Brain Dynamics, Reward, & Mocap

Howard Poizner and David Peterson

I. MC/BDL Developments

A. Science meets Art

B. VR System Development
   a. Multimodal VR
   b. Mocap-EEG-fMRI

II. Project 2.1.3 Update

(With Scott Makeig & Terry Sejnowski)

Multimodal VR & integration with fMRI

Virtual Reality

Panoramic HMD

EEG + fMRI

BRAIN VISION LLC
Solutions for neurophysiological research

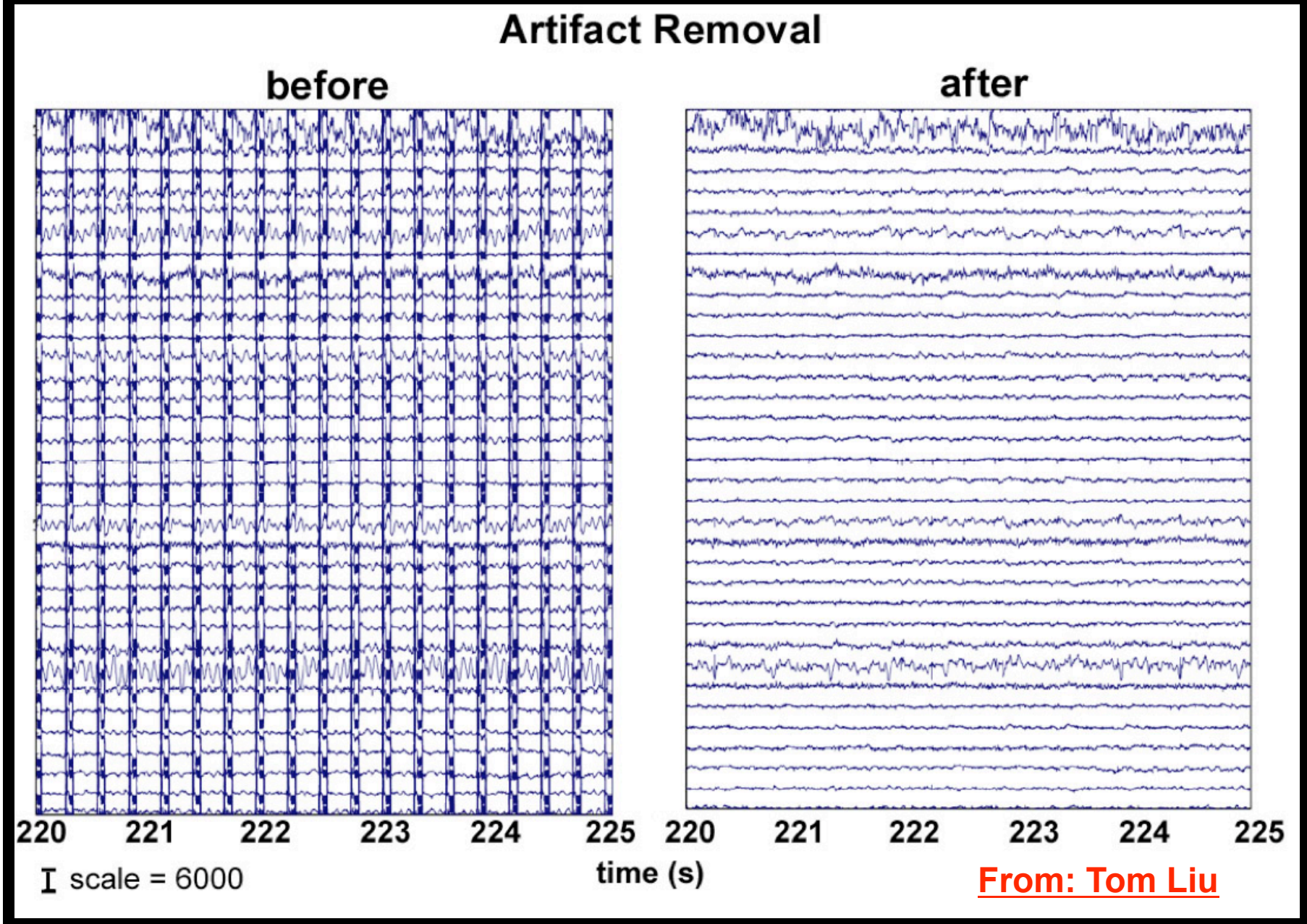
VR + Motion Capture +MRI

MRI HMD with Eye-tracker

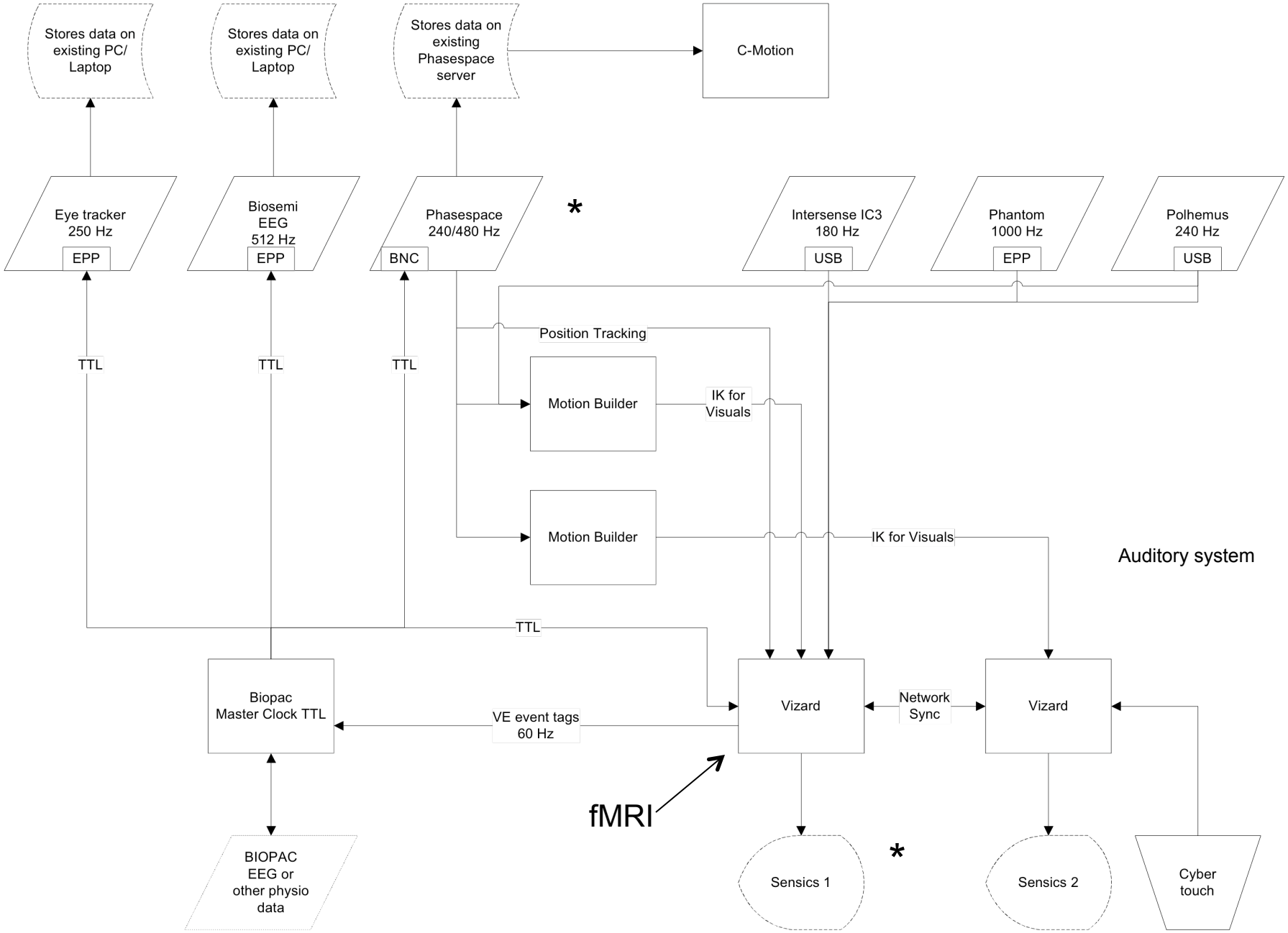
Haptic Robot

Eye Tracker

MRI Glove



EEG data from a simultaneous EEG-fMRI experiment before (left) and after (right) the application of artifact removal.


Stores data on existing PC/ Laptop
Stores data on existing PC/ Laptop
Stores data on existing Phasespace server
C-Motion
Eye tracker 250 Hz
EPP
Biosemi EEG 512 Hz
EPP
Phasespace 240/480 Hz
BNC
*
Intersense IC3 180 Hz
USB
Phantom 1000 Hz
EPP
Polhemus 240 Hz
USB
TTL
TTL
TTL
Position Tracking
Motion Builder
IK for Visuals
Motion Builder
IK for Visuals
Auditory system
TTL
Biopac Master Clock TTL
VE event tags 60 Hz
Vizard
Network Sync
Vizard
fMRI
BIOPAC EEG or other physio data
Sensics 1
*
Sensics 2
Cyber touch

Brain Dynamics, Dopamine, & Reward-Based Learning [Project 2.1.3]

- Simultaneous recording of EEG and Movement

- Reward-based learning & Computation Modeling in normals and ***dopamine depleted*** patients

- **Simultaneous recording of EEG and Movement during reward-based learning in normals**

- Simultaneous recording of EEG and Movement during reward-based learning in dopamine depleted patients

Time Scales, Dopamine, & Behavior

Wolfram Schultz, *Annual Review of Neuroscience*, 2007, p.259

"Dopamine is involved in mediating the reactivity of the organism to the environment at ***Different Time Scales***, from fast impulses related to reward, via slower changes with uncertainty, punishment, and possibly movement, to the tonic enabling of postsynaptic motor, cognitive, and motivational systems deficient in Parkinson's disease."

DA Time Scales

1. Reward predicting response (graded; **latency = 60-100ms**

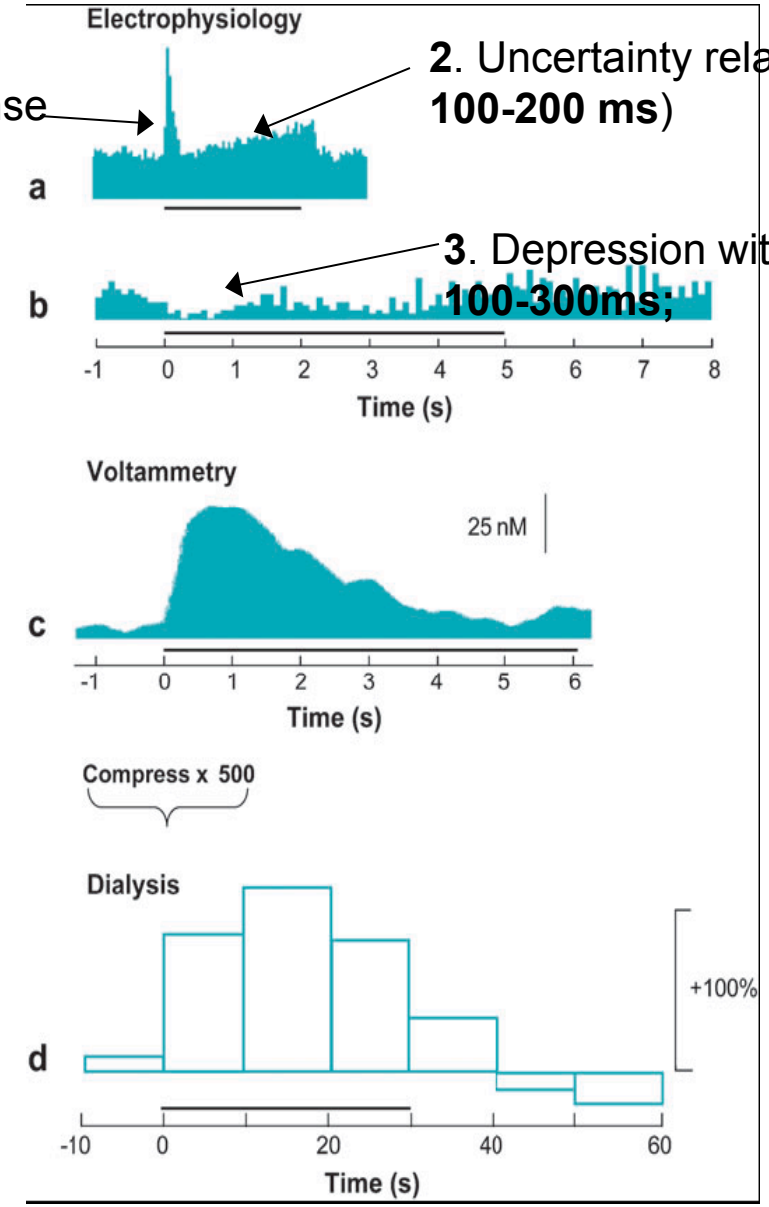
Duration <200 ms)

2. Uncertainty related response (**latency = 100-200 ms**)

Duration < 2 seconds

3. Depression with pain (**latency = 100-300ms;**

Duration = seconds



Modified from **Schultz (2007)** *Ann Rev Neurosci*

4. Tonic enabling function

e) Tonic enabling of post synaptic receptors – very slow; *Minutes*

*

5. Decision function

f) History of DA cell responses encodes decisions for future action; Minutes to hours

Brain Dynamics in Rewarded Learning

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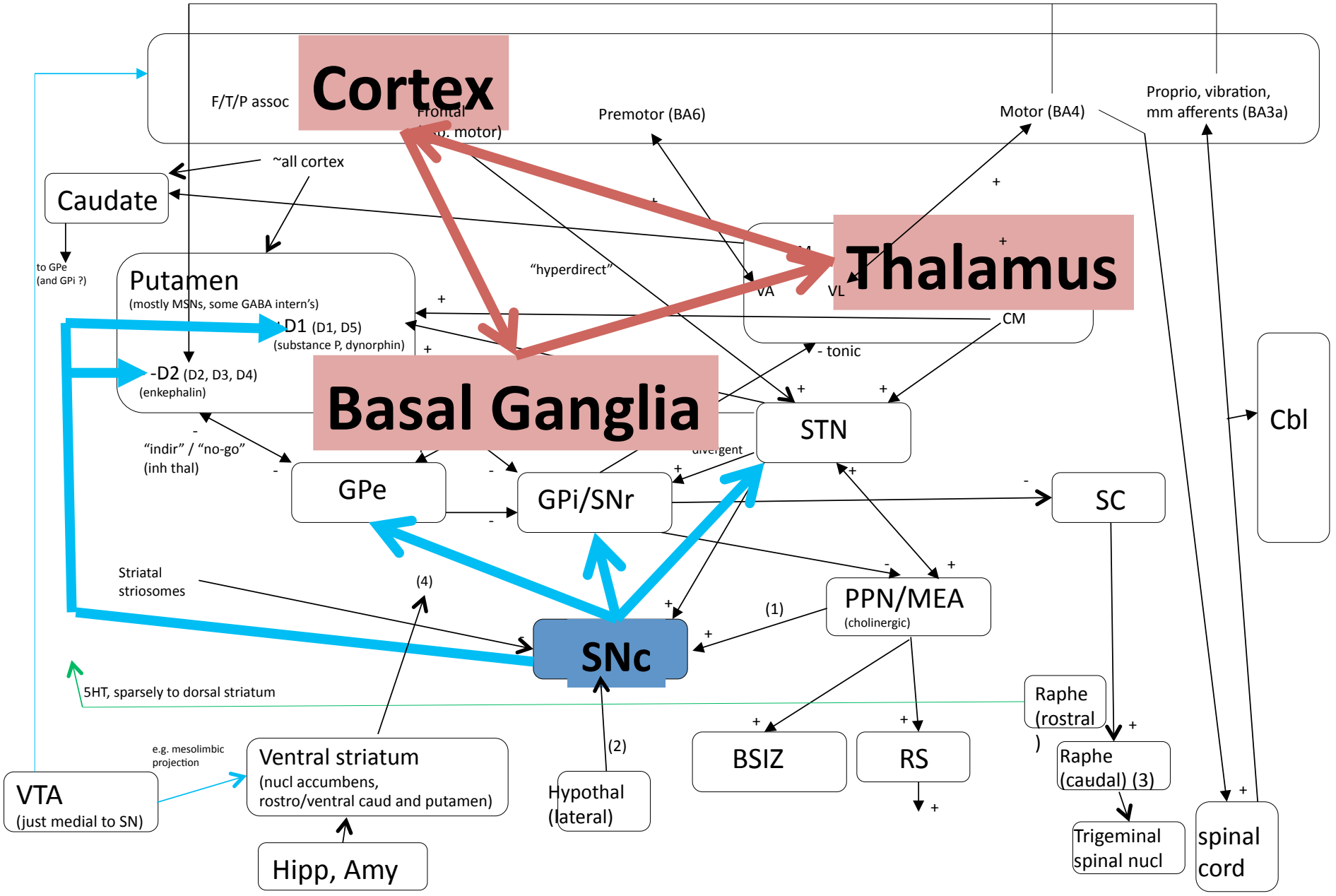
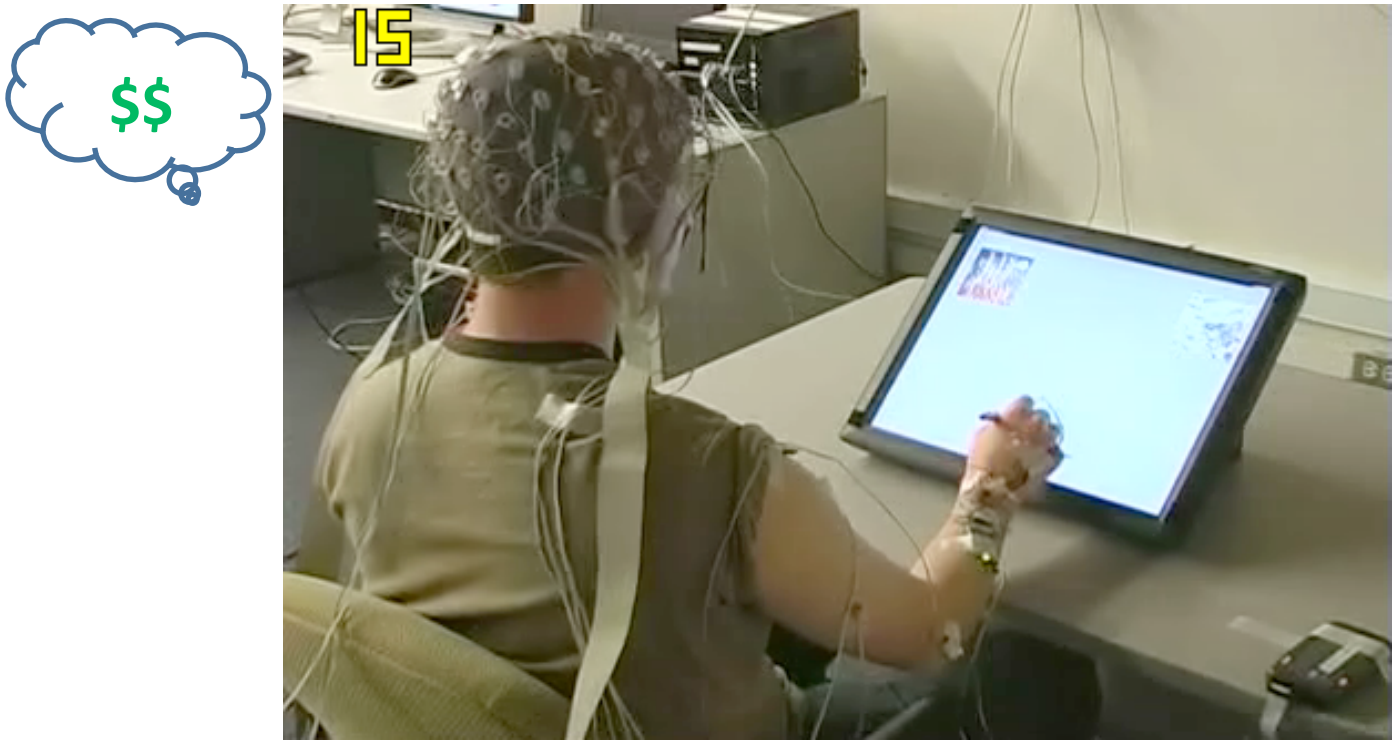
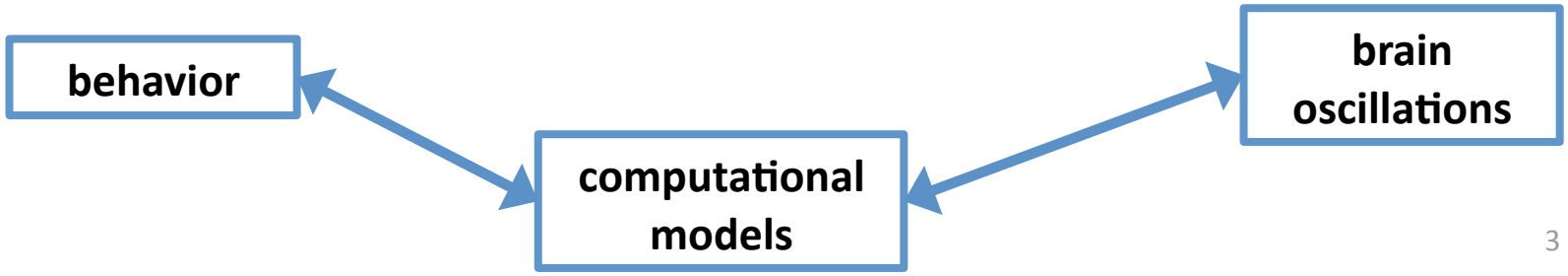
Basal ganglia mediate cortical oscillations

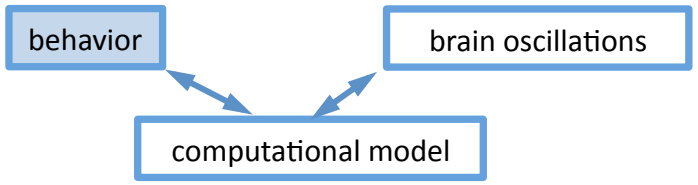


Experimental Paradigm

What aspects of **ensemble dynamics** important for rewarded learning?



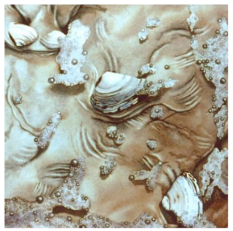


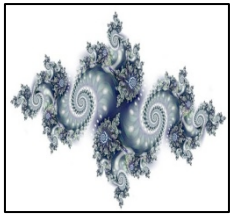


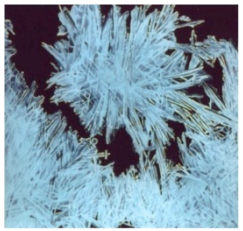
Images and rewards

2 phases,
256 trials each

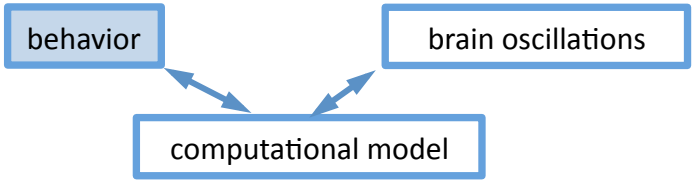
Image



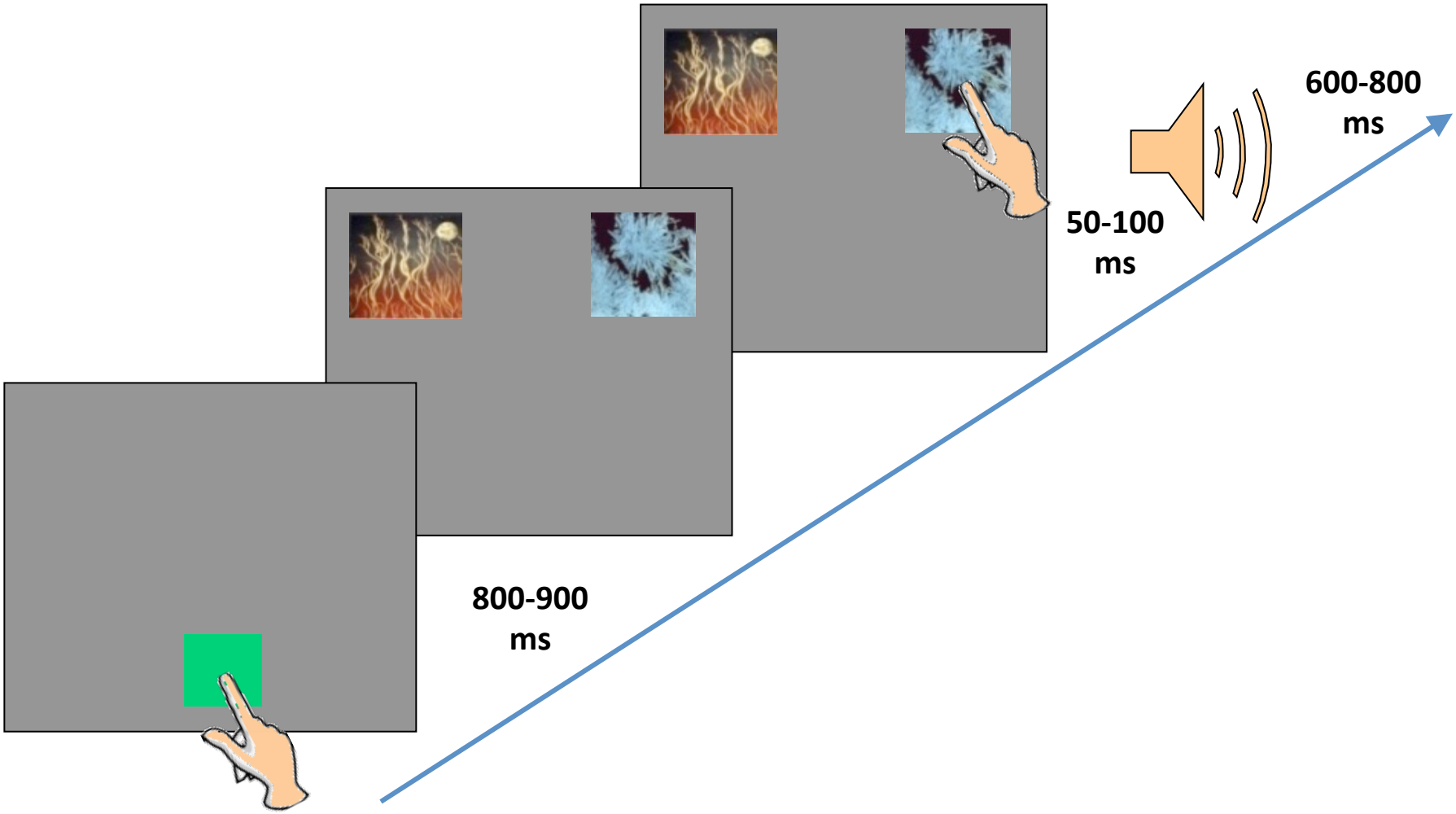


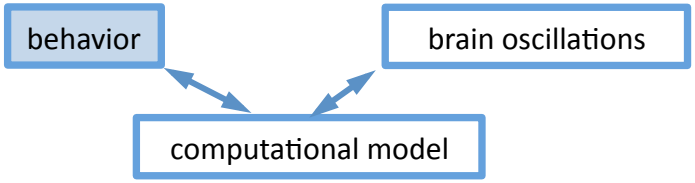


j	Probability (reward) Initial Phase	Reversal Phase
1	0.25	1.00
2	0.50	0.75
3	0.75	0.50
4	1.00	0.25

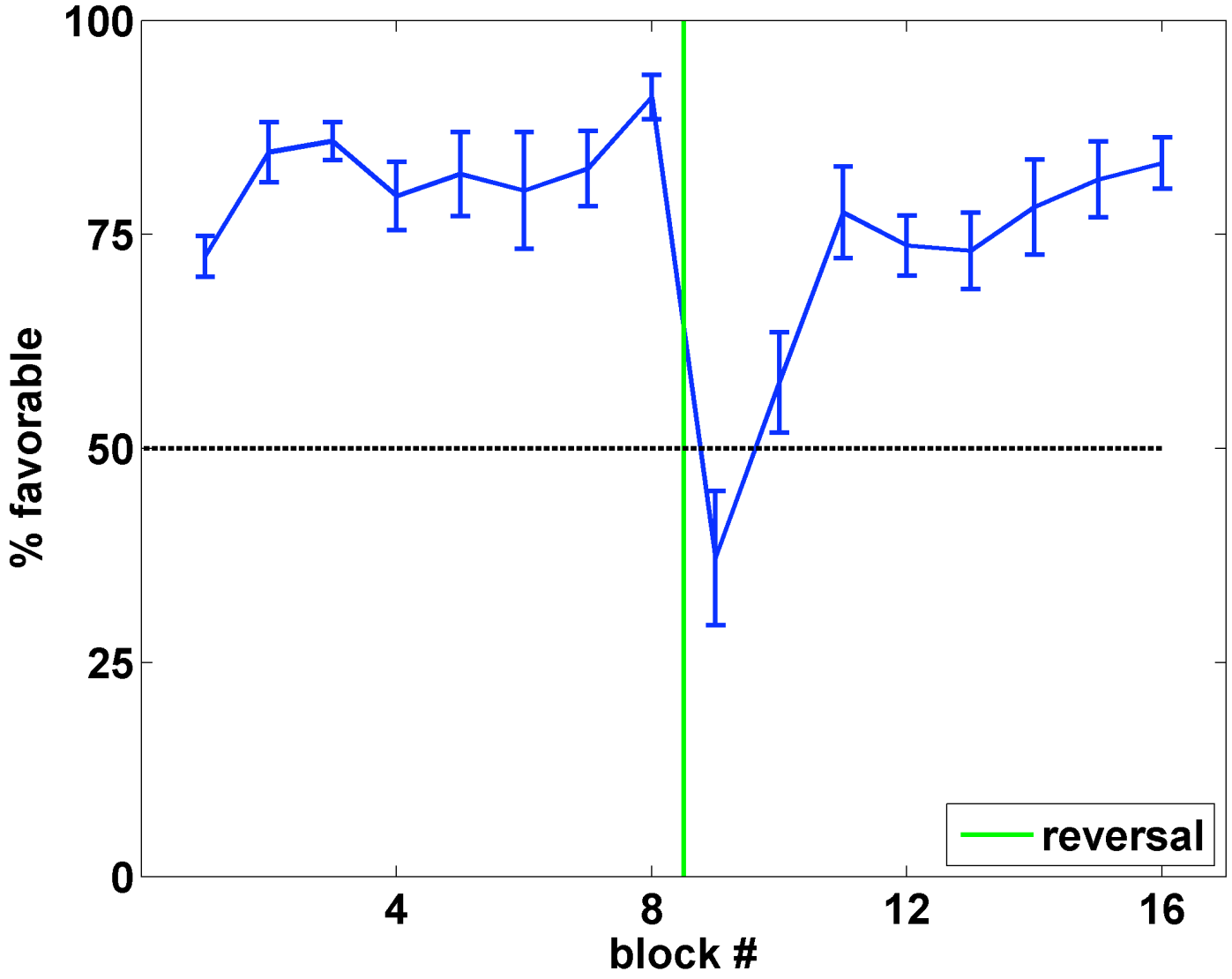

behavior
brain oscillations
computational model

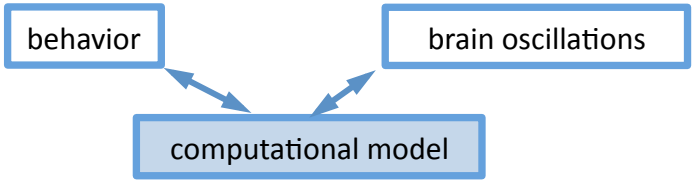
2-AFC trial


50-100
ms
600-800
ms
800-900
ms



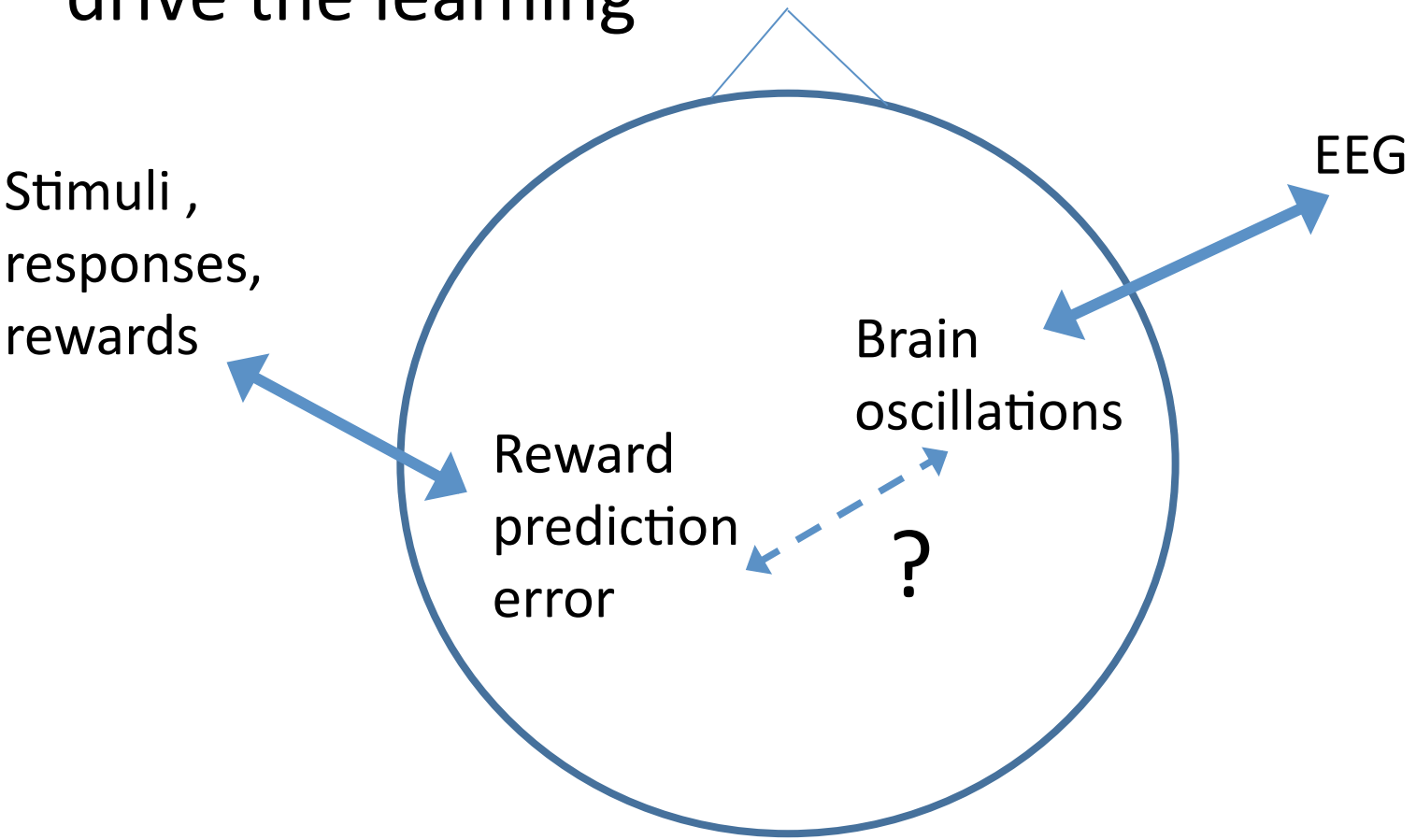
Learning curve (N = 13)

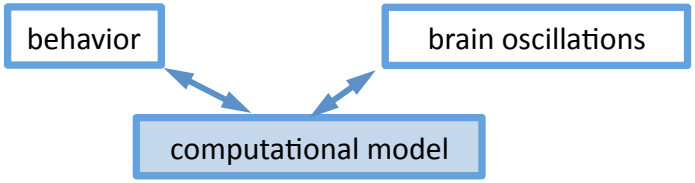




Why model the behavior?

- Infer internal, unobservable "processes" that drive the learning





RL model

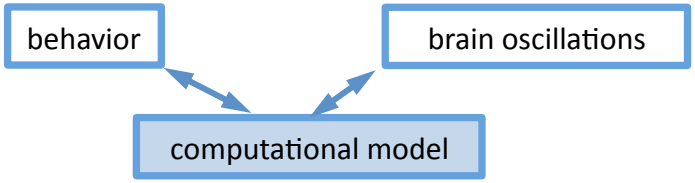
Learning from reward prediction error (**PE**):

$$Q_j(t+1) = \begin{cases} Q_j(t) + \varepsilon\overbrace{\left[r(t) - Q_j(t)\right]} & j\ chosen \\ Q_j(t) & o.w. \end{cases}$$

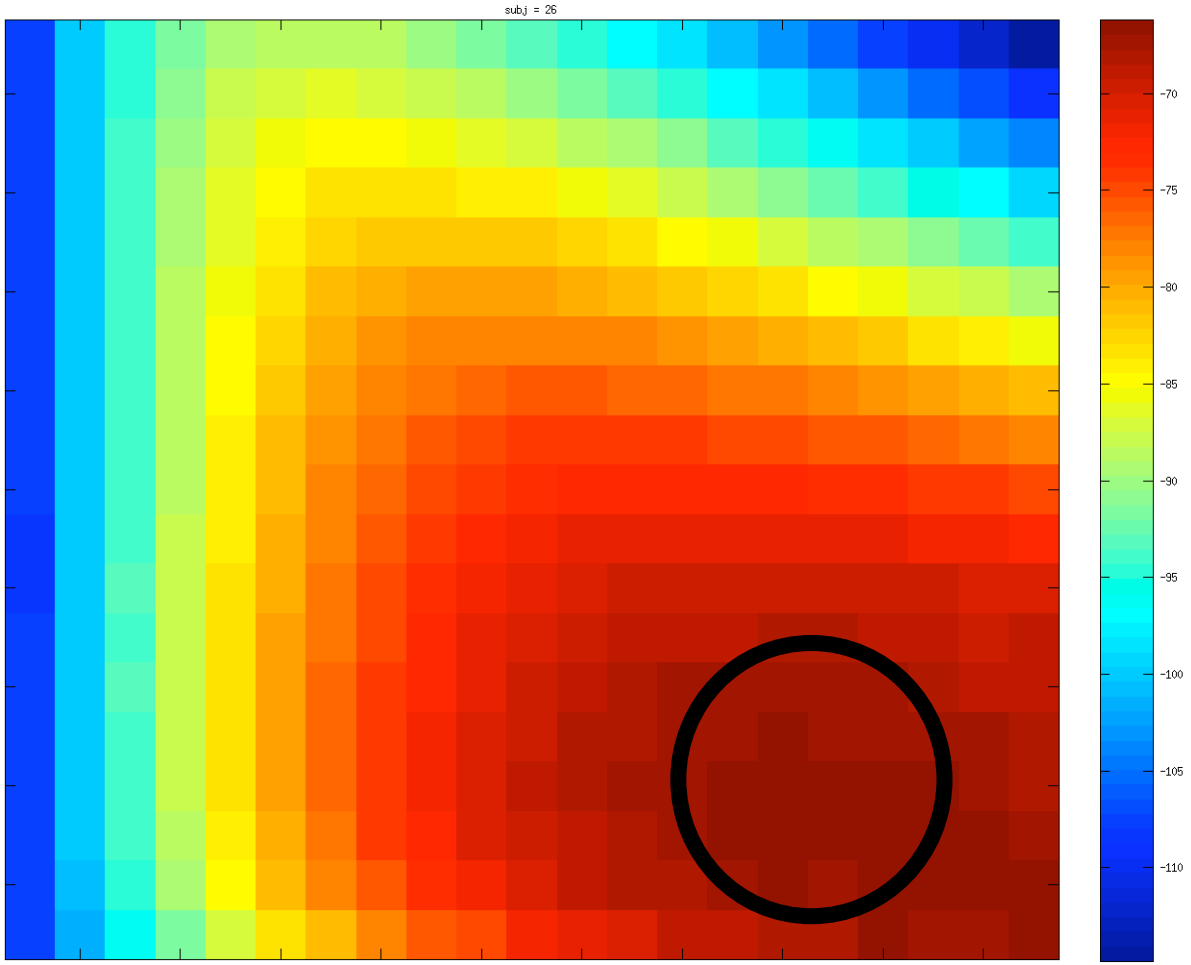
Action selection: Probability of choosing image *k* from {*k*,*m*}:

$$p_k(t) = \frac{1}{1 + e^{-\tau(Q_k(t) - Q_m(t))}}$$

Exploration vs. exploitation



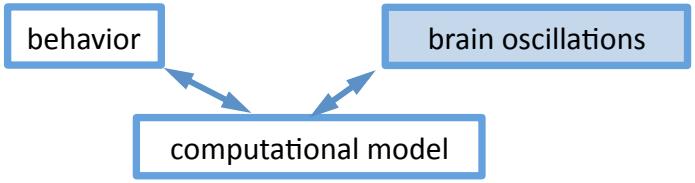
Best model fit: varies by subject



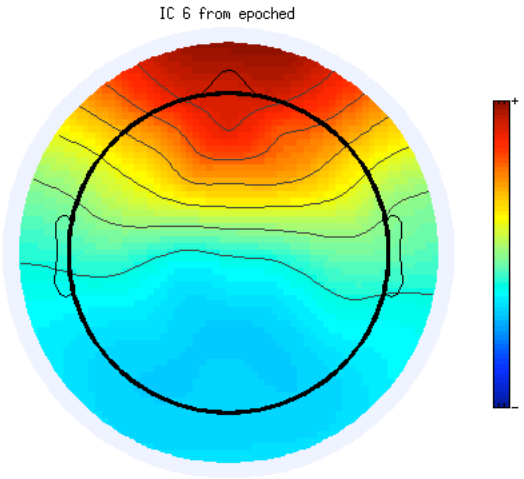
ε

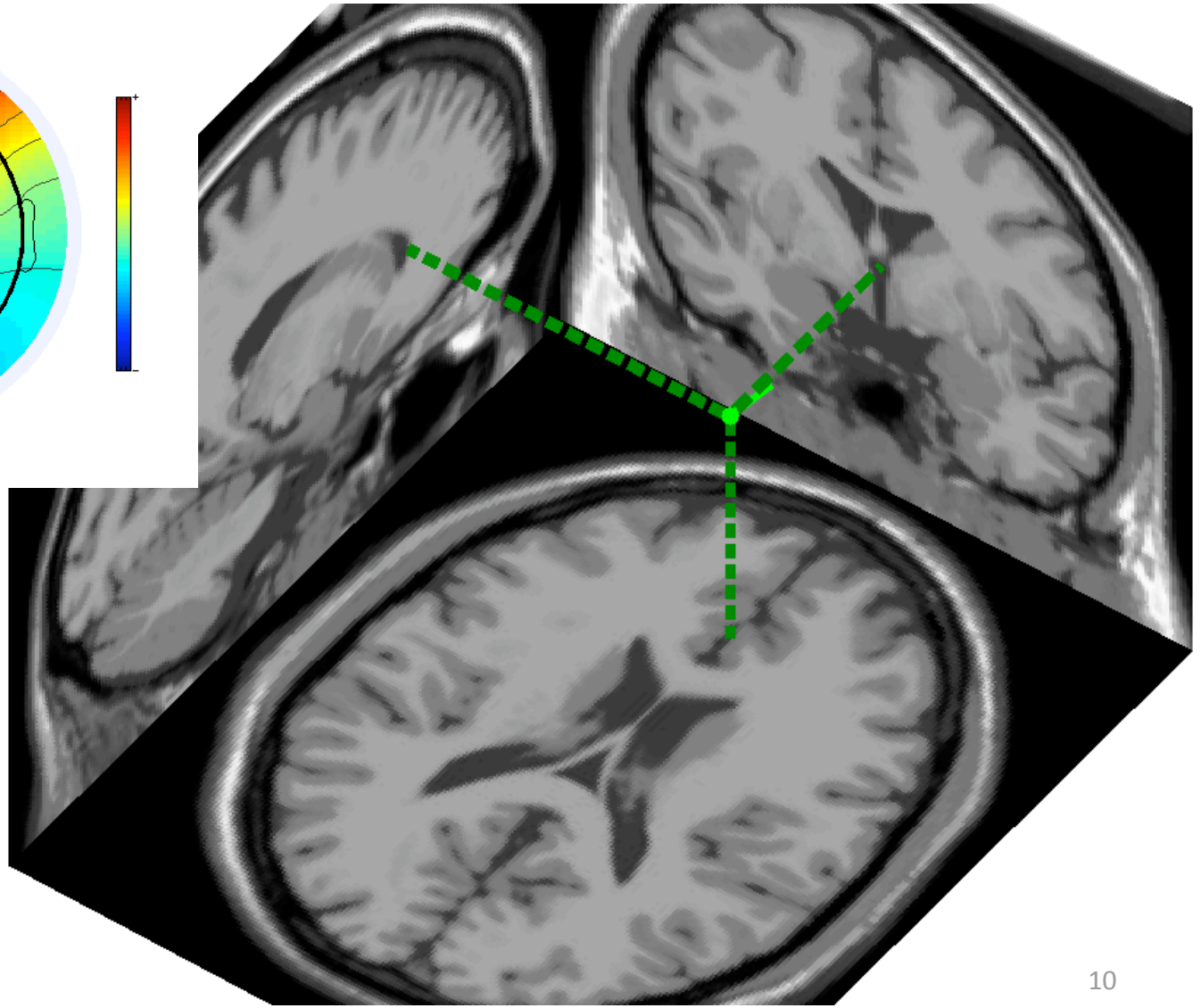
τ

fit

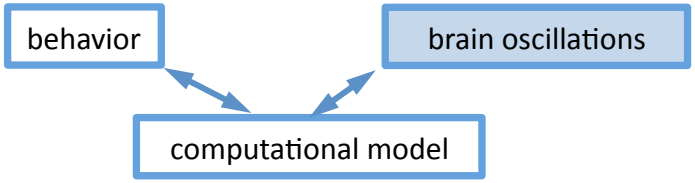


ICA → e.g. dipole in vmPFC

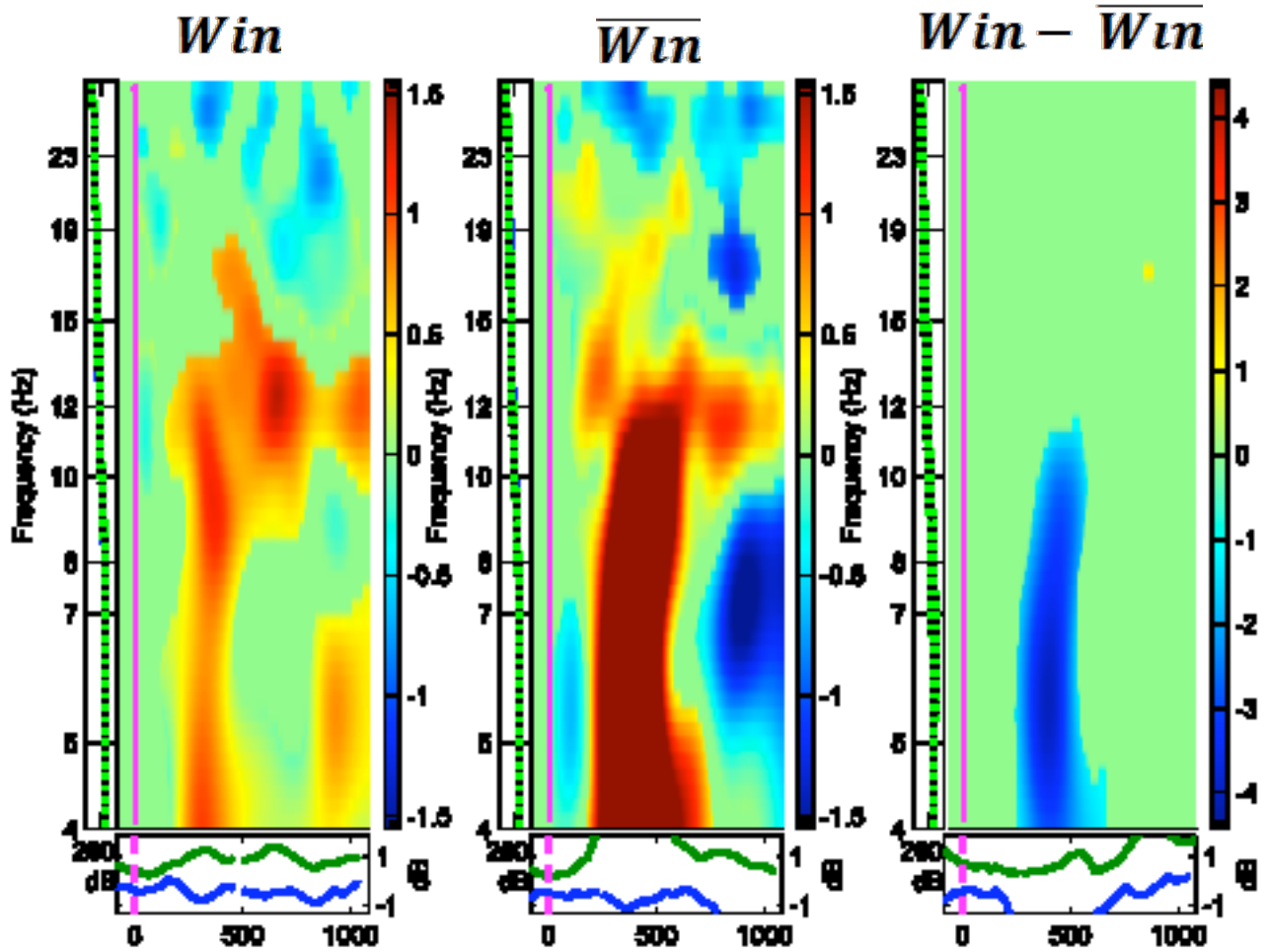


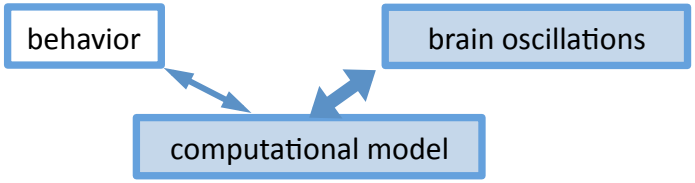


becy21, IC6



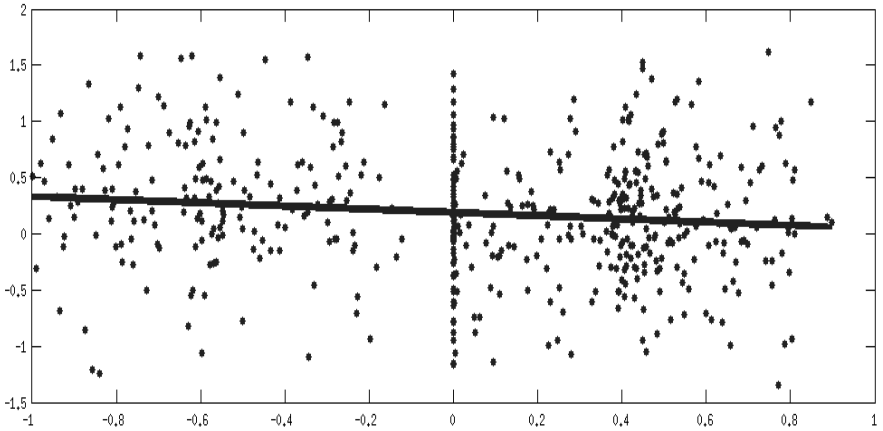
Spectral dynamics & PE sign



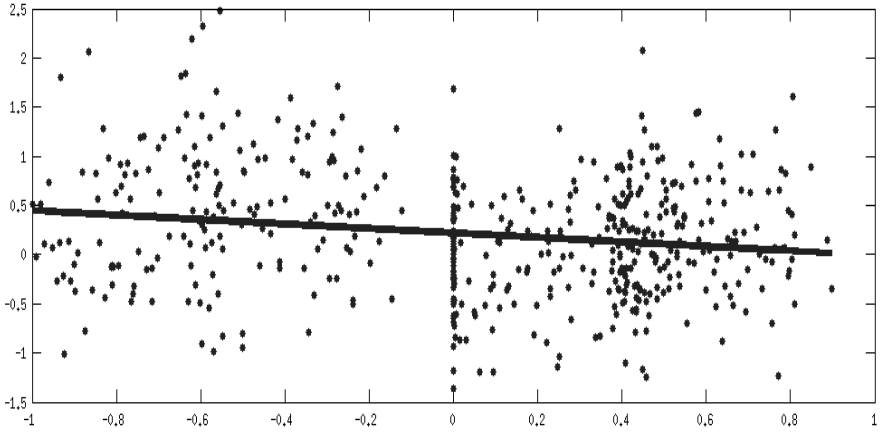


Spectral dynamics correlated with PE

alpha…
slope = -0.14
R^2 = 0.016
p = 0.004

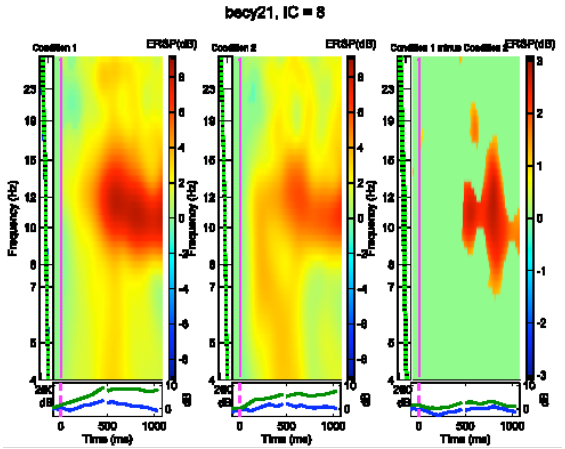


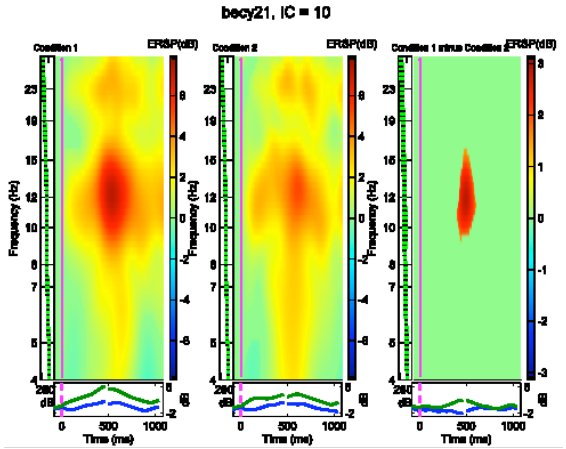
theta…
slope = -0.23
R^2 = 0.031
p = 0.00006

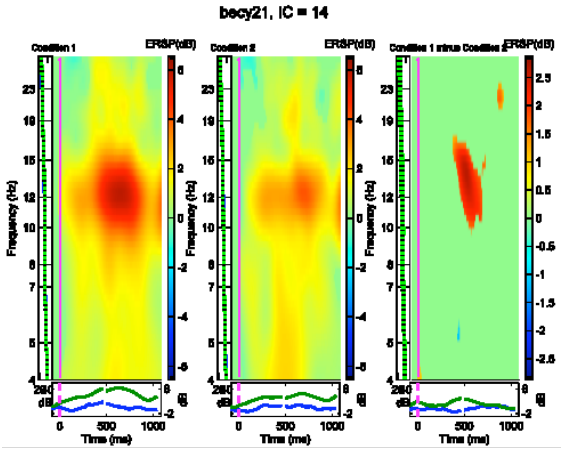


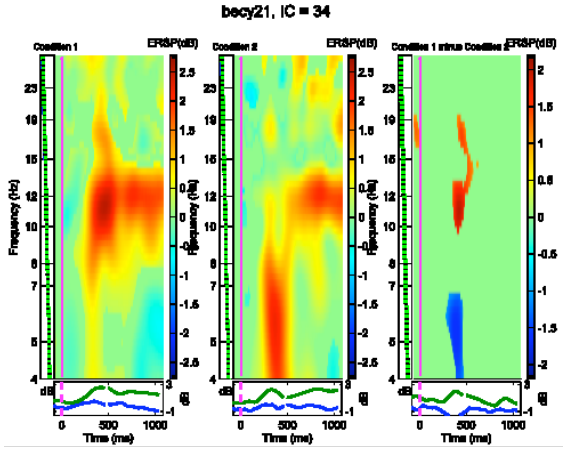
Prediction Error

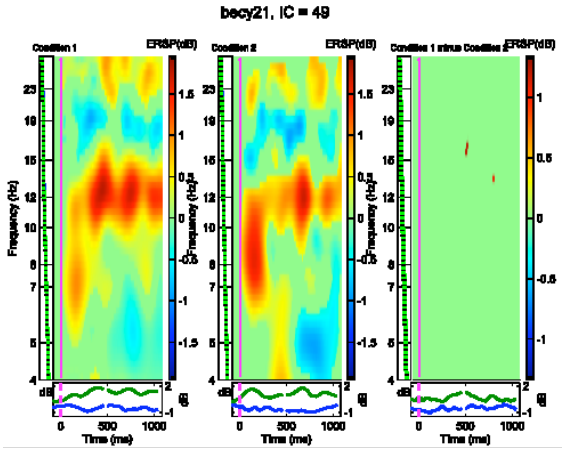
What about PPC?











Summary

- Rewarded learning is associated with intra-trial temporal dynamics in macroscopic brain oscillations.
  - putatively driven by PE
  - frontal sources: relative desync in theta and alpha

- Next steps:
  - Spatial selectivity ? (e.g. parietal sources)
  - what is the influence of electrophysiological neuromodulation (e.g. deep brain stimulation) ?

Contributors:

UCSD

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MIL: Eric Halgren

Salk: Terry Sejnowski, Jason McInerny

Our Participants !