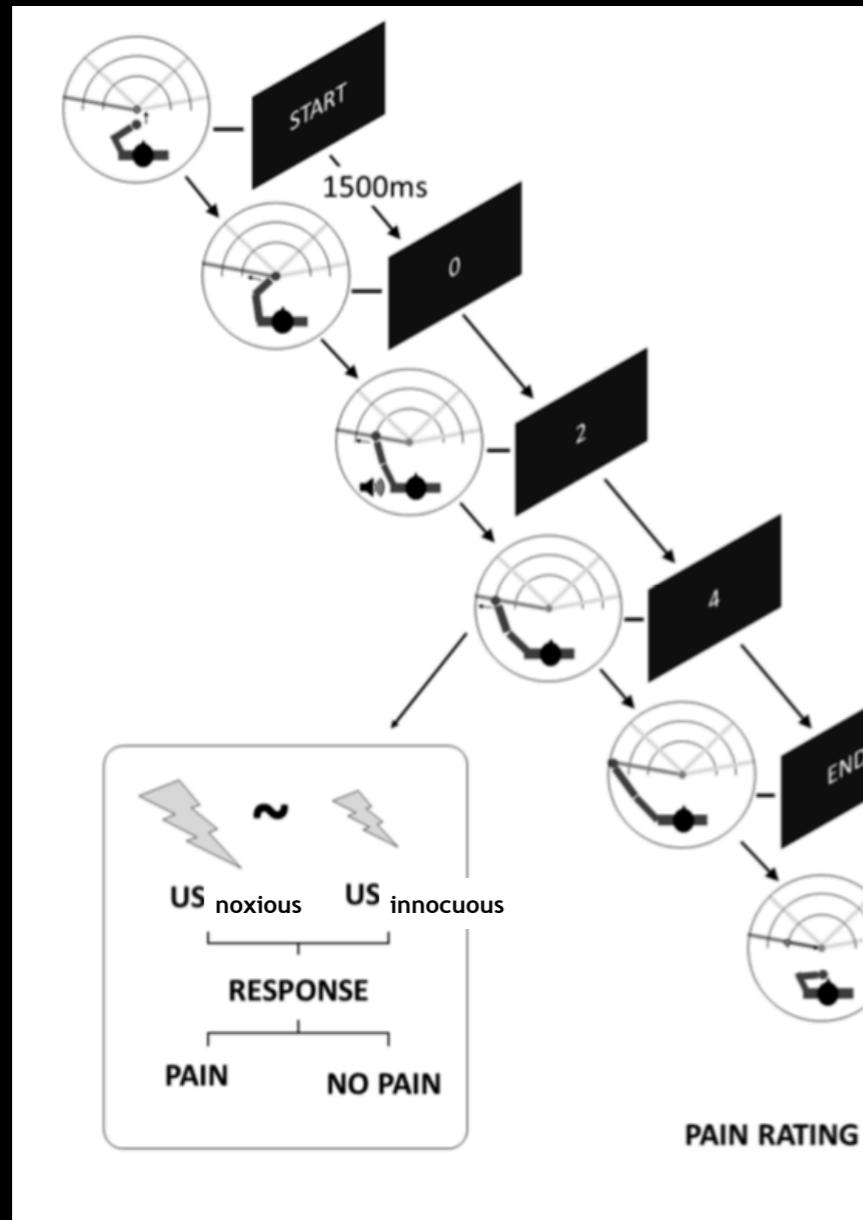
PPI analysis on left amygdala during unexpected high intensity stimulation: stimulation phase



Correlation between DDM parameters and pain intensity ratings

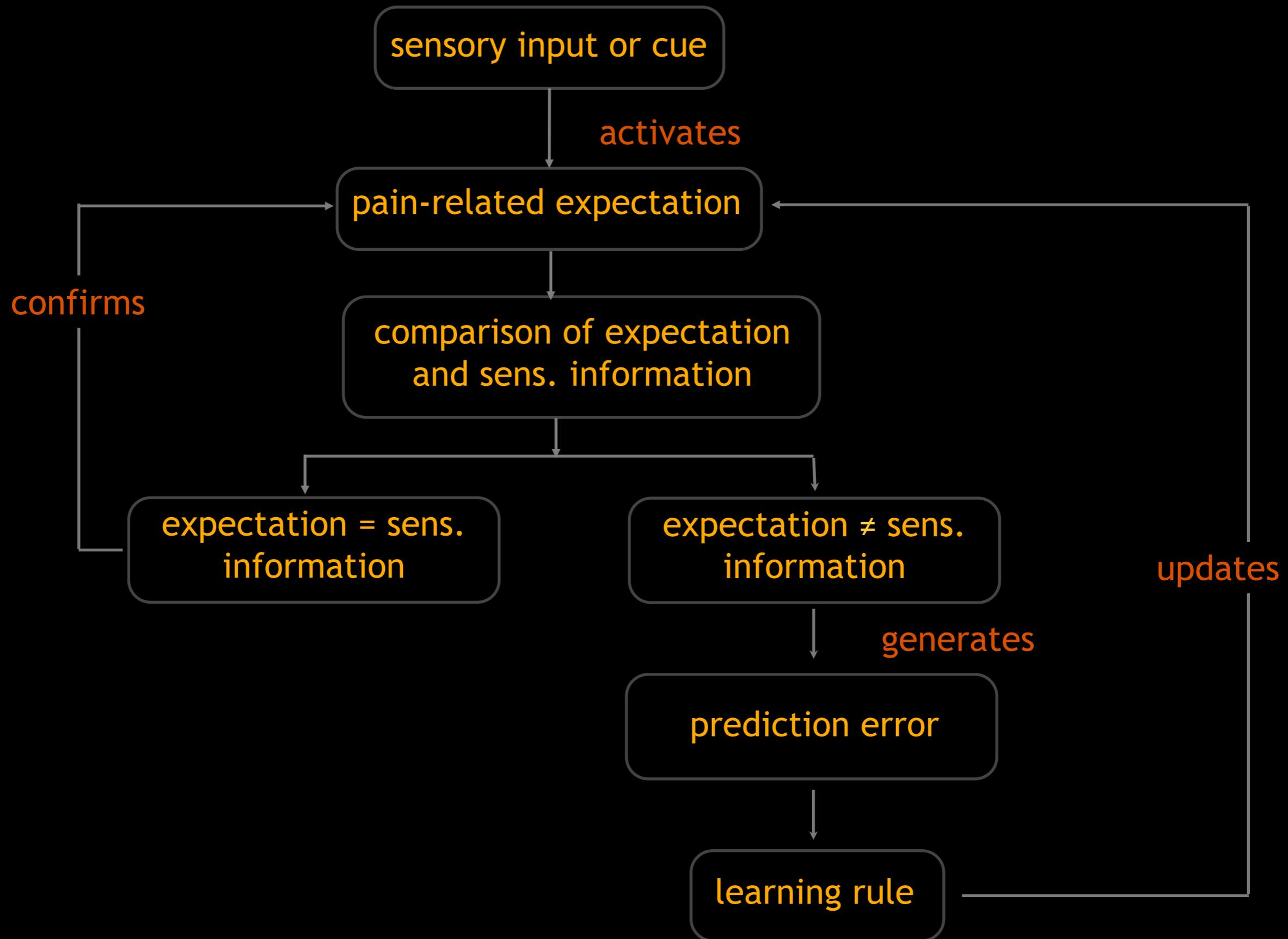


Jonas Zaman



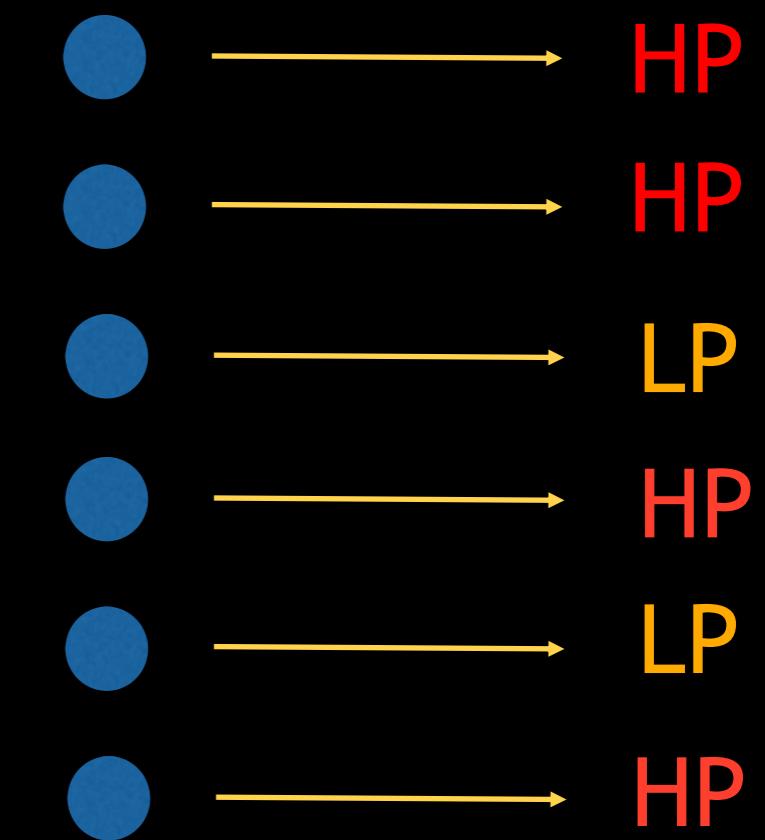
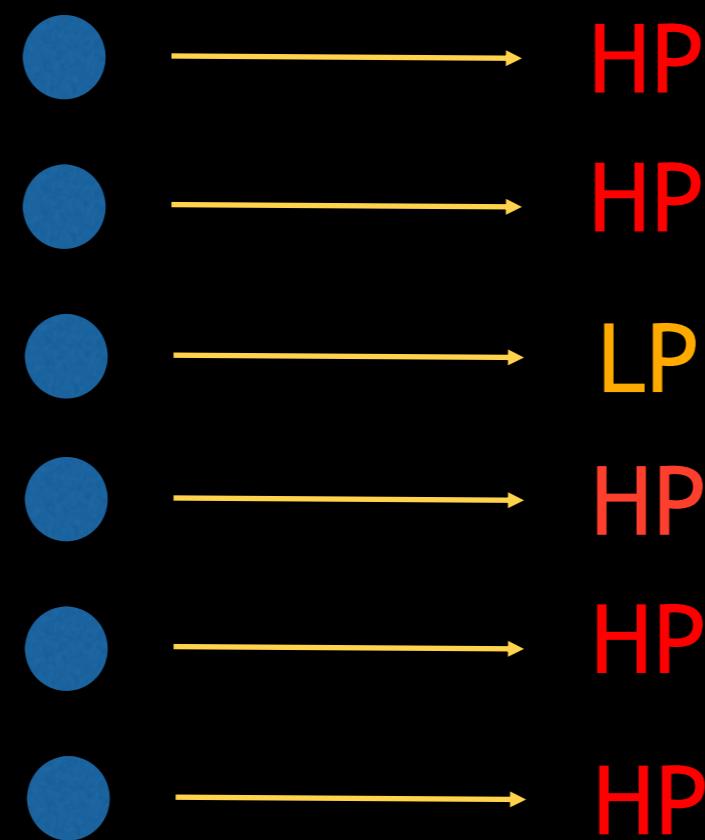
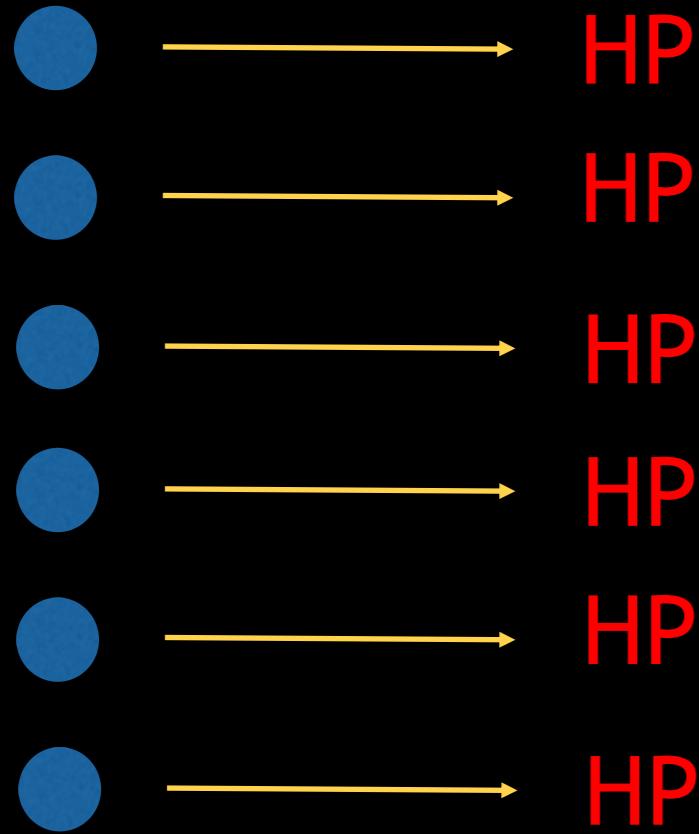
Zaman et al., 2019

Learning about pain



- The interface between beliefs and perception
- Changes in pain-related beliefs:
learning and updating
- Role of beliefs in pain treatment

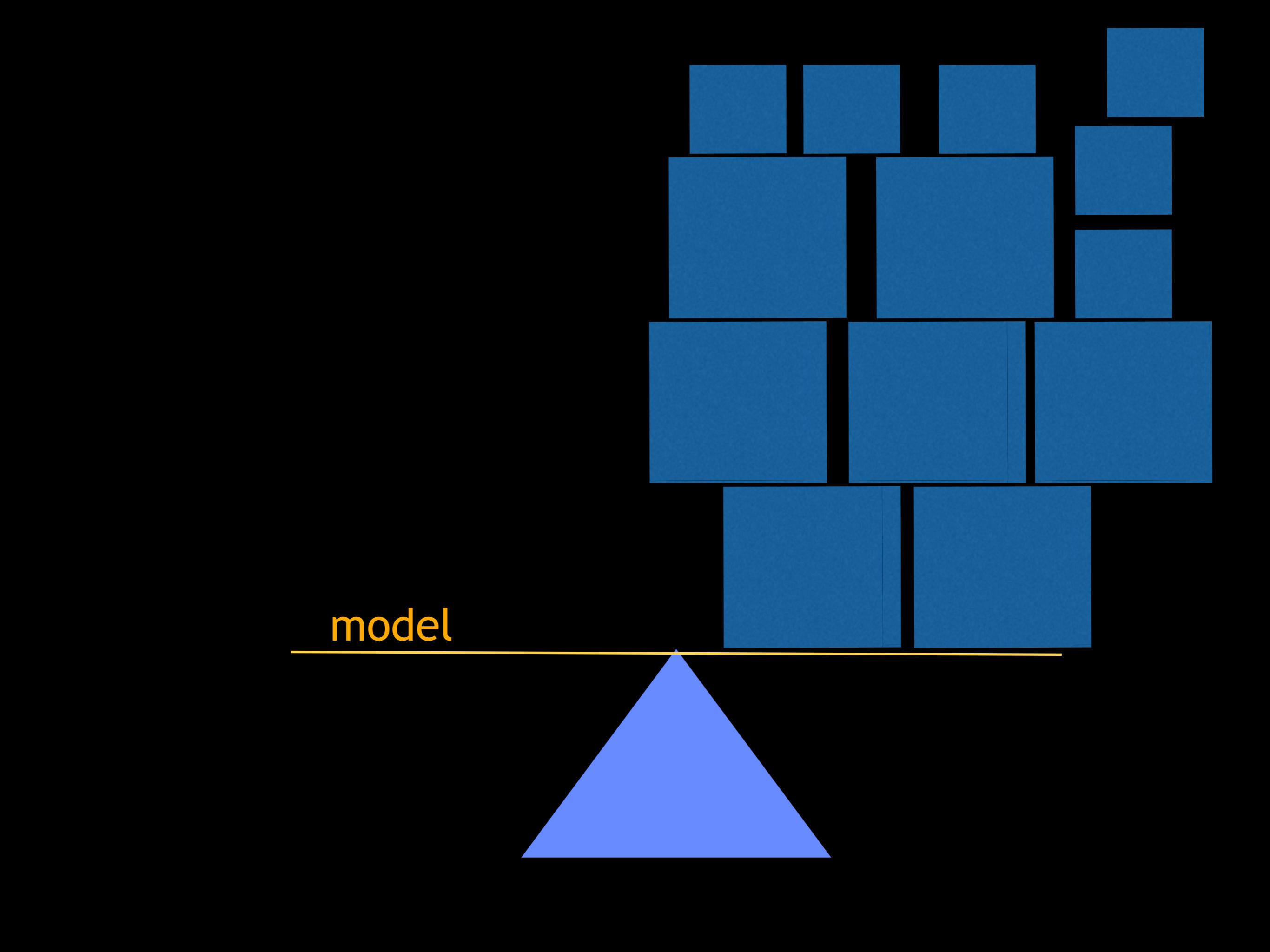
How to challenge a model



model

model

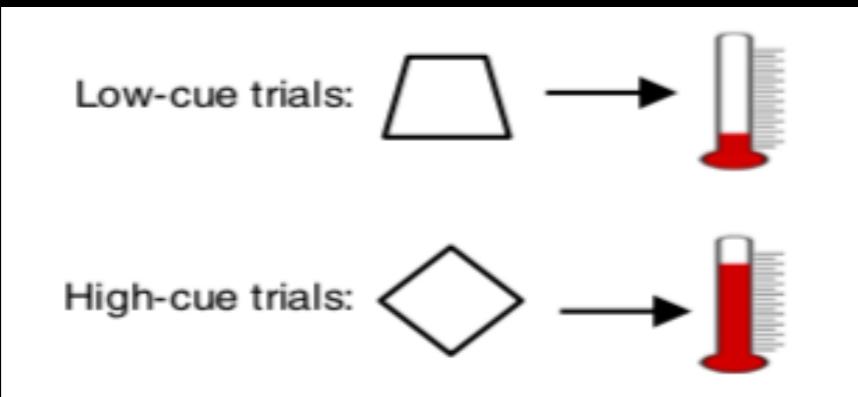
model



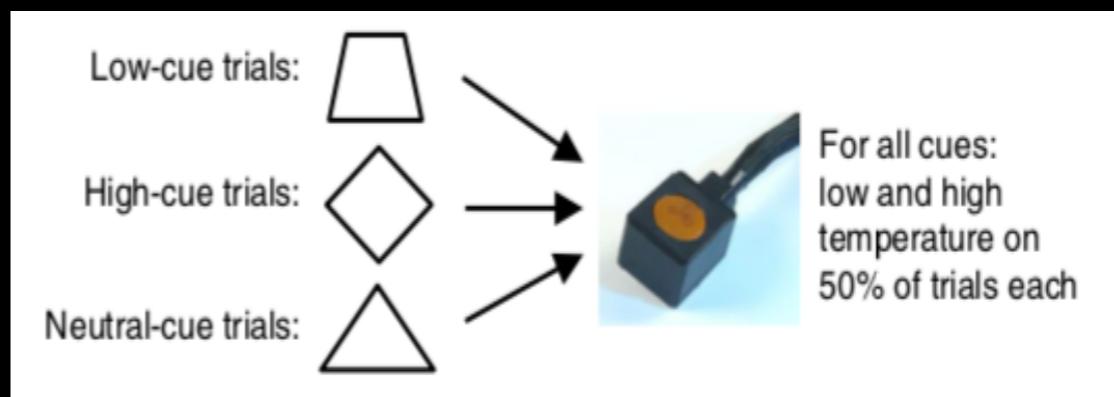
model

Behavioural and neural evidence for self-reinforcing expectancy effects on pain

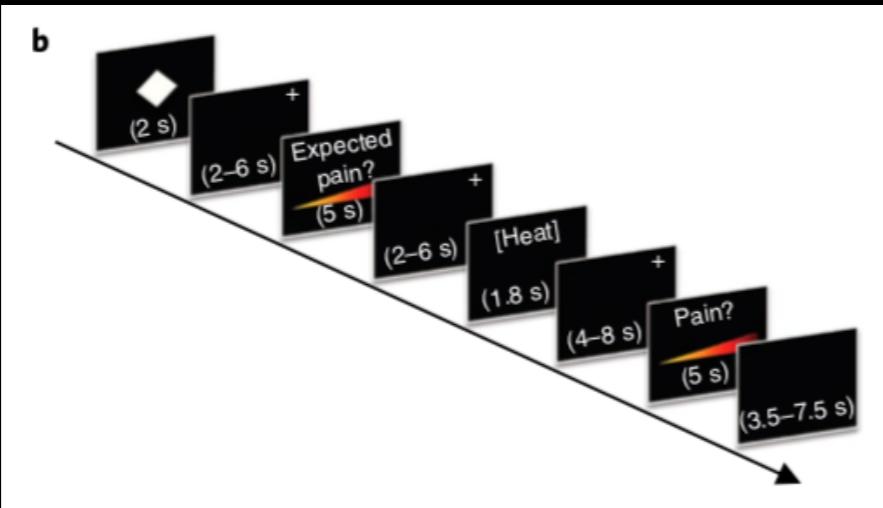
Phase 1: Expectation induction



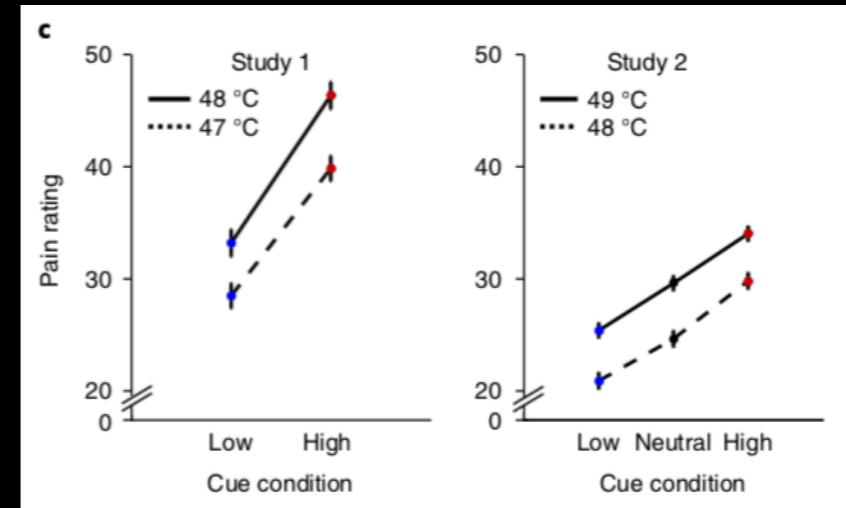
Phase 2: Test



Trial structure

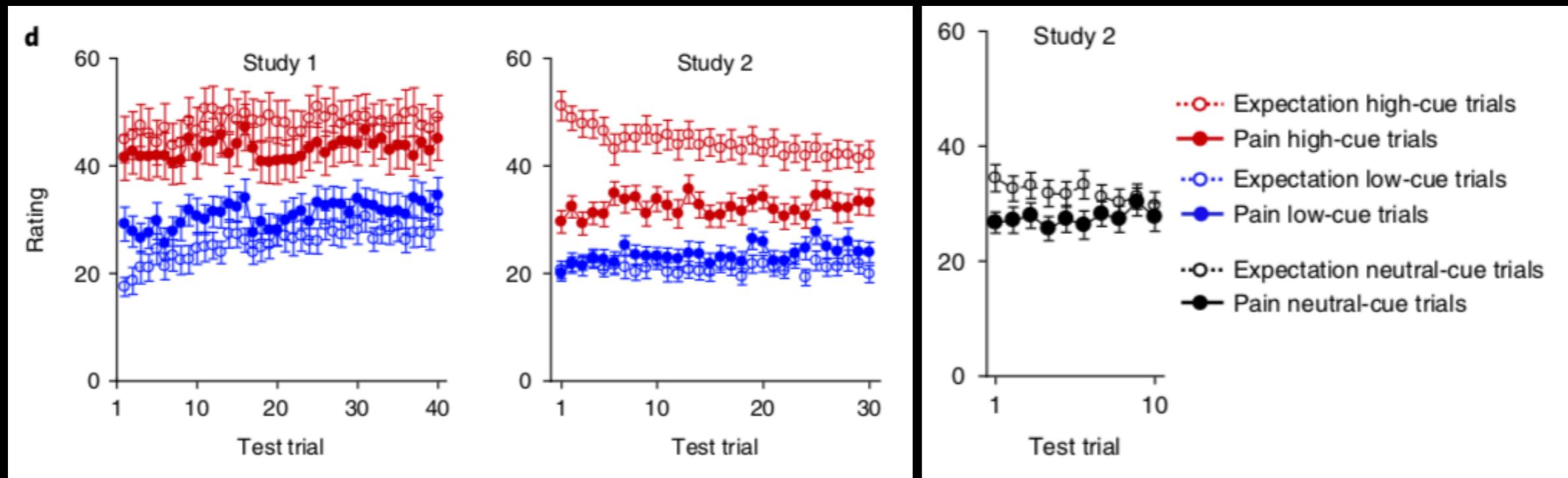


Pain intensity ratings



Average expected and experienced pain

The effect of cue type on pain ratings was stable across test trials although the cues no longer predicted heat intensity.



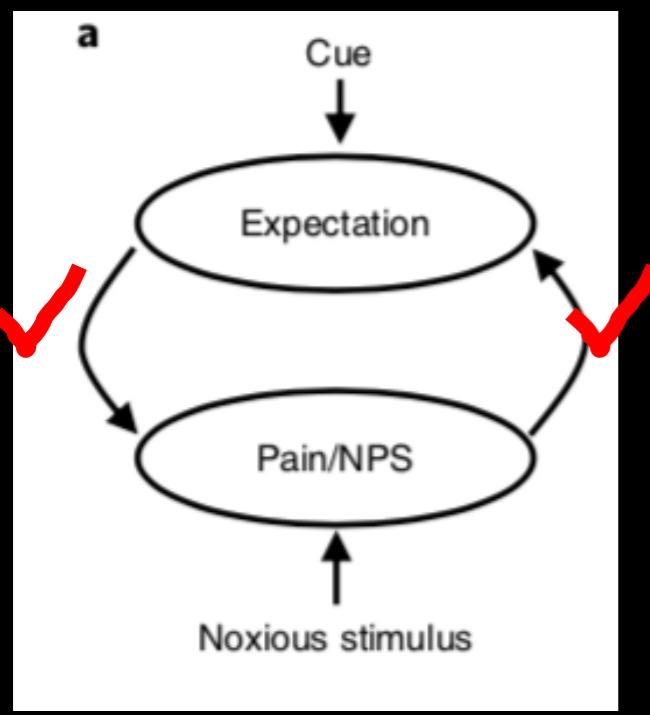
Pain expectations for **high-pain cues** were consistently worse than experience.

Pain expectations for **low-pain cues** were consistently better than experience.

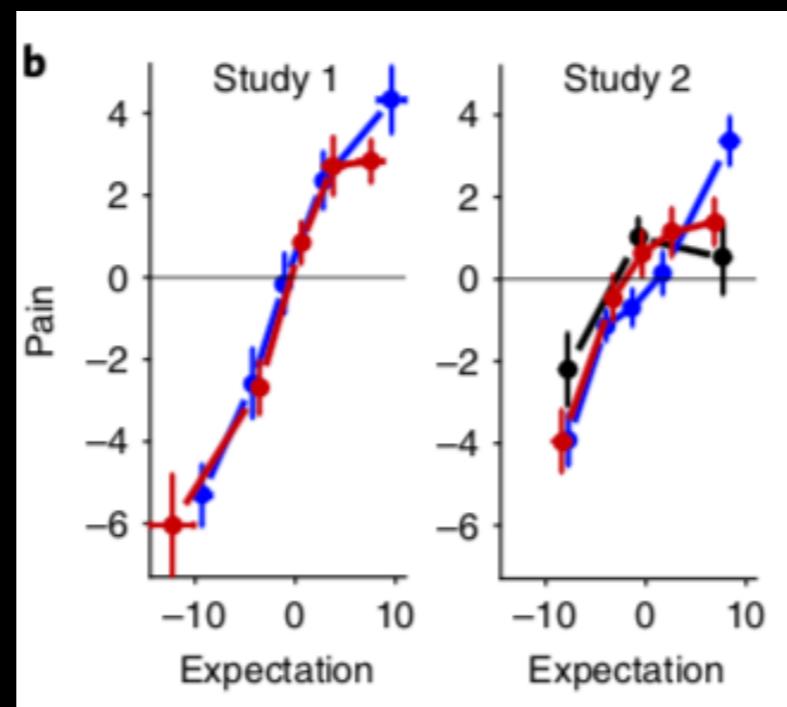
Pain and expected pain ratings for neutral cues converged over time.

Bidirectional effects of pain and expectations on one another

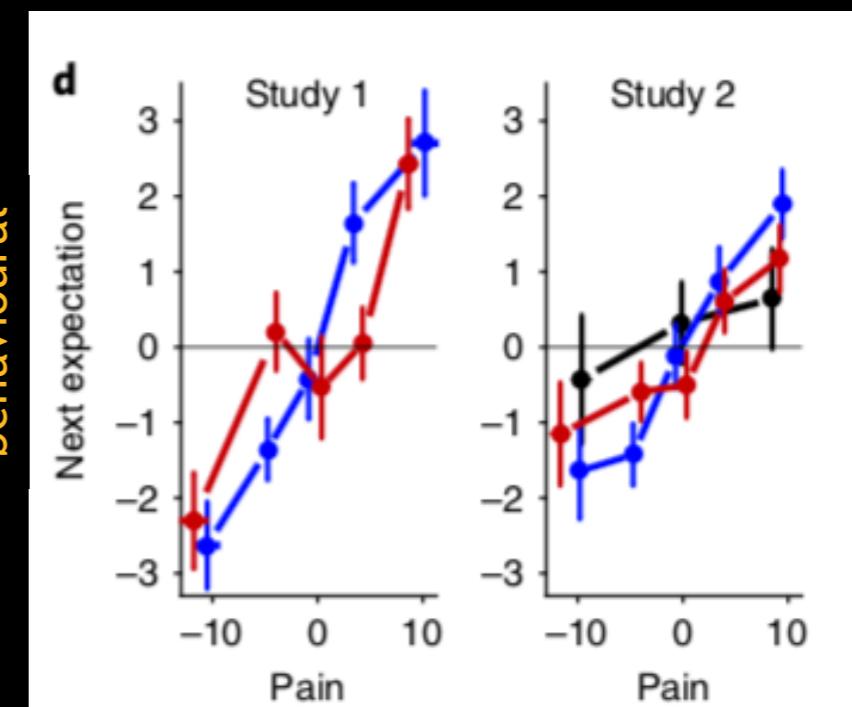
Hypothesis:



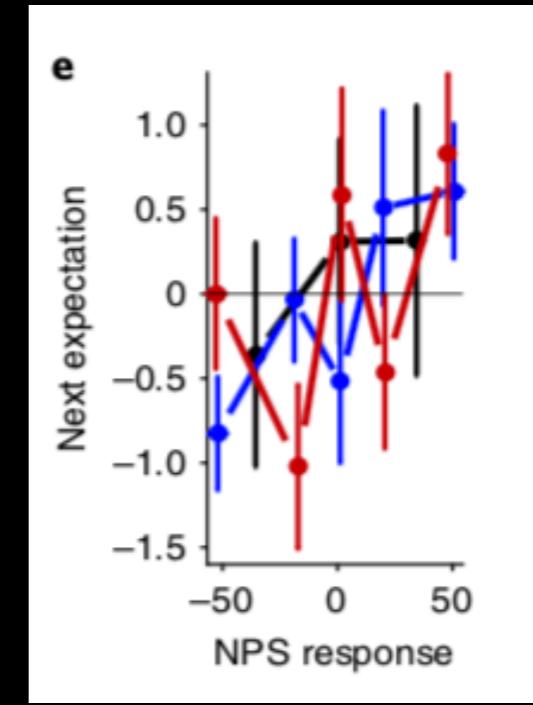
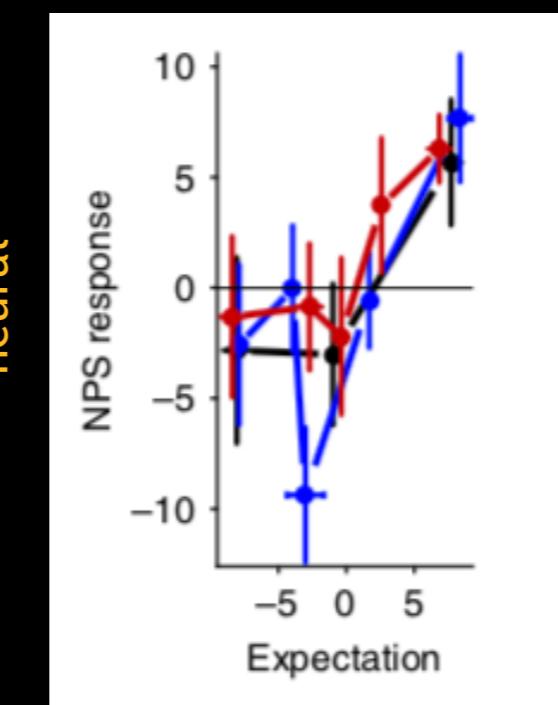
expectation → pain



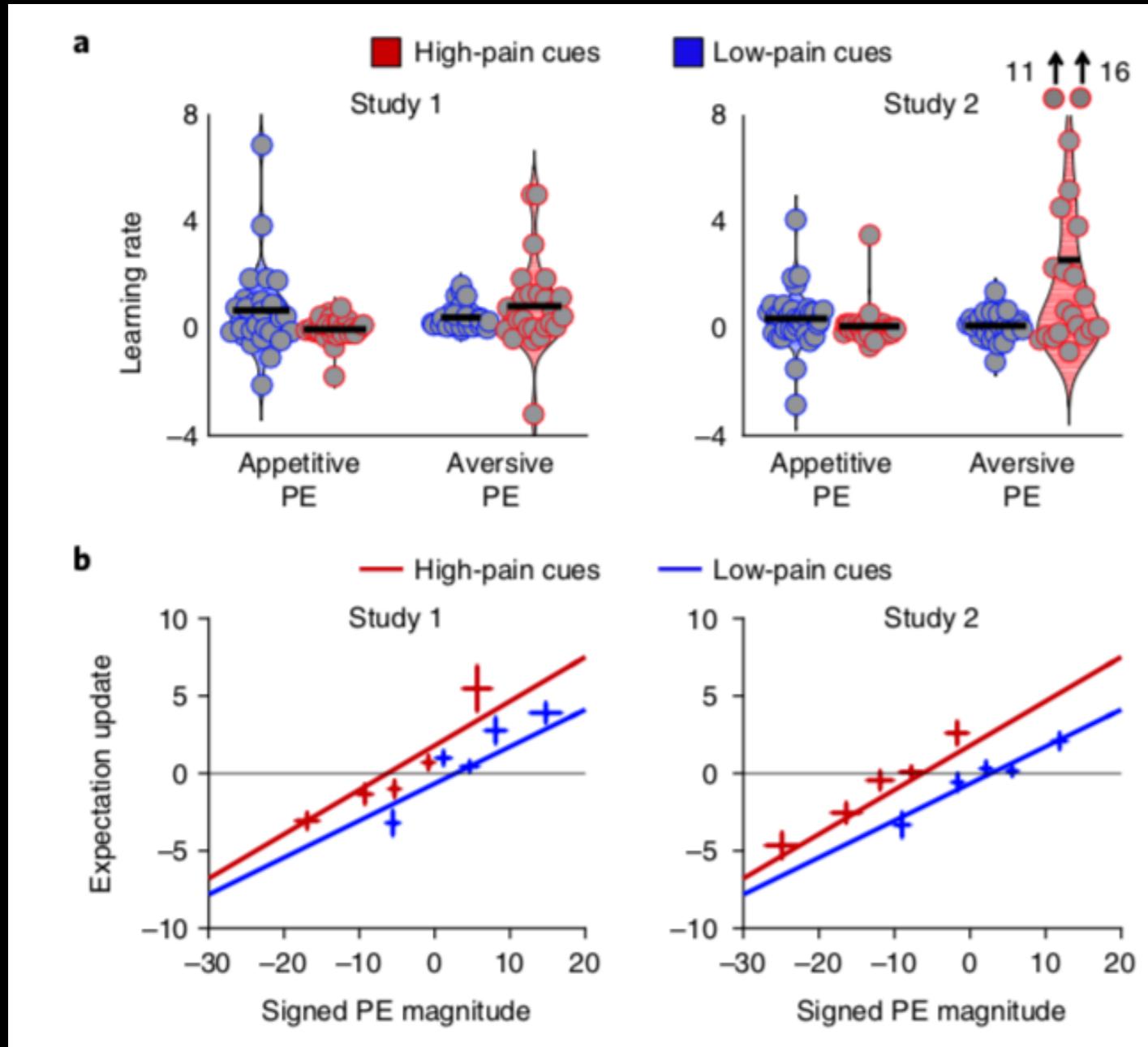
pain → next expectation



Multi-level mediation analysis:
Trial-by-trial variations in NPS response mediate effect of expectations on pain



Confirmation bias in expectation updating



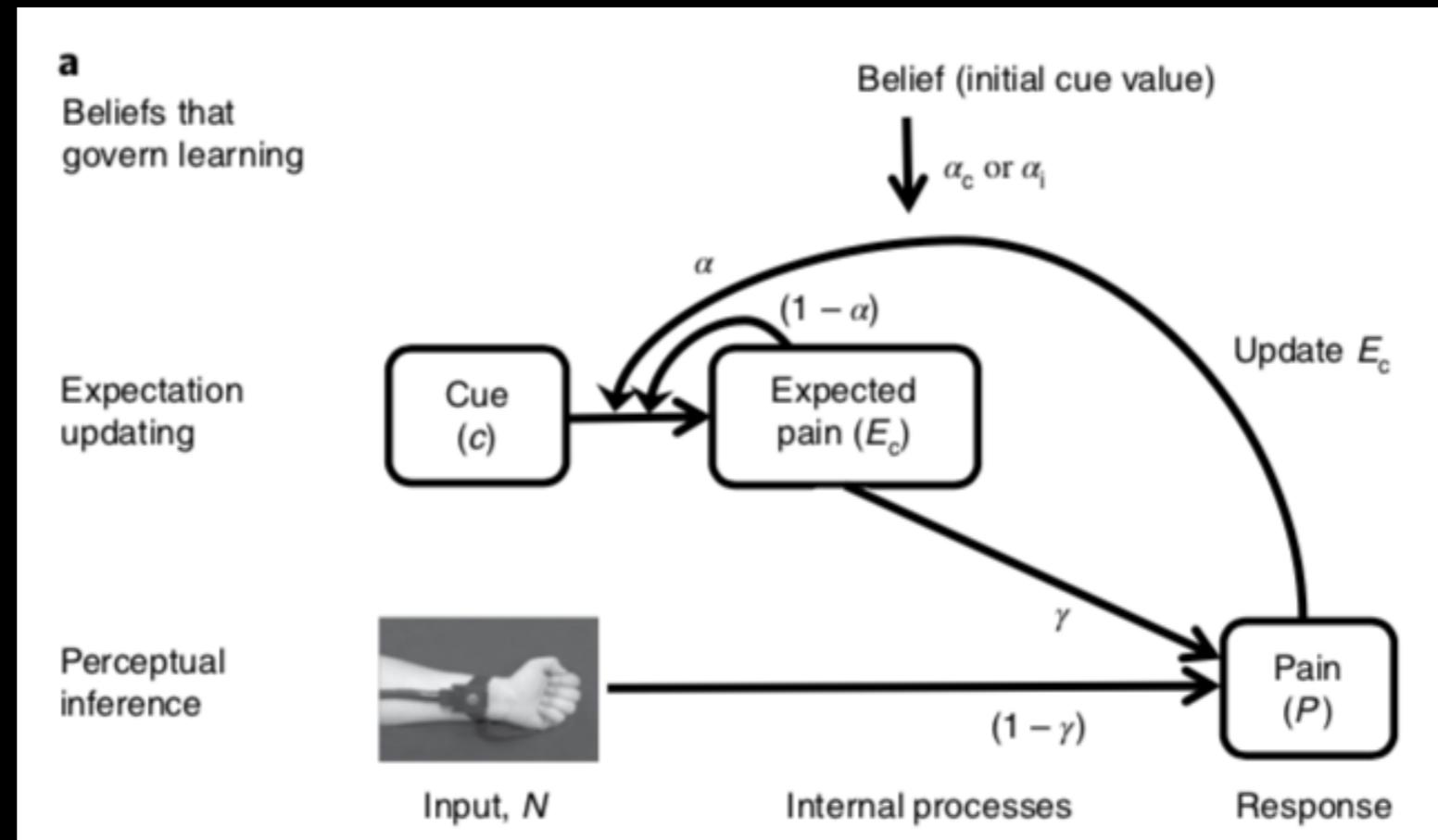
Aversive prediction error:
High-pain cue is followed by
higher-than-expected pain

Appetitive prediction error:
Low-pain cue is followed by
lower-than-expected pain

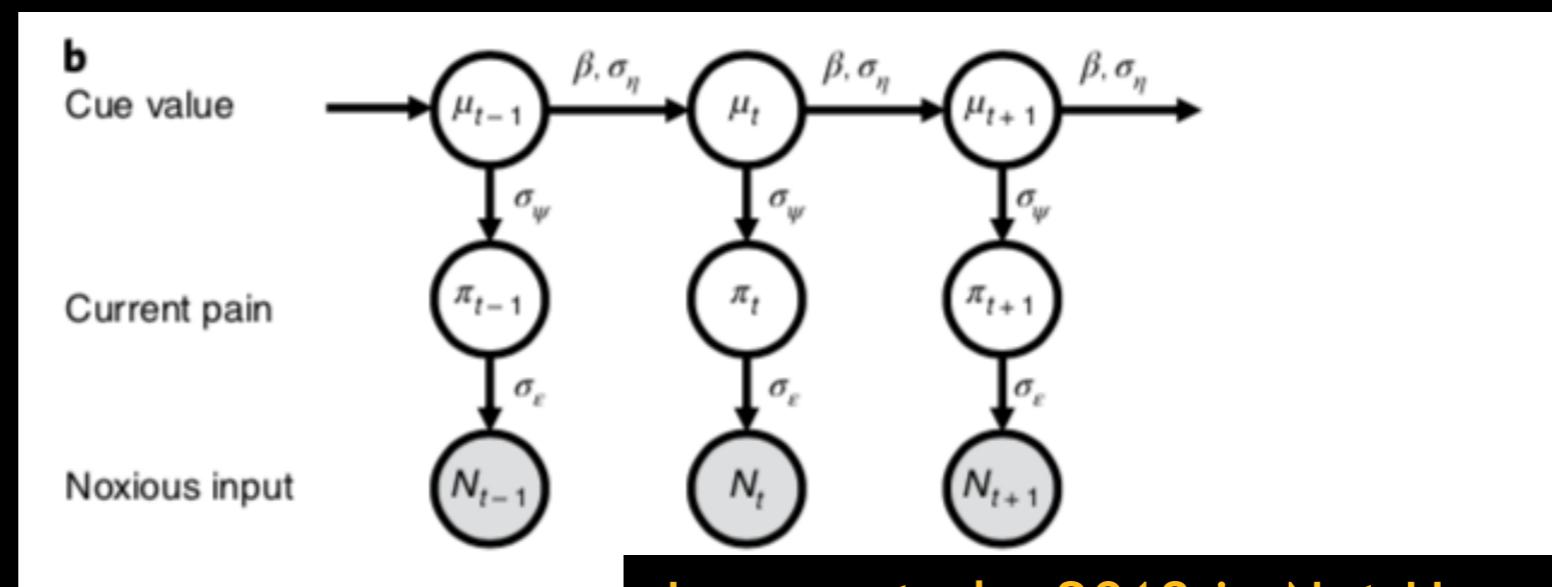
Confirmation bias:
Stronger expectation updating
when new experiences are
consistent with the initial
expectation of high or low pain
than when they are inconsistent.

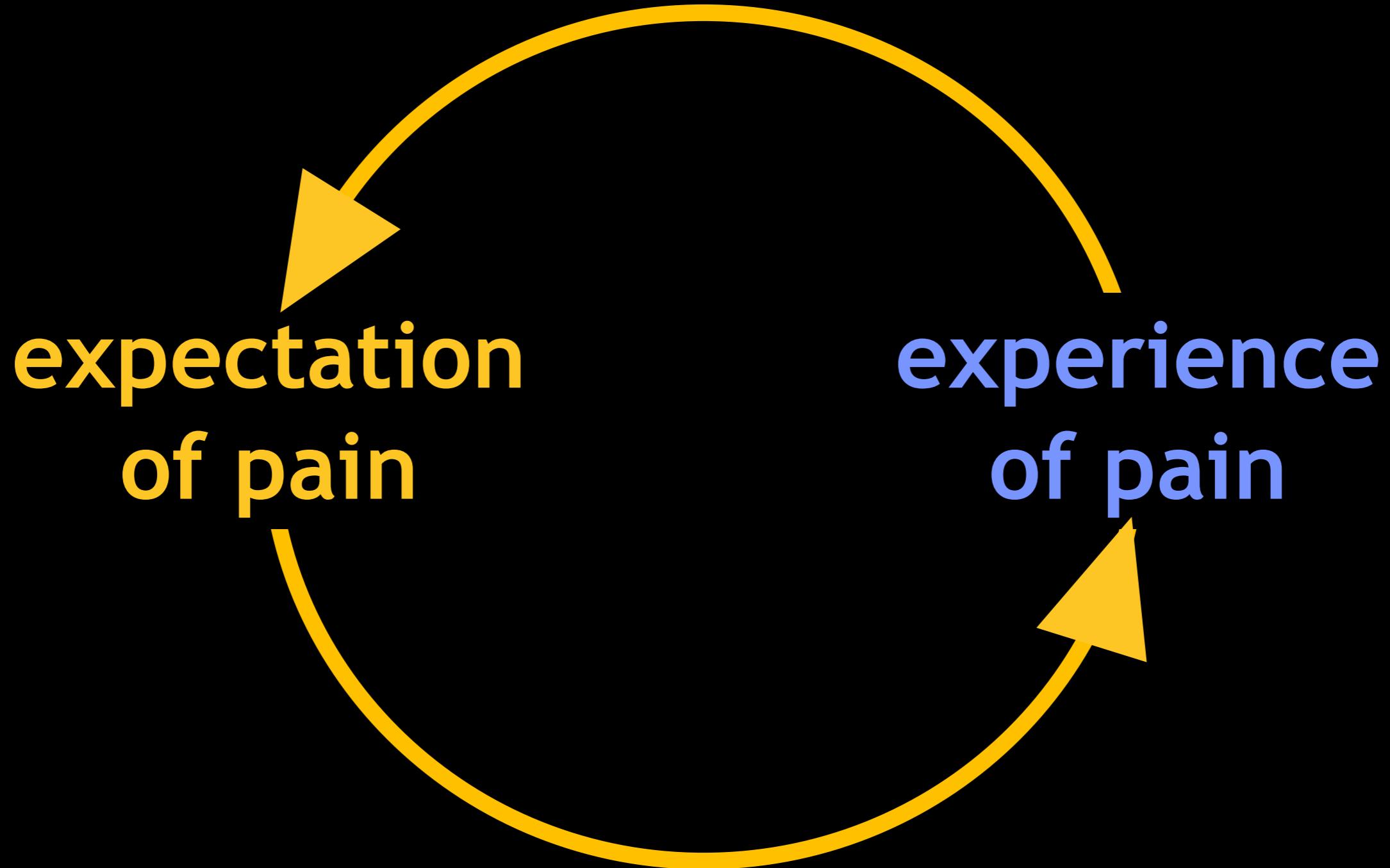
Computational models capturing effects of cue-based expectations on pain and confirmation bias on expectation updating

Reinforcement learning model



Bayesian model

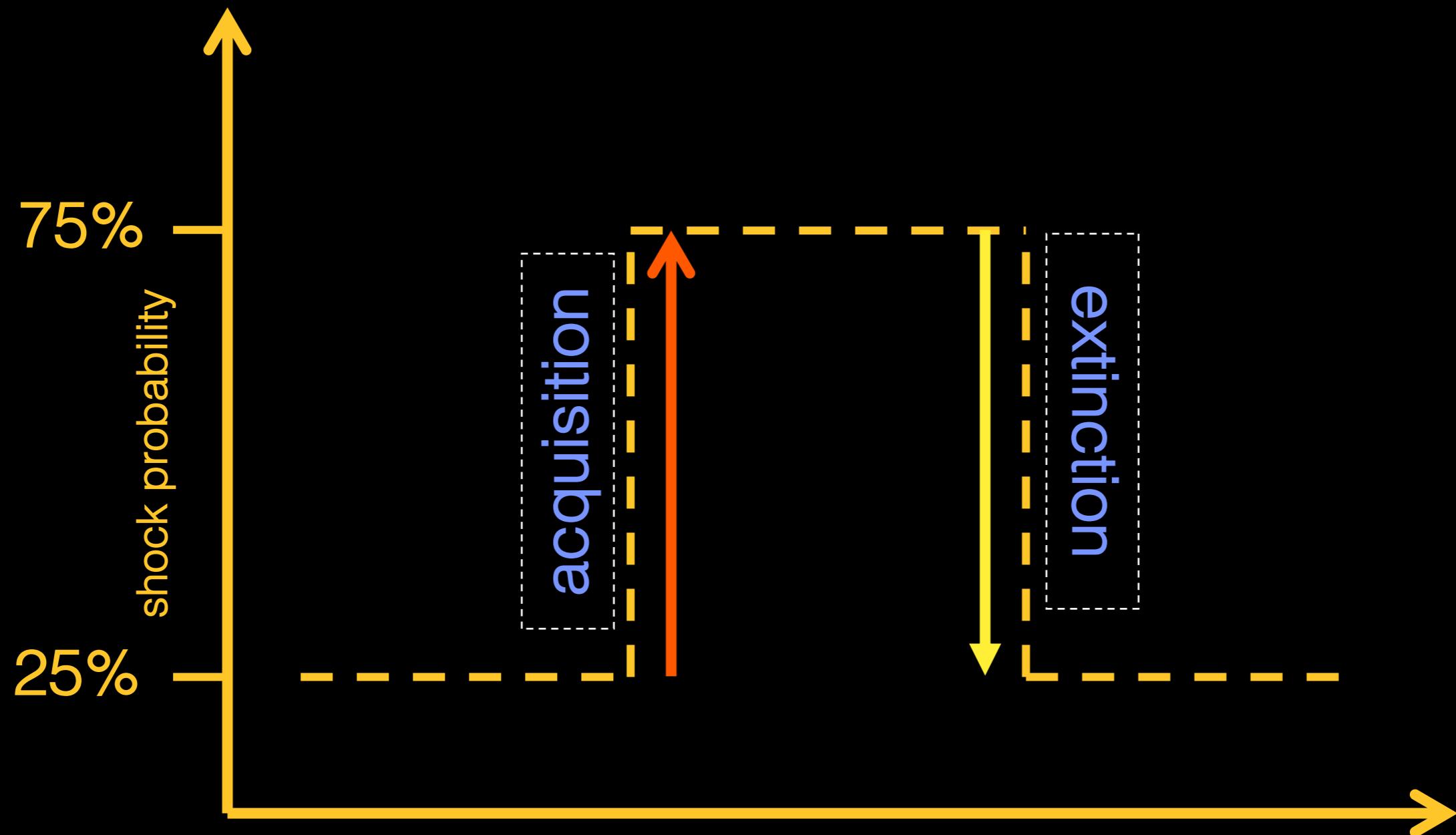




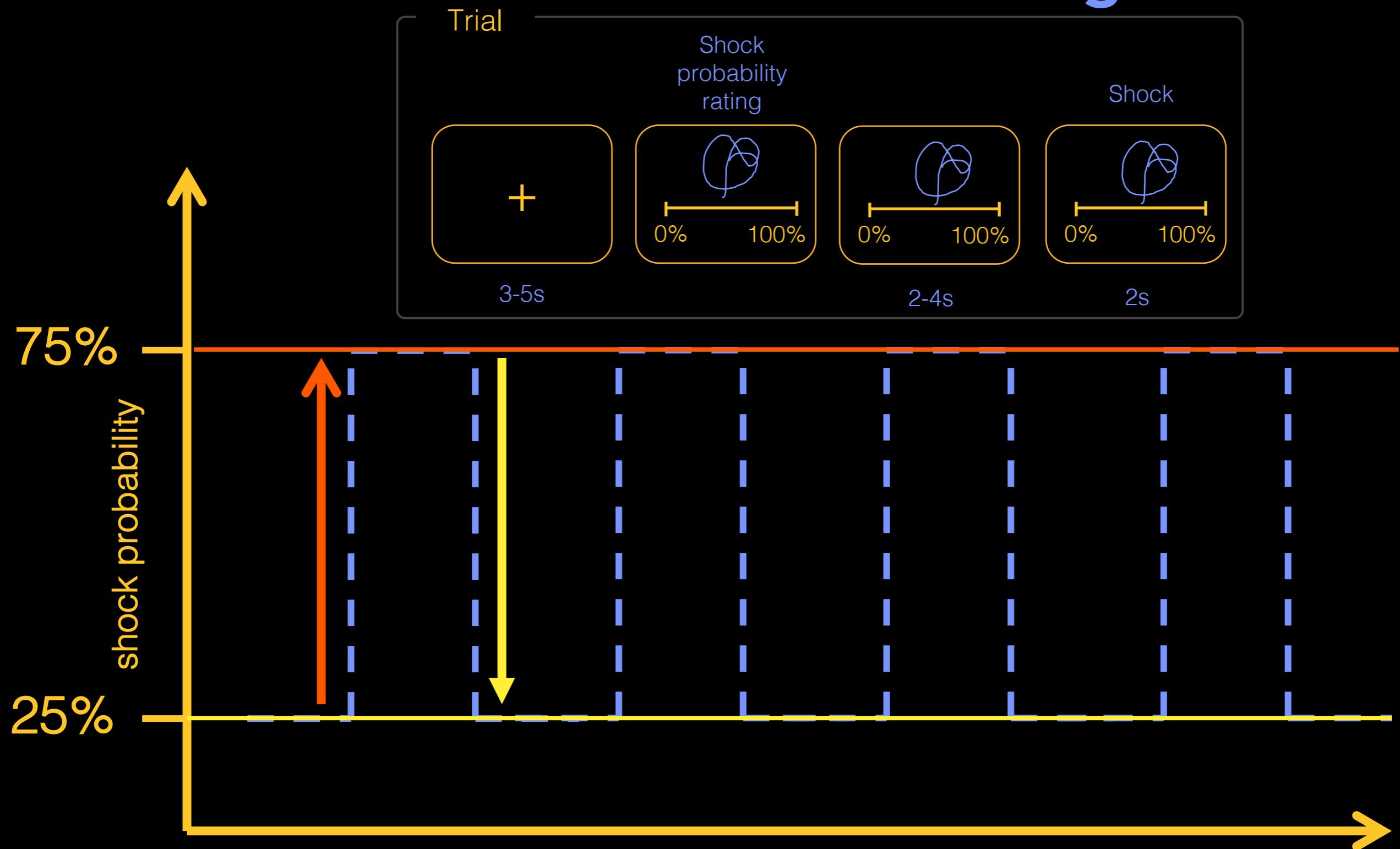


Ondrej Zika

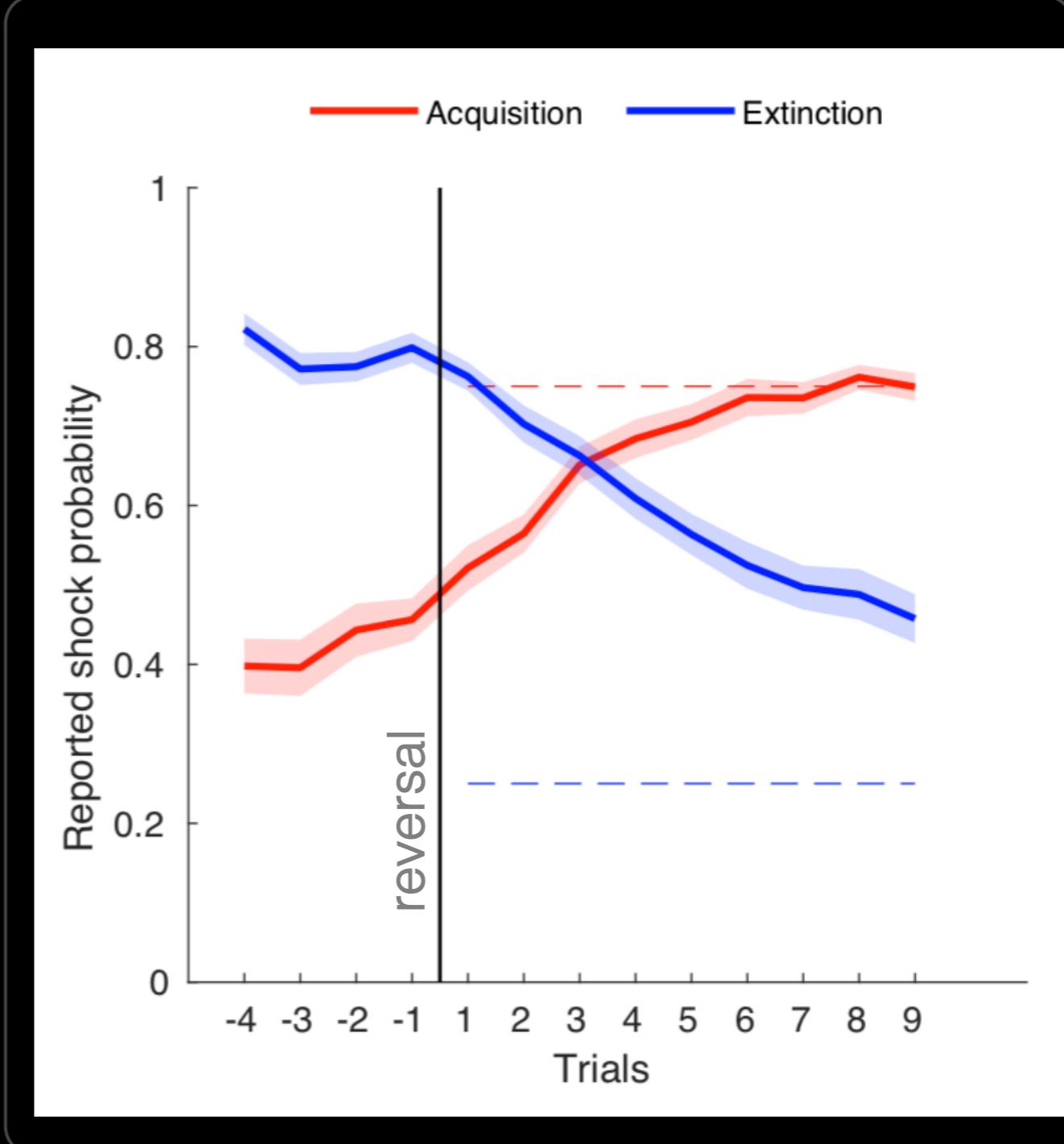
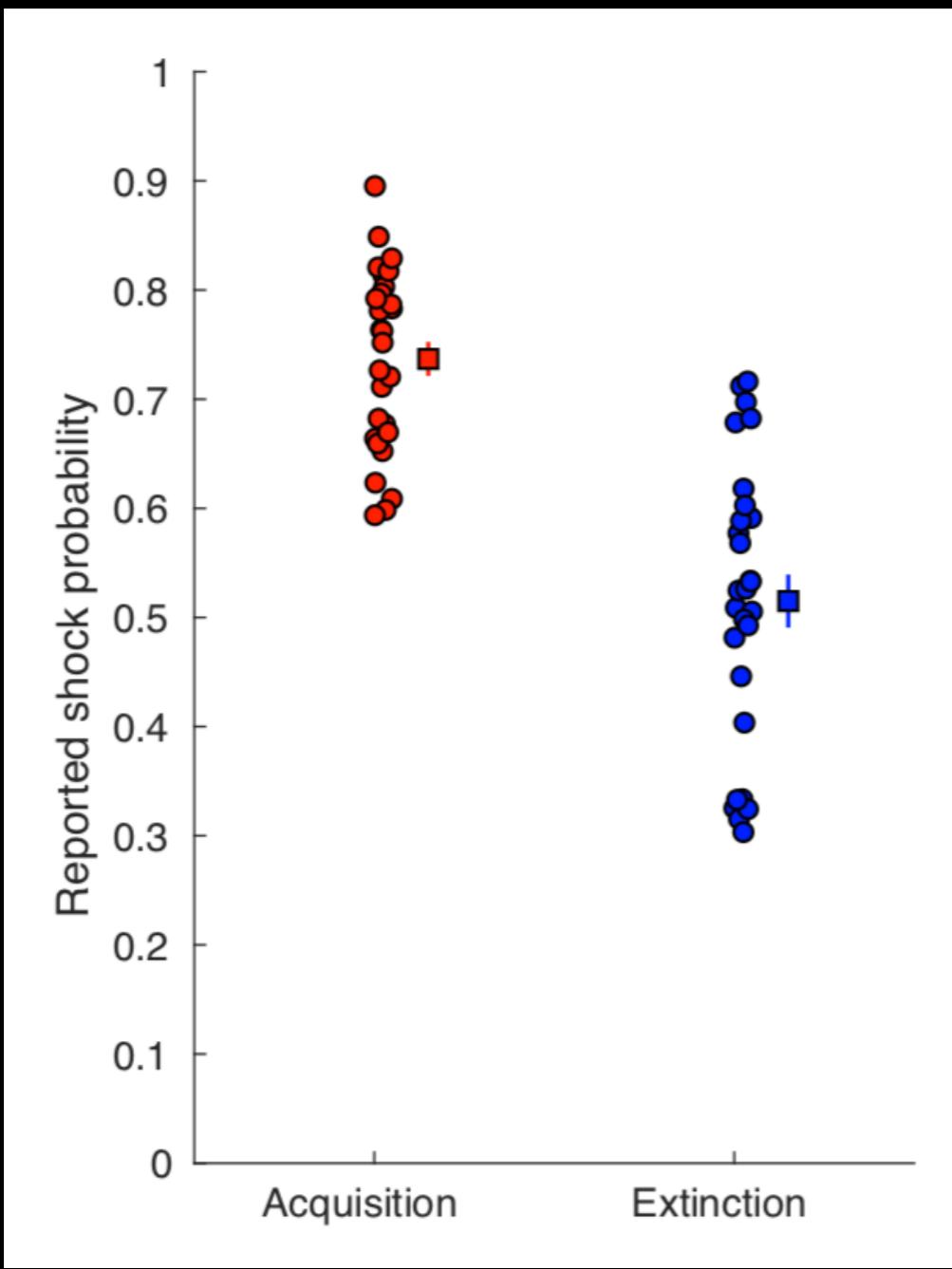
Acquisition and extinction of pain-related associations: question



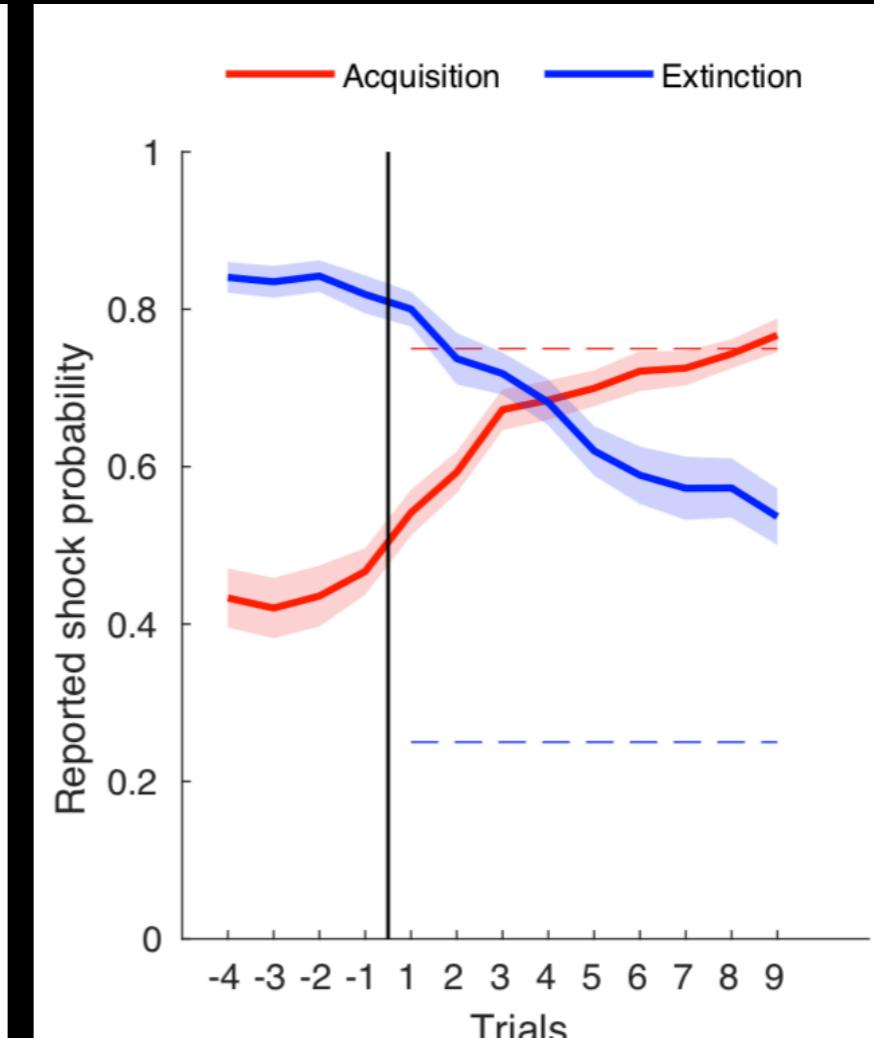
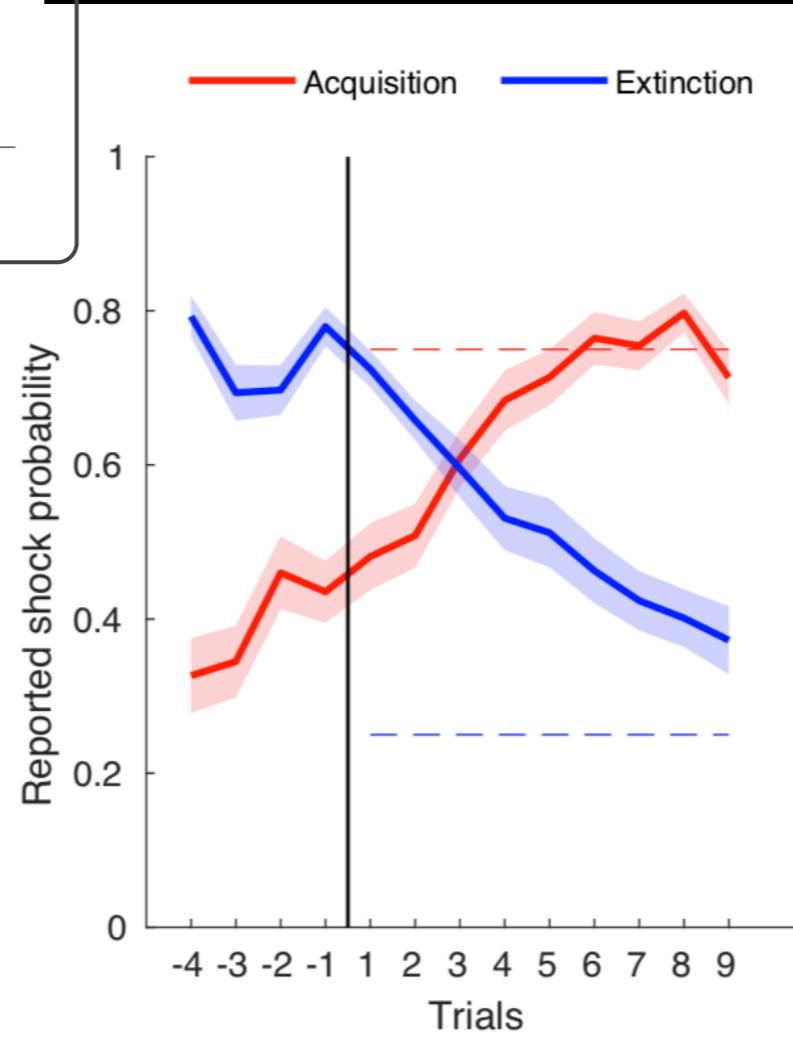
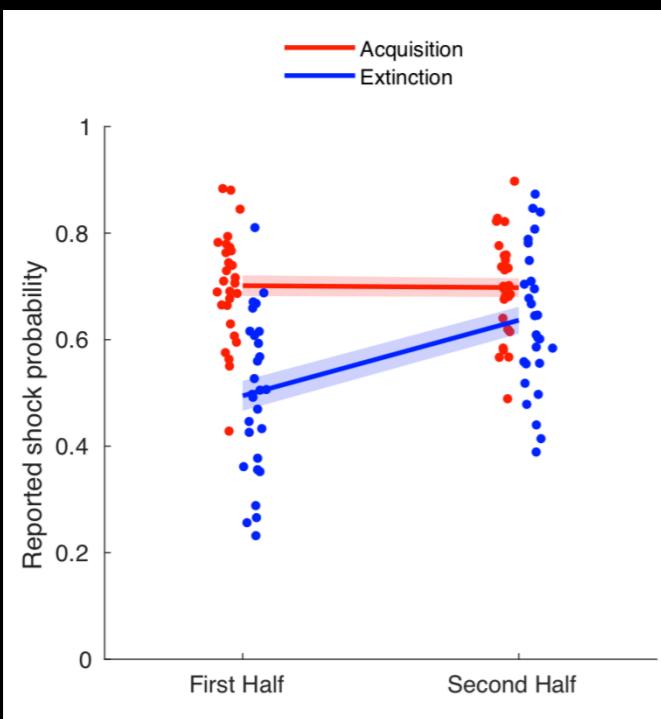
Acquisition and extinction of pain-related associations: design



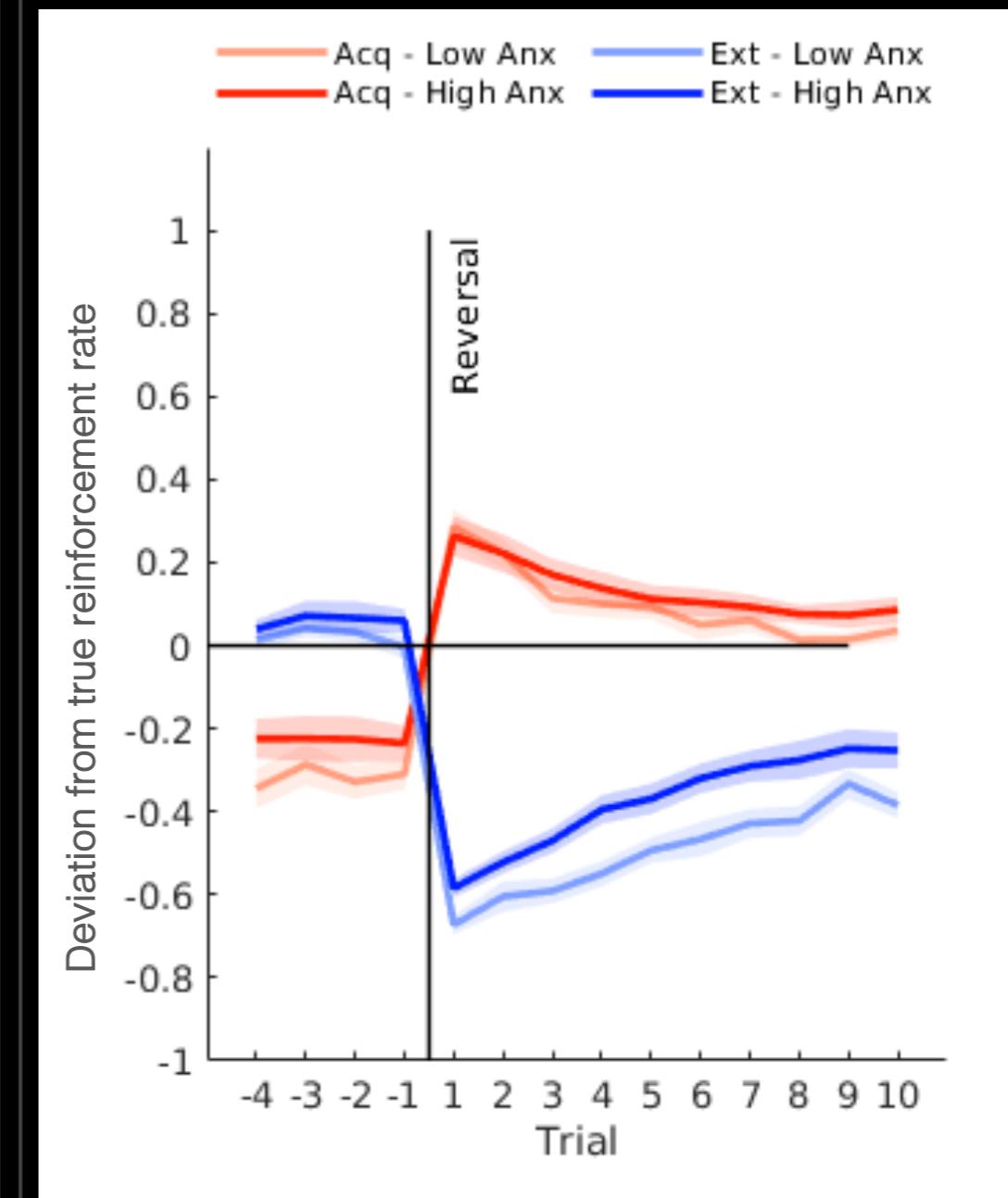
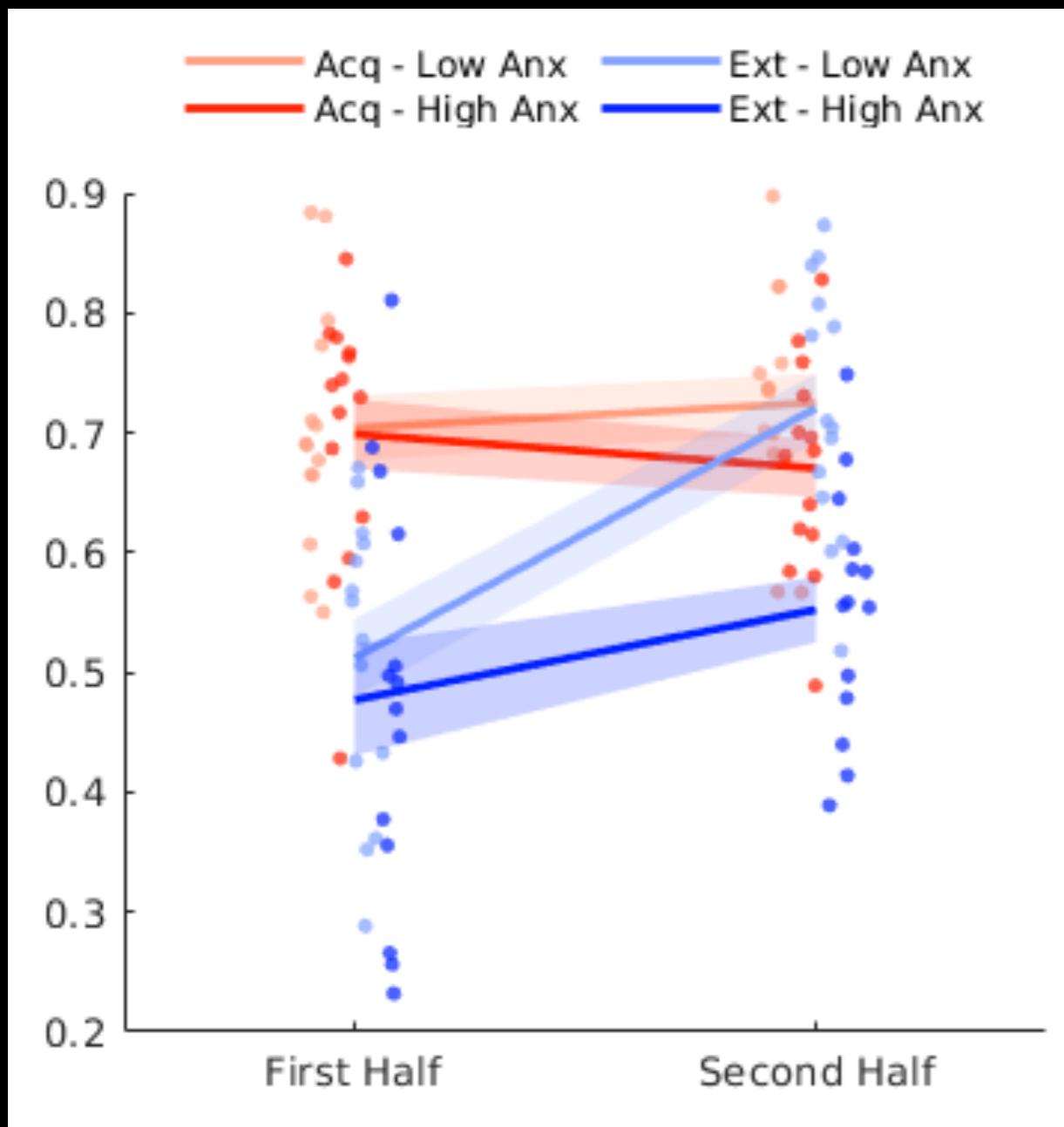
Successful acquisition, incomplete extinction



Extinction decreases over time



Extinction: modulation by trait anxiety



Modelling



zika@mpib-berlin.mpg.de
[@OndrejZika](https://twitter.com/OndrejZika)

Variables

t ... trial number
 P_t ... probability of pain on trial t
 i ... outcome (1=shock, 0=noshock)

Rescorla-Wagner

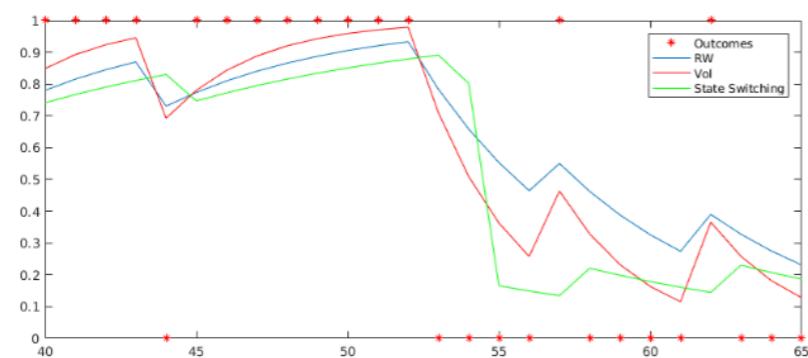
$$P_{t+1} = P_t + \alpha_i(O_t - P_t)$$

Pearce-Hall

- Learning rate is increased after large errors

$$P_{t+1} = P_t + \alpha_t(O_t - P_t)$$

$$\alpha_{(t+1)} = \alpha_{(t,i)} + \eta_i |O_t - P_{(t-1)}| - \lambda_i \alpha_{(t,i)}$$

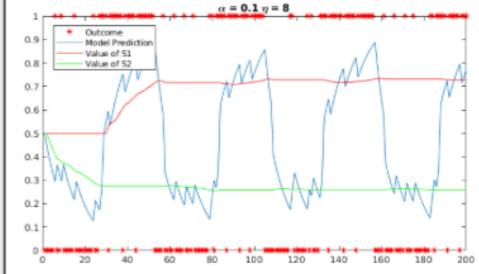


State Switching Model (I)

State classification

Given past probability of outcomes on the past η trials which state is the agent more likely to be in

Evaluate for each state: $\varepsilon_t^{S_i} = |\mu_{S_i} - \sum_{n=\eta}^{i=1} O_{t-n}|$



Learning

For state with lower error: if $\varepsilon_t^{S_1} > \varepsilon_t^{S_2}$

Update:

Probability estimate for current state: $P_{t+1}^{S_2} = P_t^{S_2} + \alpha(O_t - P_t^{S_2})$

$$R_{t+1} = P_{t+1}^{S_2}$$

$$P_{t+1}^{S_1} = P_t^{S_1}$$

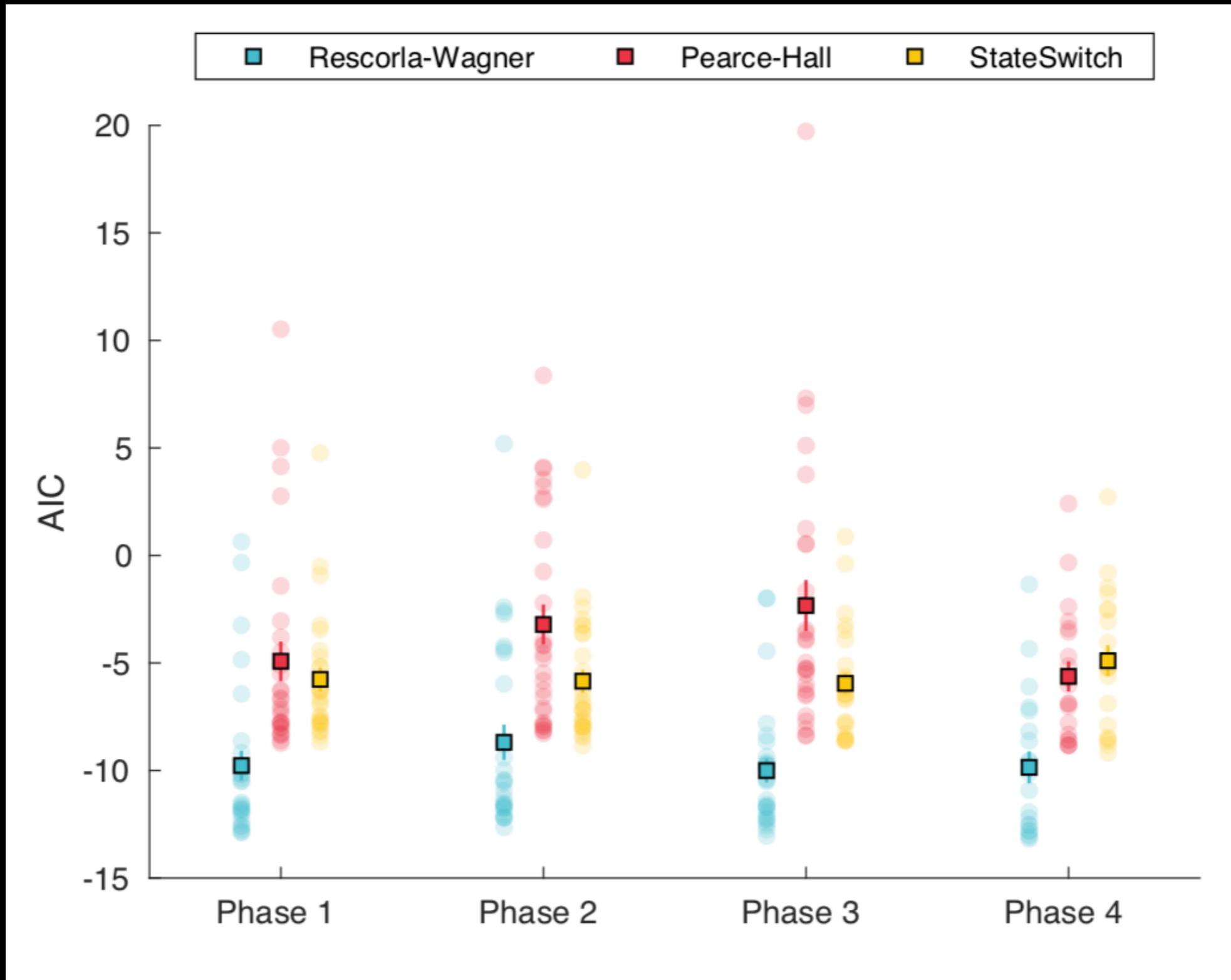
$$\mu_{t+1}^{S_2} = \sum_{n=t}^{i=1} P_{i...t}^{S_2}$$

Overall reported value:

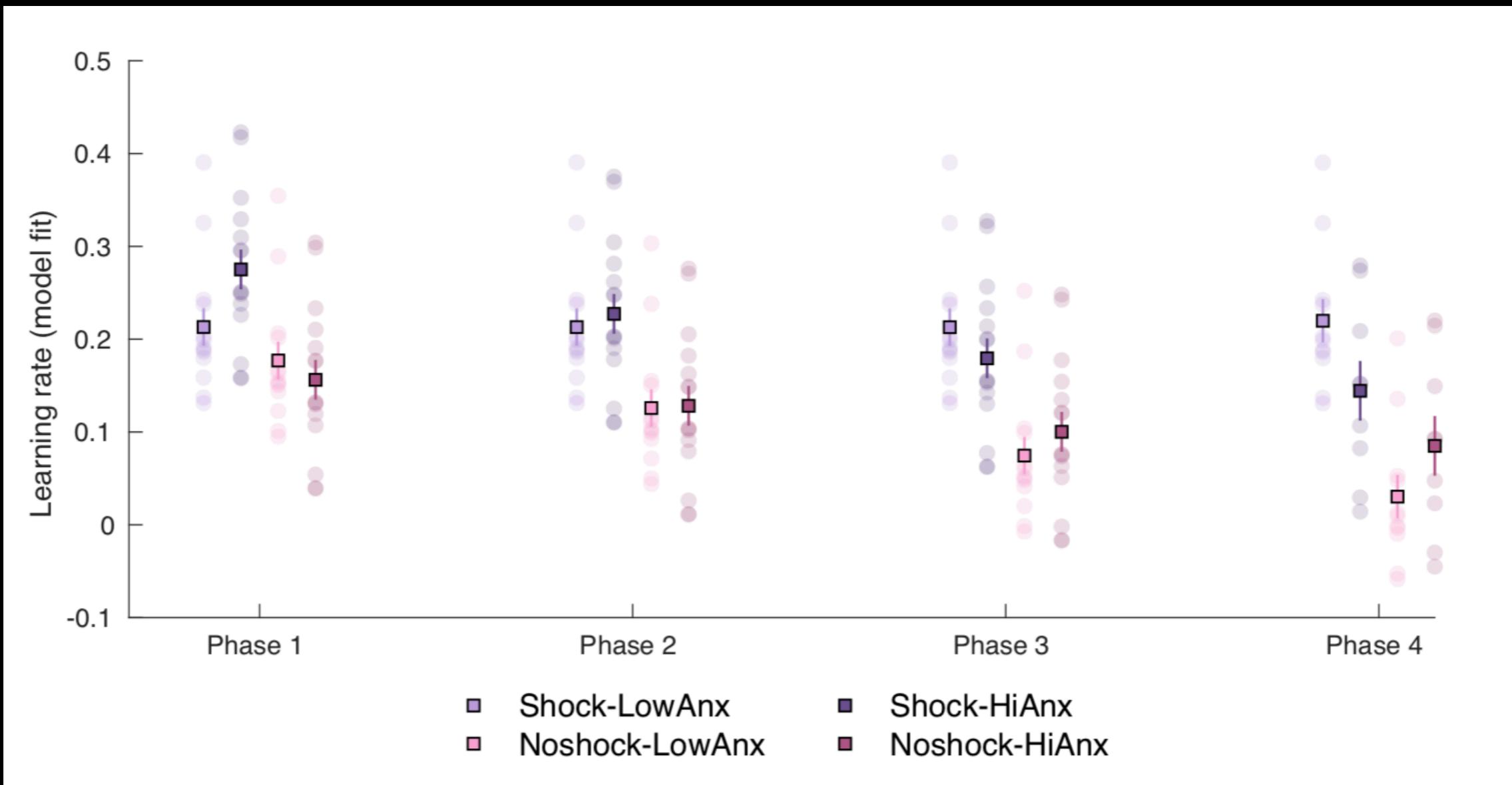
Keep probability estimate for not current state:

Value of the current state:

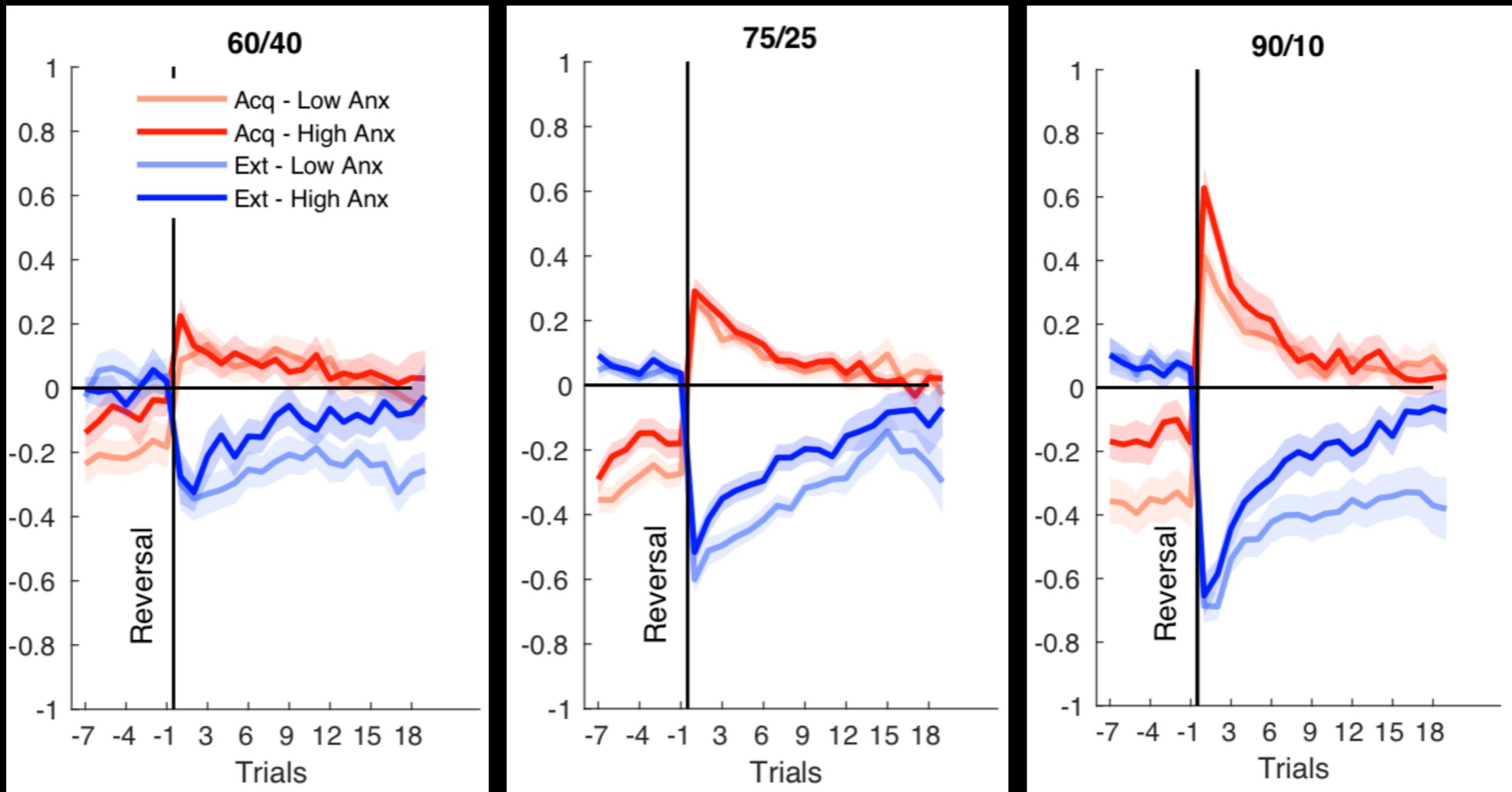
Model comparison



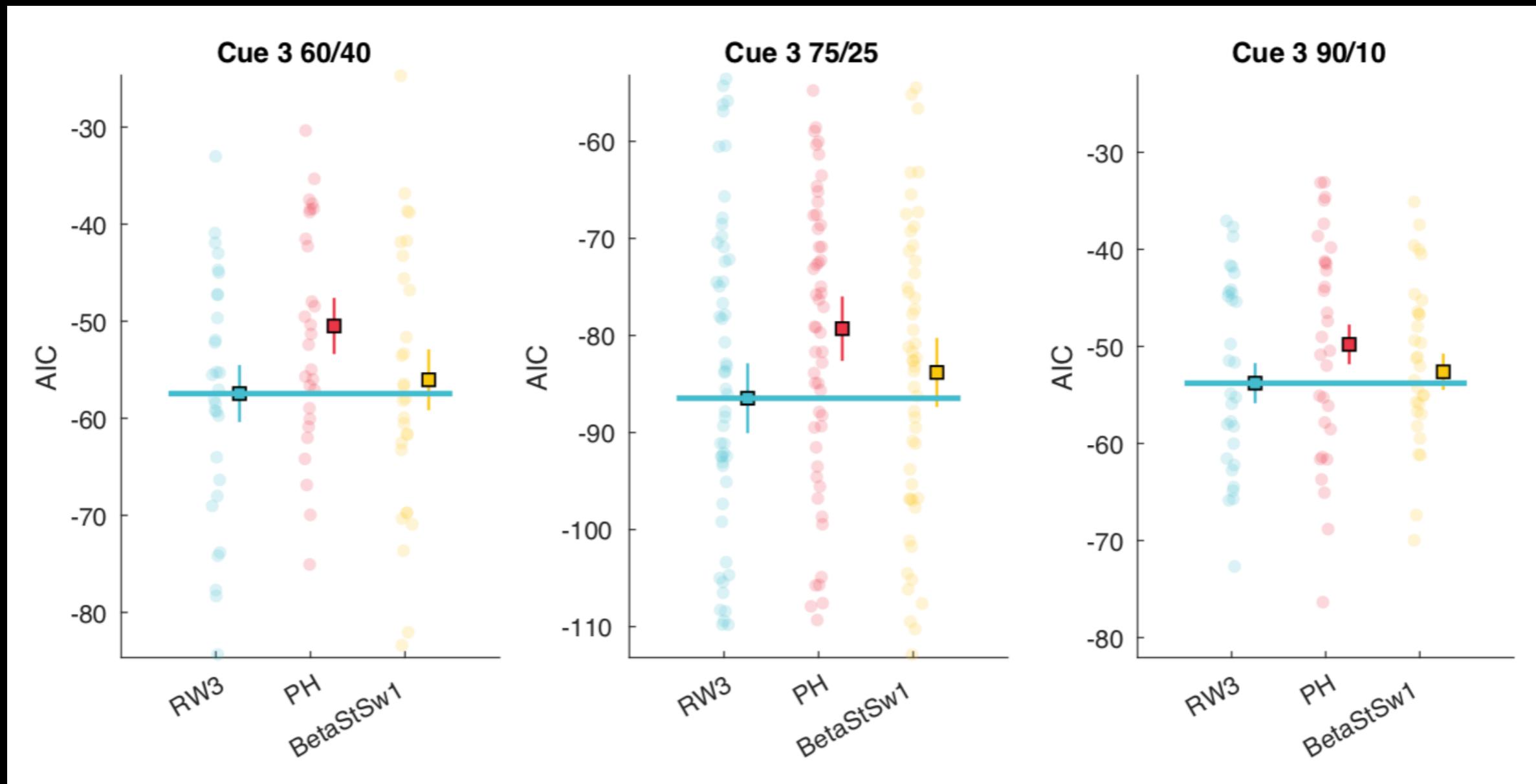
Anxiety-related differences in learning from shock and no shock



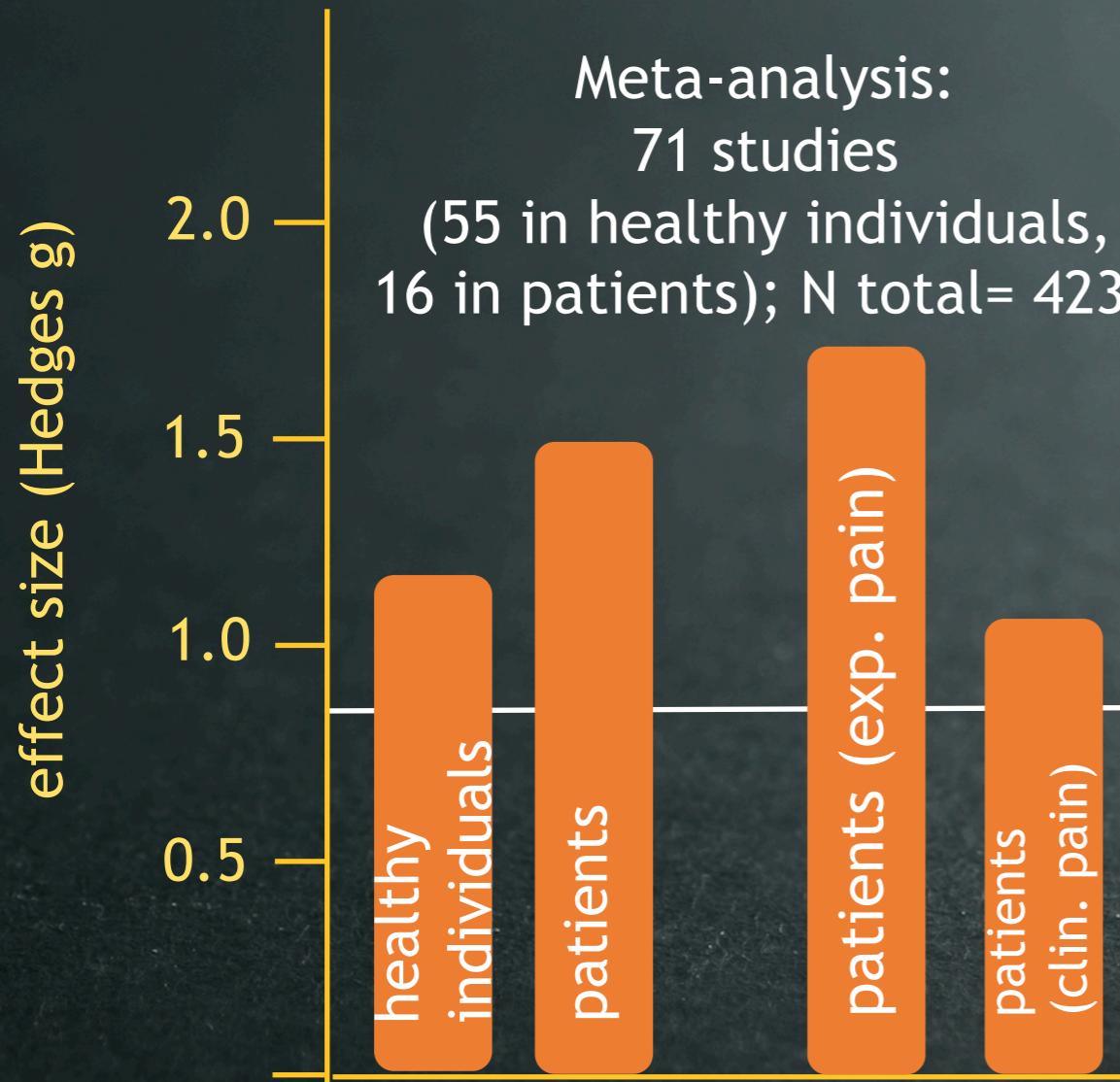
Does environmental statistics influence the learning strategy?



Model comparison



Placebo analgesia

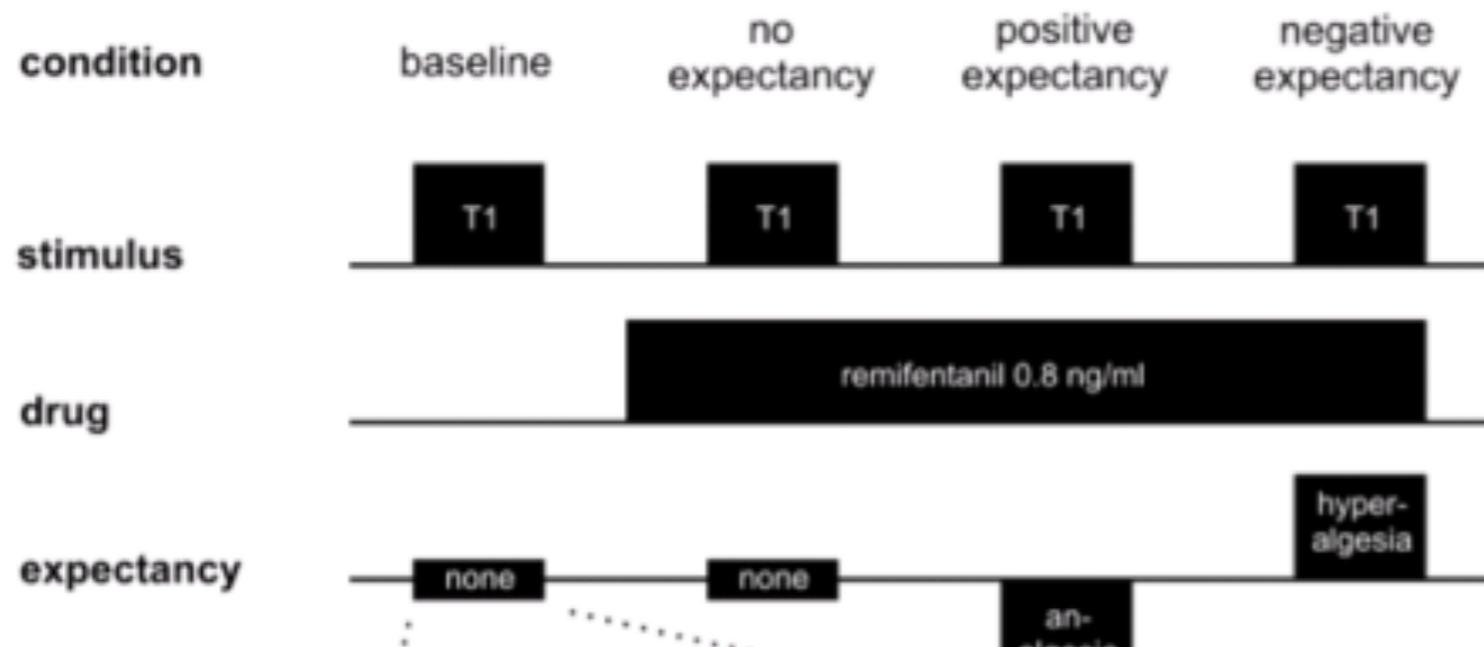


Forsberg et al., 2017

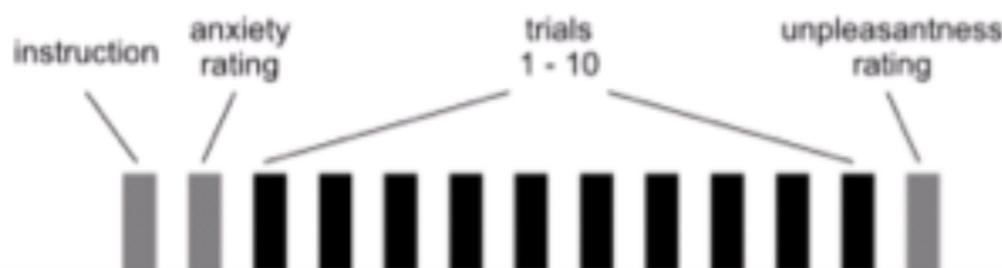


Effect of expectancy on opioid analgesia: design

A Experiment

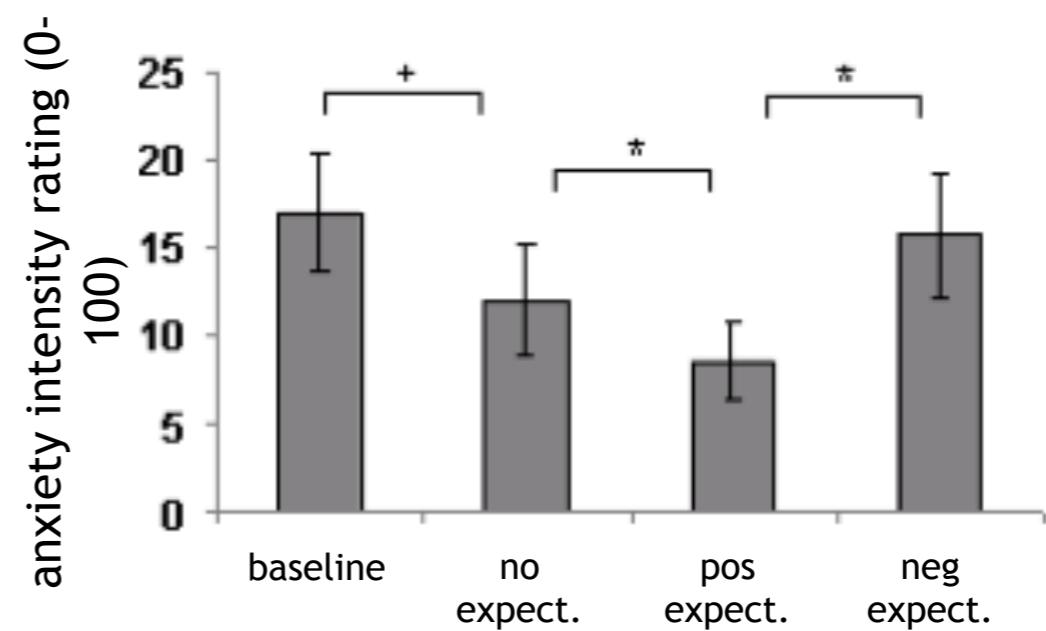
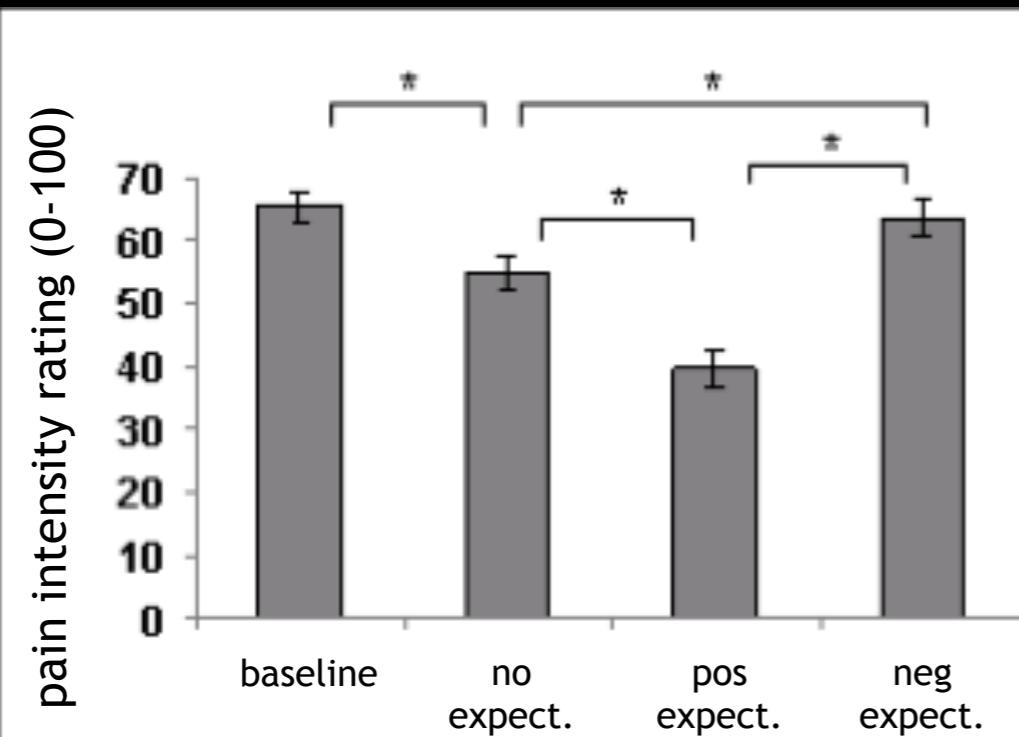


B Run



Bingel et al., 2011 in
Science Translational Medicine

Effect of expectancy on opioid analgesia: behavioral findings



Bingel et al., 2011 in
Science Translational Medicine

Key information about treatment:

- magnitude of expected effect
- likelihood of symptom improvement
- timing



Boundary effects of expectations



PAIN® 152 (2011) 1449–1450

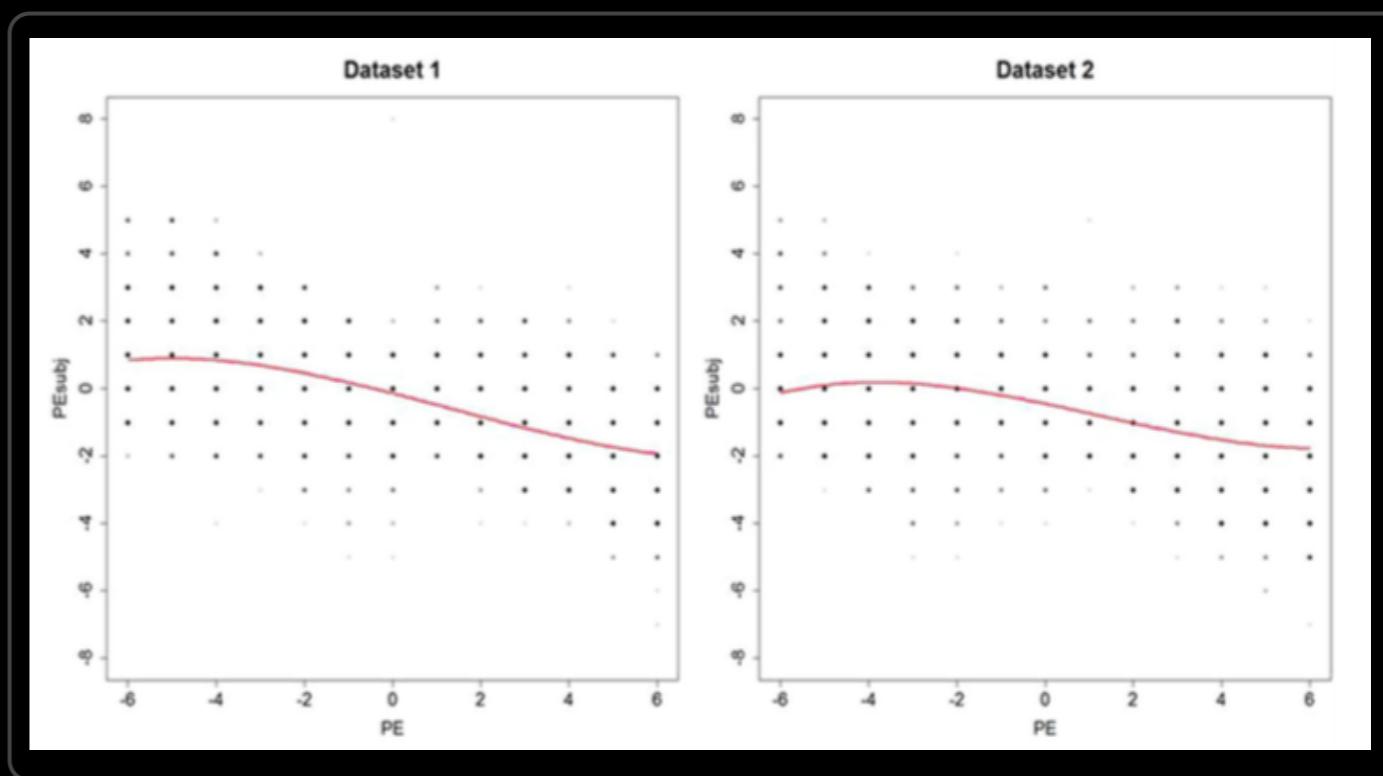
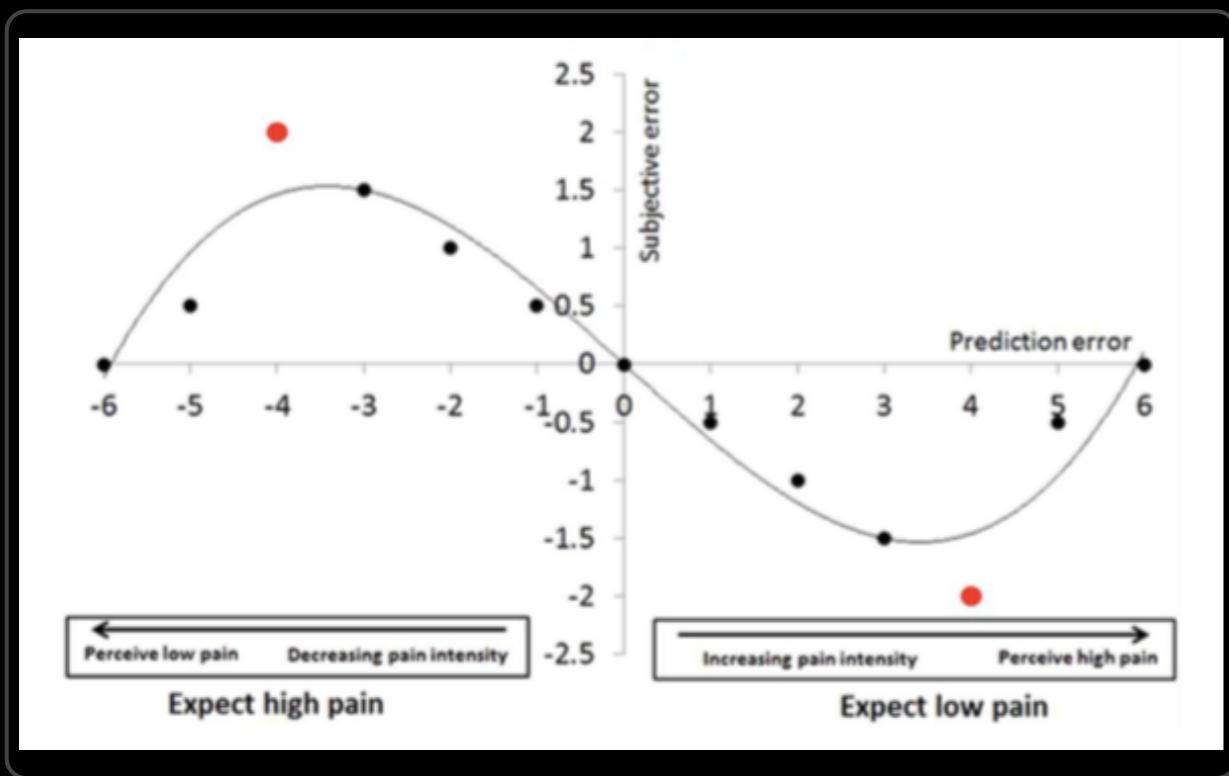
PAIN®

www.elsevier.com/locate/pain

Commentary

You may (not always) experience what you expect: In search for the limits of the placebo and nocebo effect

Crombez, Wiech 2011



Influence of cues on perceived pain decreases the more different the stimulus intensity is from the expected intensity

Hird et al., 2019

Summary

The concept of ‘perception as inference’ helps us understand how beliefs are woven into the perceptual process.

Beliefs are not static but can be updated.

We need to understand factors that trigger updating and factors that prevent updating in the individual.

Something to think about:

50% of patients leave office visits not understanding what the physician has told them.

Bodenheimer et al., 2008