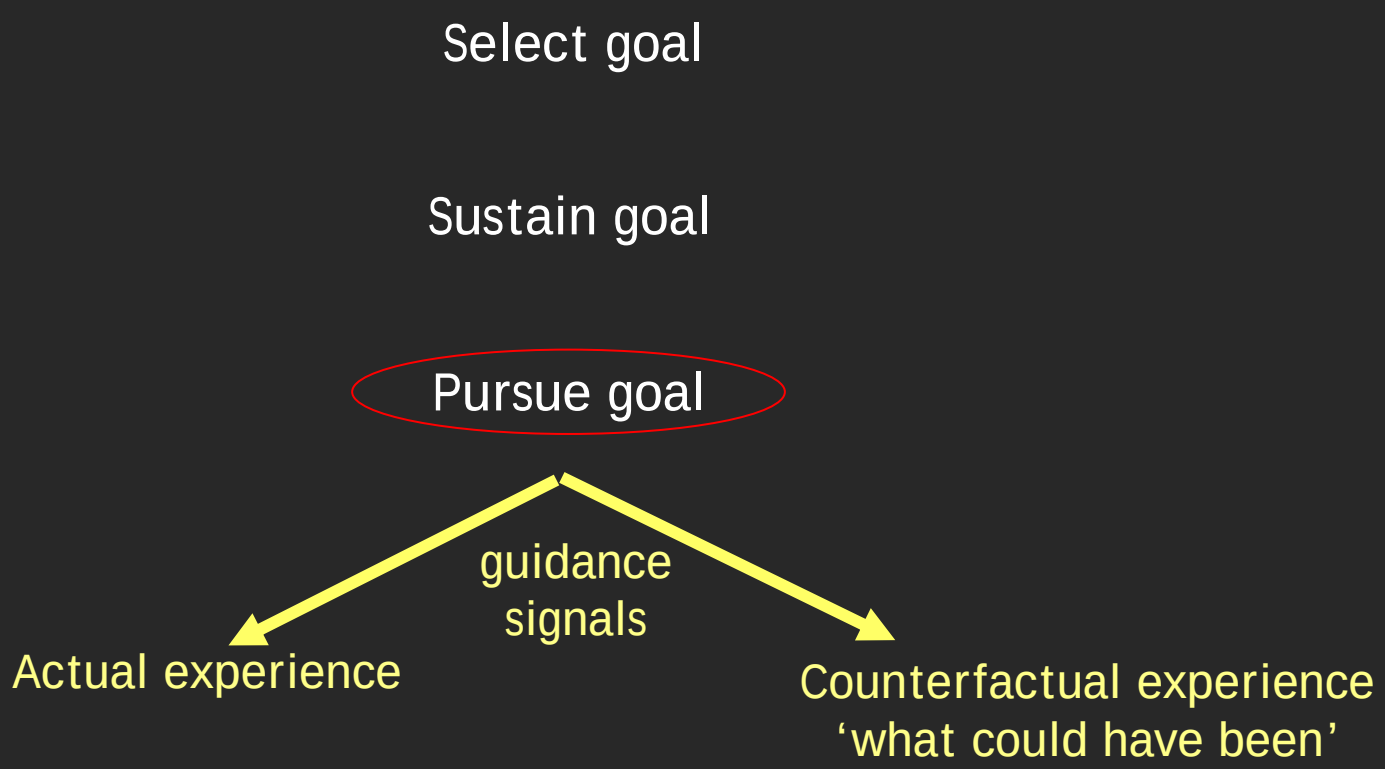
Imaging control signals that govern choice

Ann H. Harvey
Department of Neuroscience
Computational Psychiatry Unit
Baylor College of Medicine
Houston, TX

www.hnl.bcm.tmc.edu

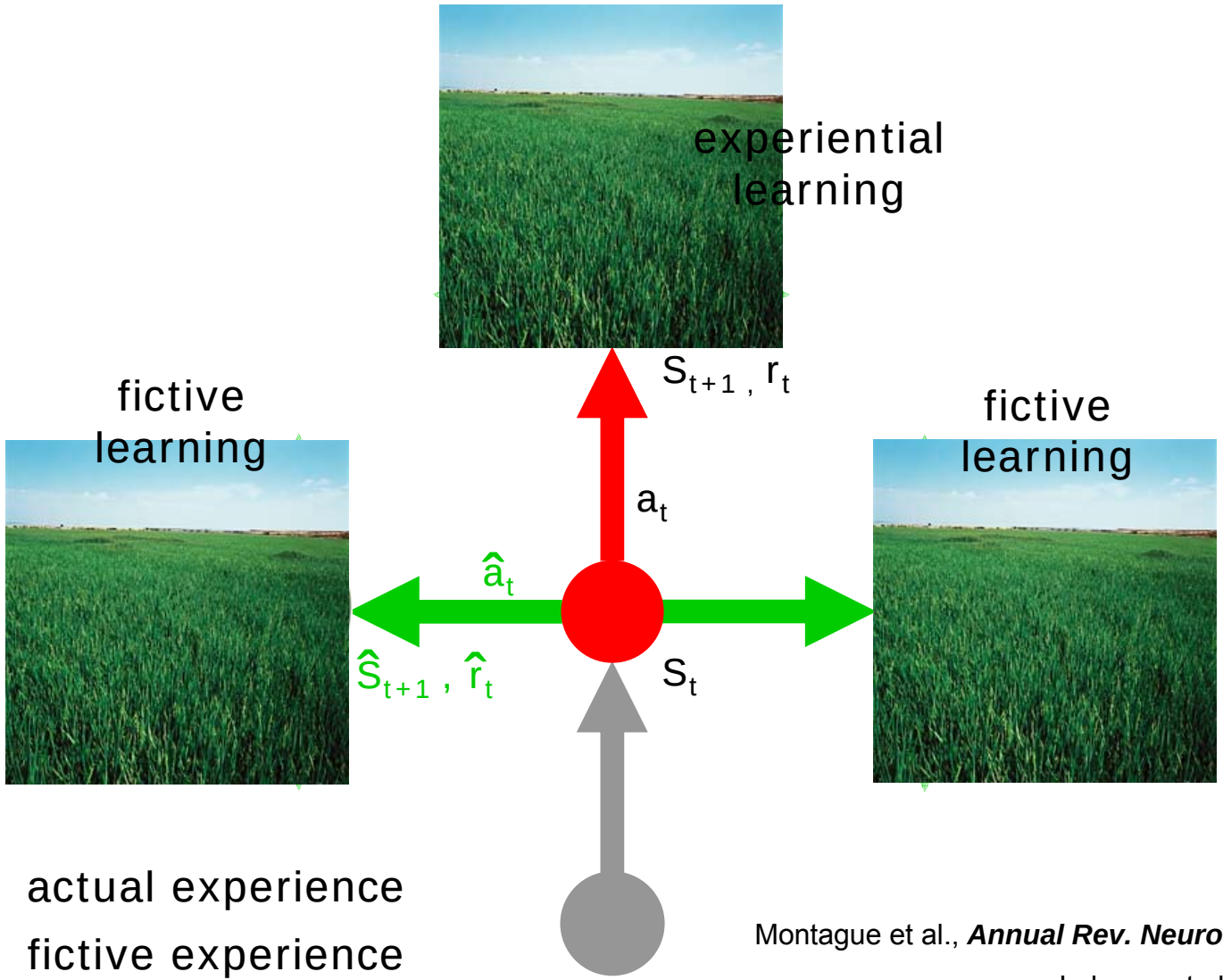
Goal-directed choice



Why is dopamine system so important?

1. Motivated learning, attention, reward processing
2. Disease – Parkinson's, drug addiction, ADHD, …
3. Valuation and decision-making

Multiple learning signals guide behavior



Montague et al., ***Annual Rev. Neuroscience***, 2006

Lohrenz et al., ***PNAS***, 2007

The measurable influence of ‘what could have been’

Can we visualize fictive reward error responses in human brains?

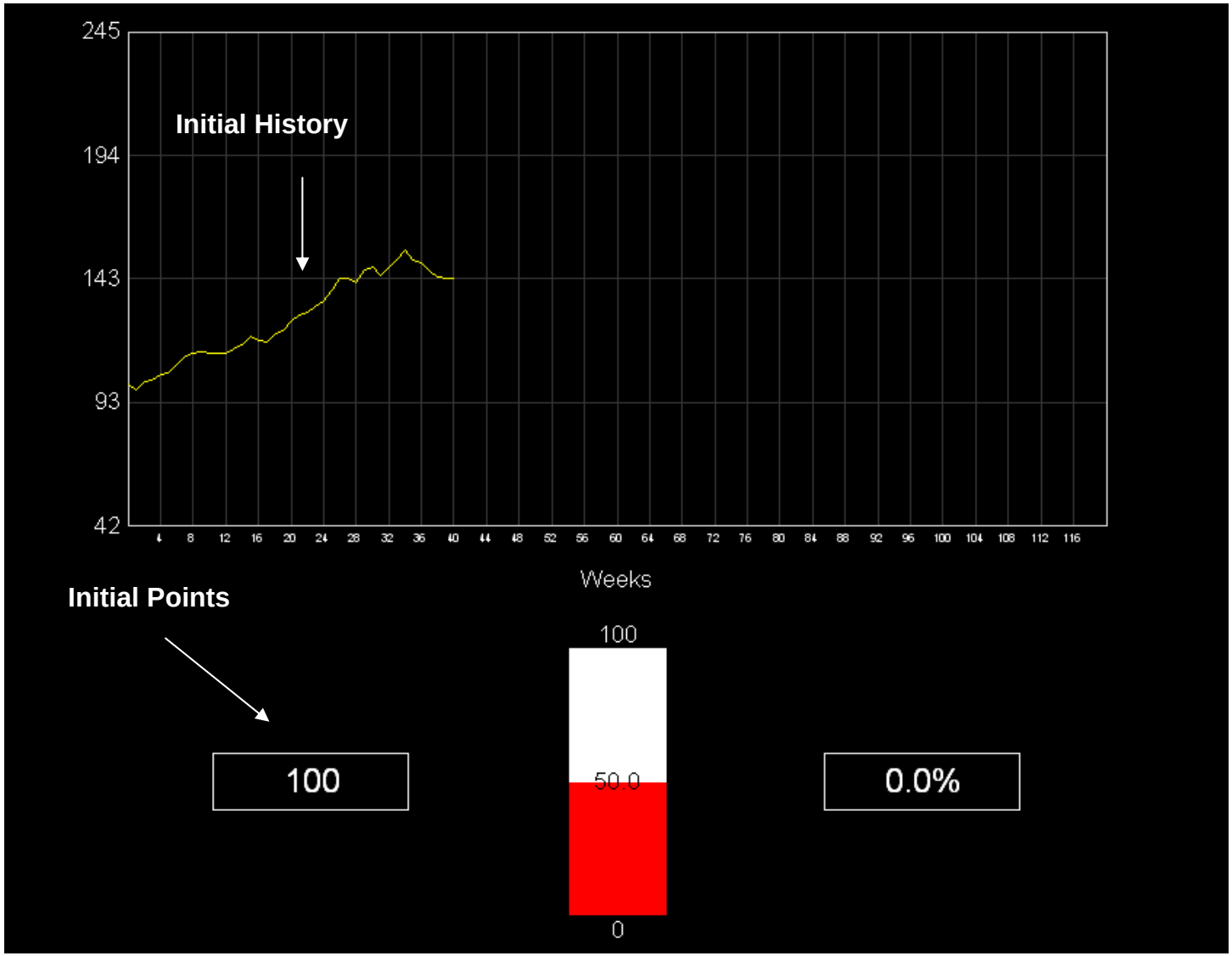
Using economic games to probe decision-making

Ecologically relevant decision-making

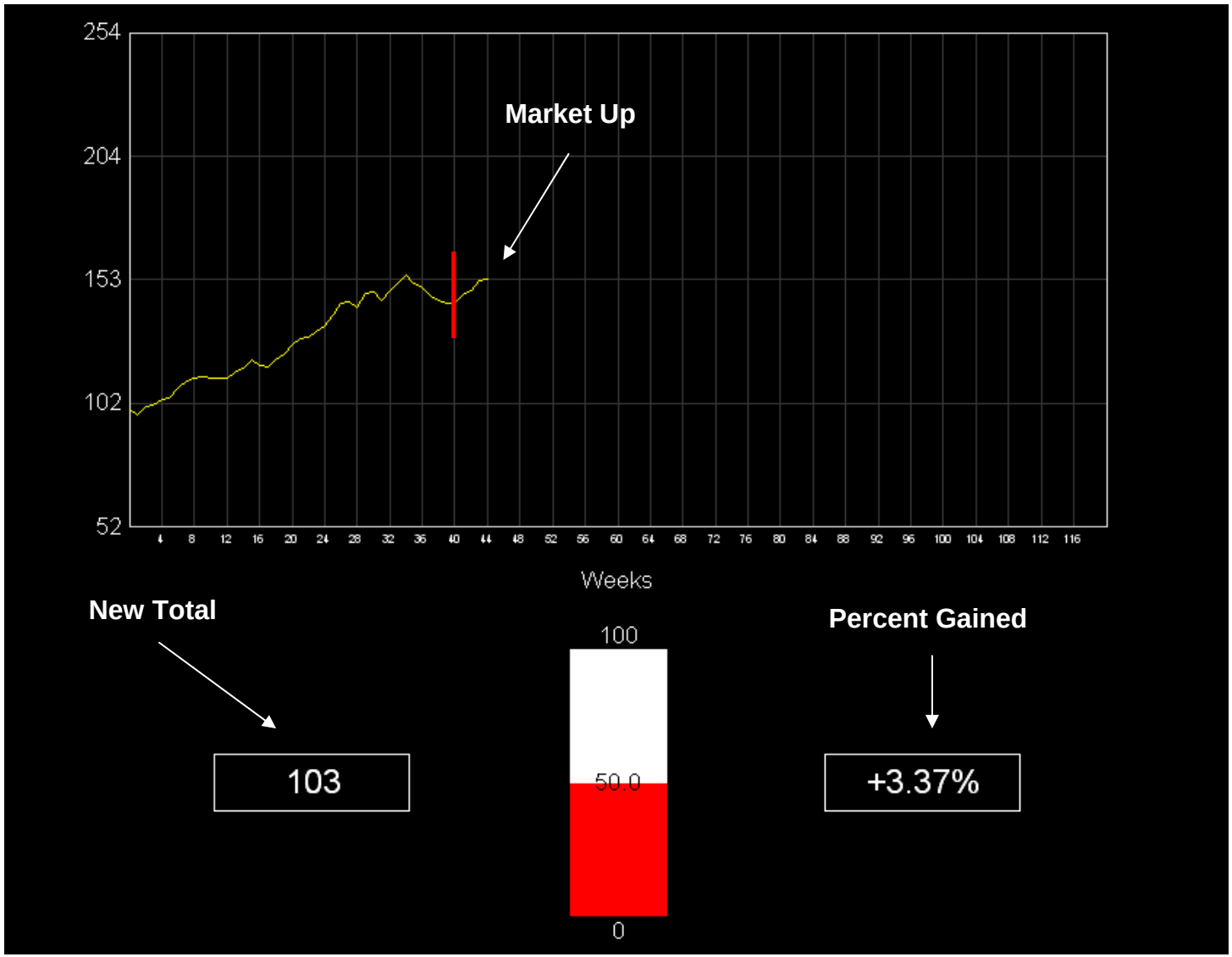
Well-defined notions of optimality

Ability to extract quantitative signals

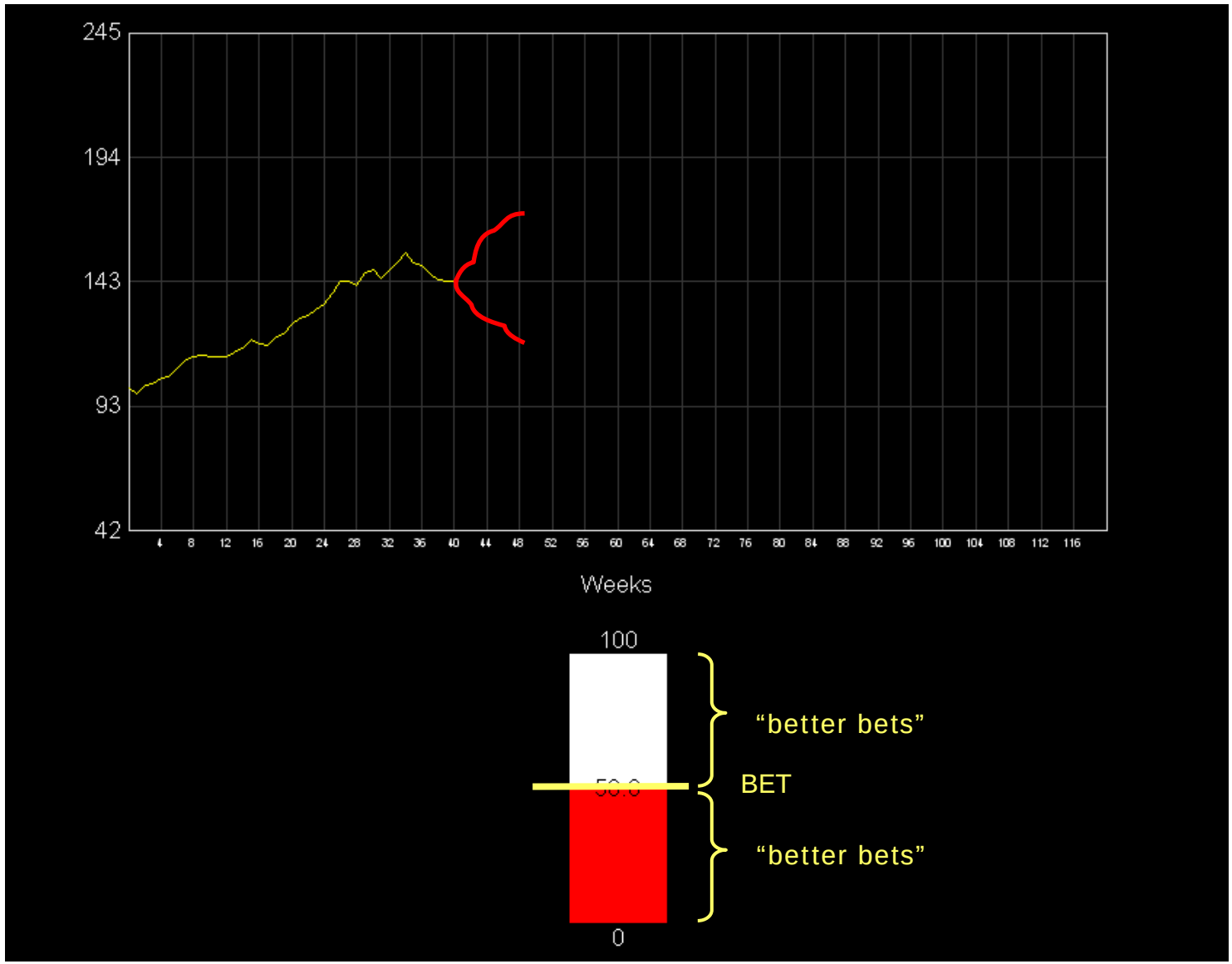
Experiment setup



Experiment setup



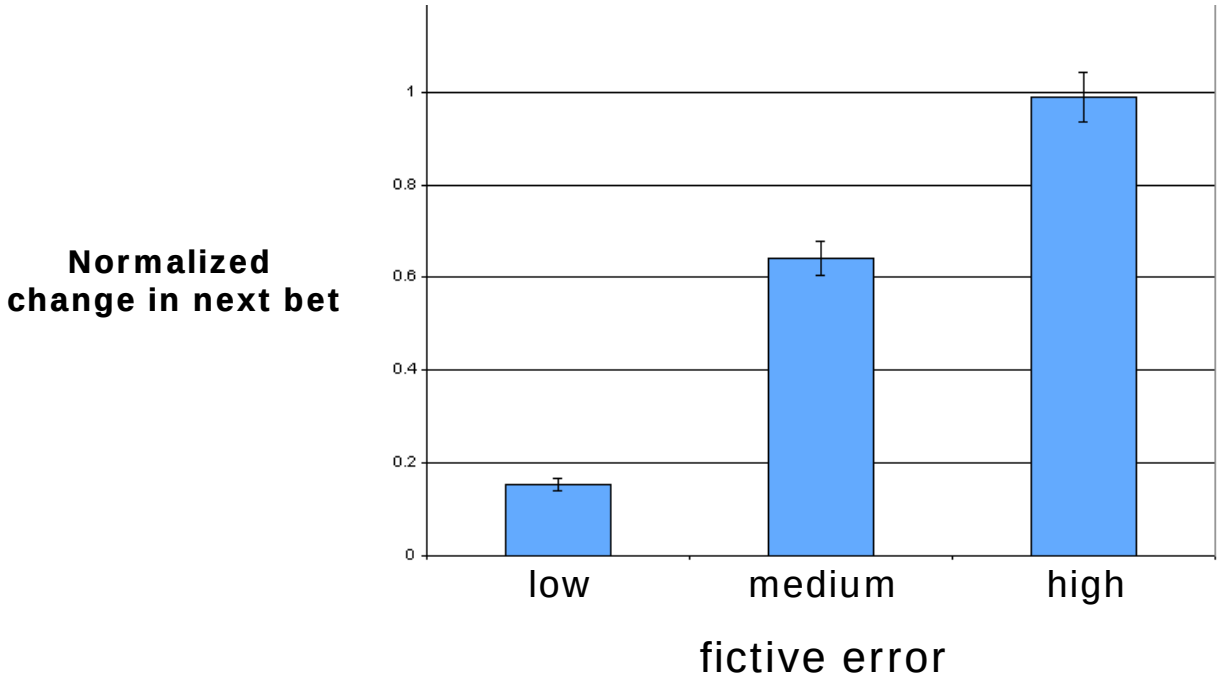
Computing Fictive Error



Do fictive errors guide behavior on investment game?

YES

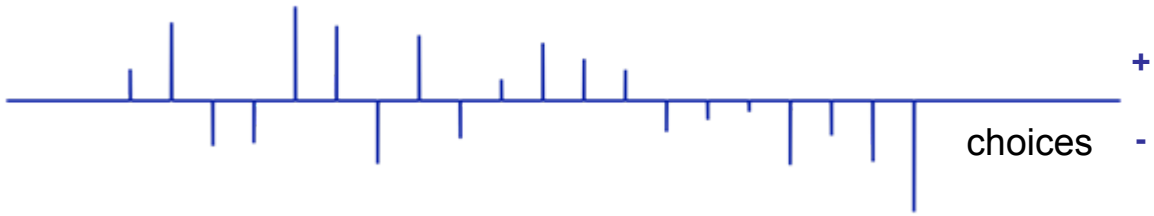
$$f^{+} = (1 \cdot r_t^{+}) - (b_t \cdot r_t^{+})$$ = "could have won" – "actually won"



Lohrenz et al., PNAS, 2007

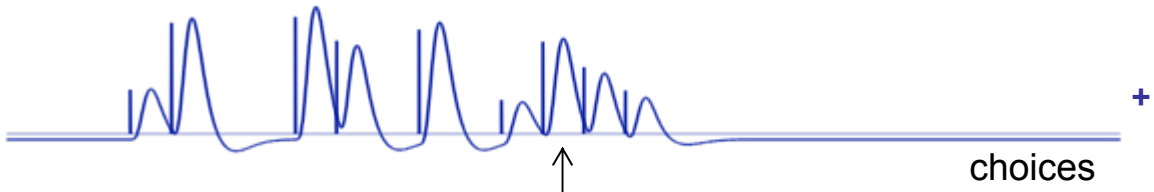
Constructing fictive error regressors over investment game

market changes:
$r_t = (p_t - p_{t-1}) / p_{t-1}$



bet for each market piece:
b_t

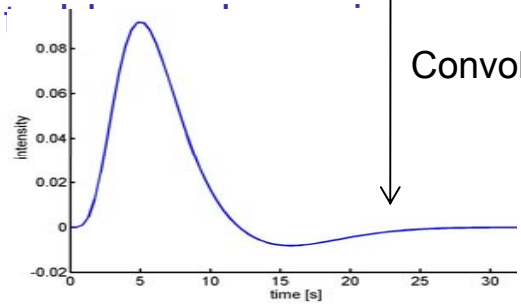
fictive error over gains:
$f^+ = (1 \cdot r_t^+) - (b_t \cdot r_t^+)$



predic nse to fictive error

Convolve

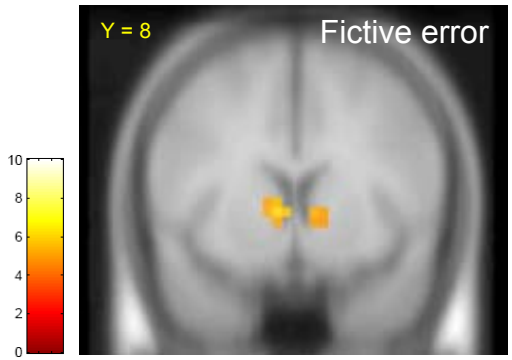
Hemodynamic
Impulse response function



Fictive error signals can be separated from experiential error signals

fictive error:

$$f^{+} = (1 \cdot r_t^{+}) - (b_t \cdot r_t^{+})$$



Lohrenz et al., PNAS, 2007

Addiction

Abstract future outcomes can't intervene on habit-learning system

These proxies





cannot surmount these proxies



Maybe the 'could be' scenarios don't generate fictive learning signals in addicts

Fictive error signals in cocaine addicts

- 39 Volunteers meeting DSM-IV criteria for cocaine dependence
- Subjects recruited through the VA hospital at Baylor College of Medicine
- Not seeking abstinence-focused treatment at time of enrollment

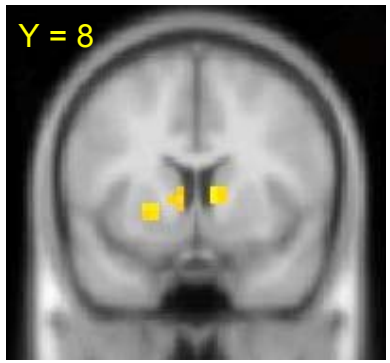
Neural fictive error signals absent in cocaine addicts

"could have won" – "actually won"

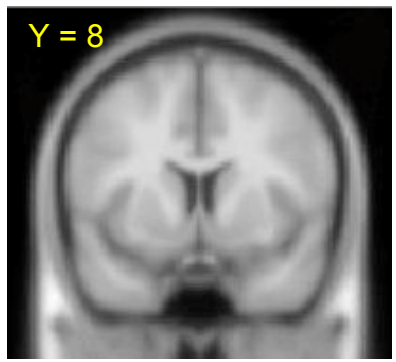
fictive error:

$$f^{+} = (1 \cdot r_t^{+}) - (b_t \cdot r_t^{+})$$

Controls



Cocaine Addicts

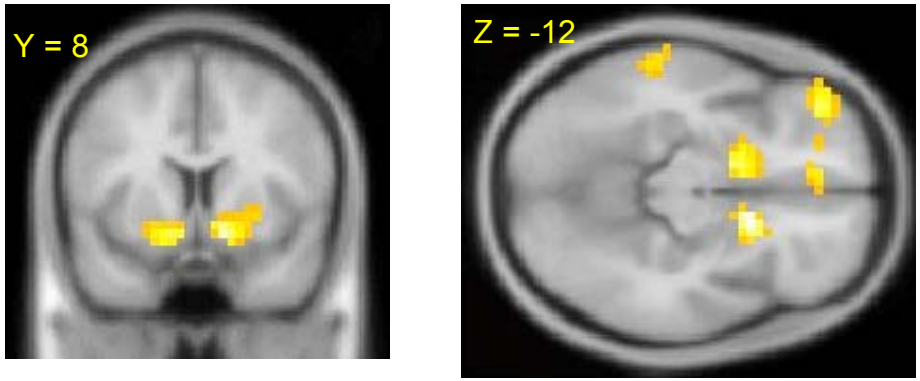


n = 31 $p < 10^{-4}$, uncorrected c.s. = 5 voxels n = 39

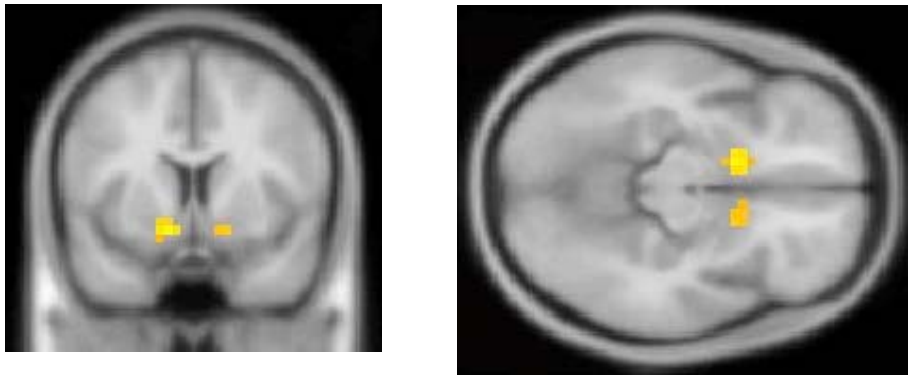
Are addicts missing all control signals? No

Addicts retain TD error signal

Non-Smokers (n = 31)



Cocaine Addicts (n = 39)

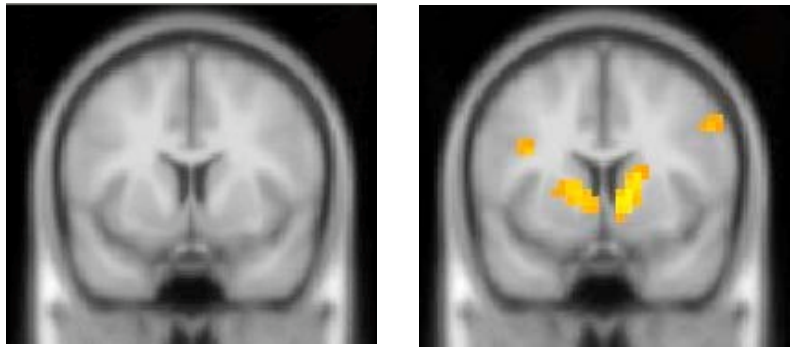


$p < 10^{-4}$, c.s. = 5 voxels, x = -12, y = 8, z = -12

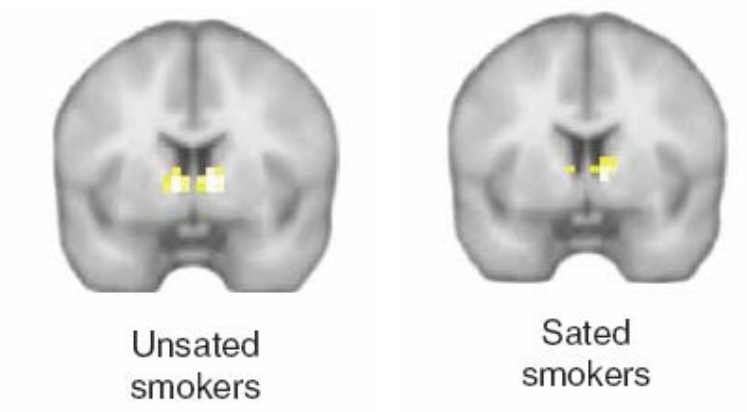
Drug state changes fictive error in cocaine addicts

Cocaine -

Cocaine +



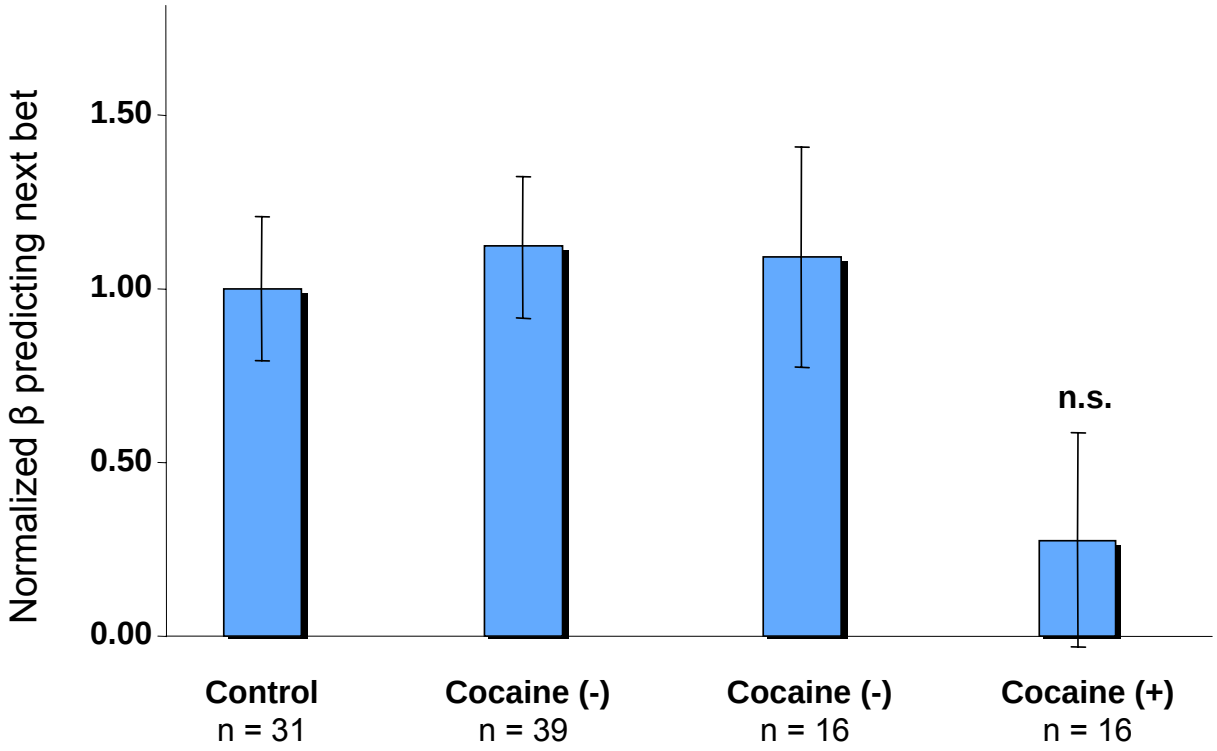
n = 16, p < 0.001, uncorrected, c.s. = 5 voxels



n = 31, p < 0.001, uncorrected, c.s. = 5 voxels

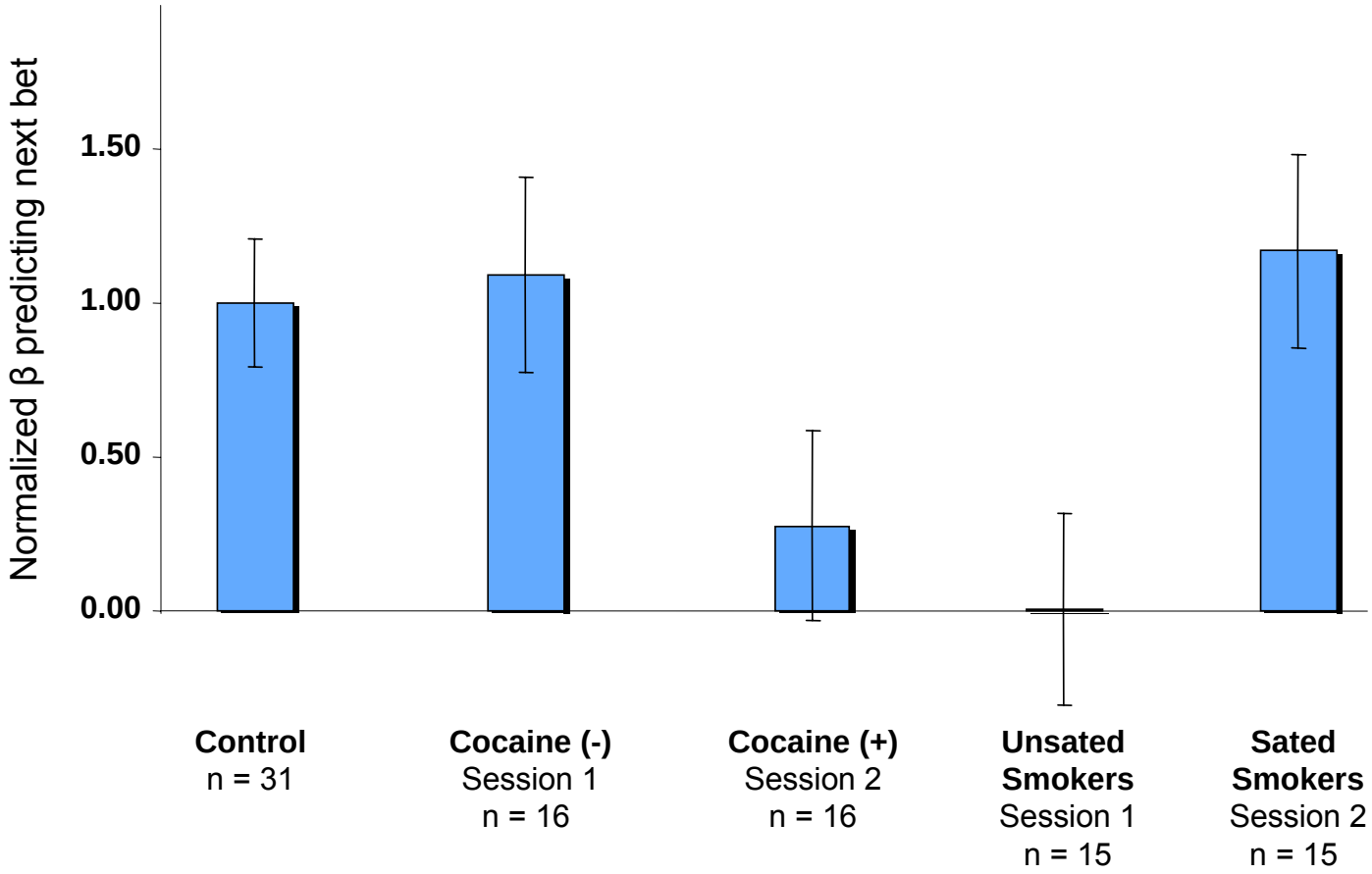
Chiu et al., Nature Neuroscience, 2008

Fictive error *does not* guide behavior in cocaine positive subjects



Does order of experiments explain change in fictive error?

No



Summary

- Economic games can be used to probe learning signals that guide choice

- Different types of learning signals can be detected in a market game

- Fictive outcomes influence choice behavior and corresponding neural activity

- Addicts compute fictive error differentially depending on drug and drug state

Acknowledgments

Pearl Chiu
Terry Lohrenz
Read Montague

Collaborators
Richard De La Garza
Thomas Newton
Gideon Yaffe

Experiments
Monica Alexander
Krystle Bartley
Christine Cortelyou
Carrie Howard
James Mahoney

MacArthur Foundation Law and Neuroscience Project

END