Neural correlates of intertemporal choice

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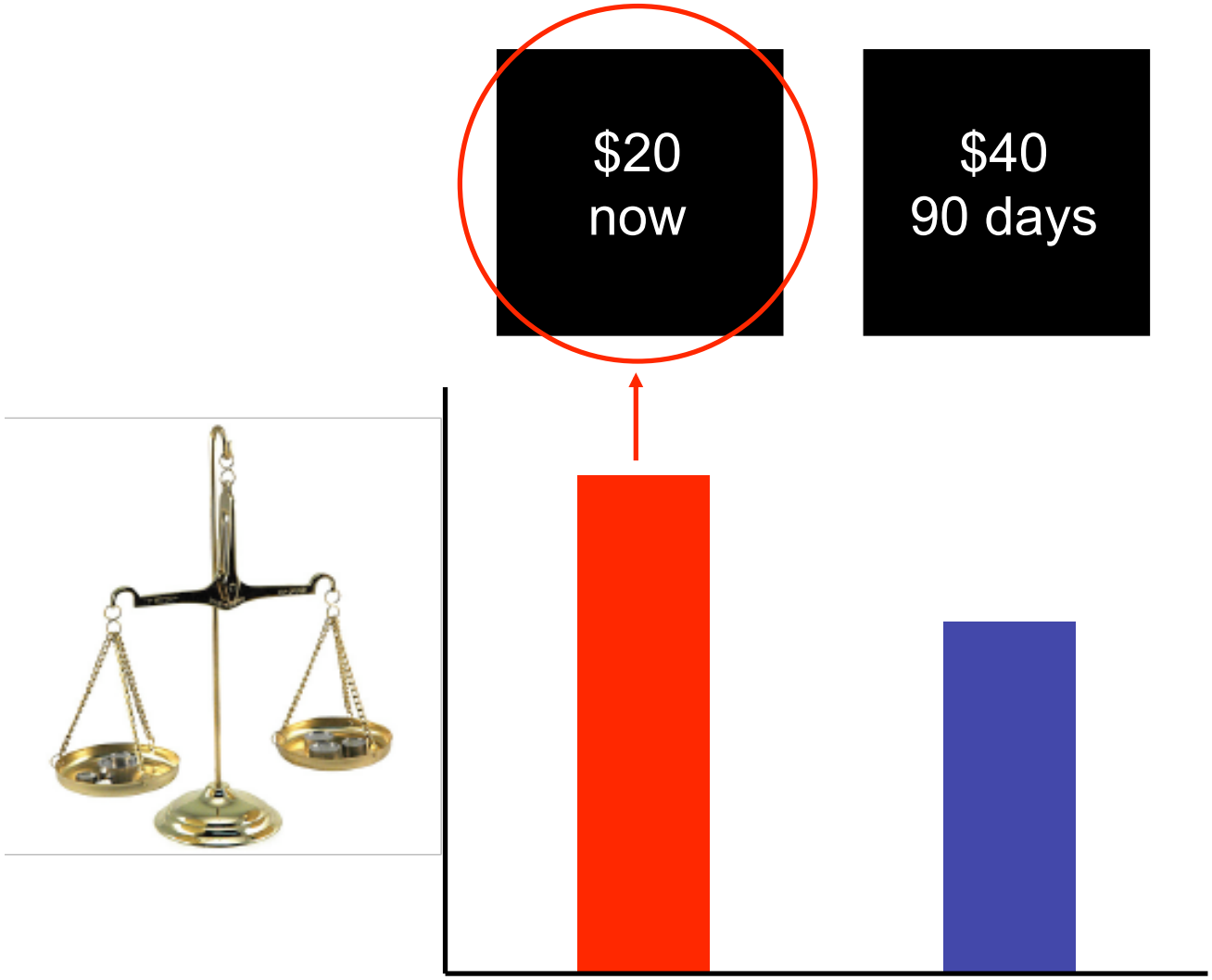
Summer Workshop in Decision Neuroscience

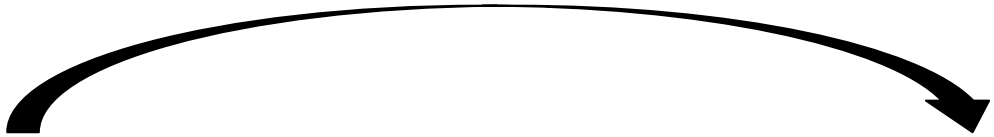
August 21, 2009

The Oenophile's Dilemma
(a.k.a. the adult's marshmallow test)

Immediate or Delayed?


$20
now
$40
90 days

Identifying Neural Correlates of Preference



Characterize how subjective value changes as a function of objective reward parameters

Search for brain areas where neural activity is correlated with subjective value

A Psychometric-Neurometric Match

Experimental Design

- 3 behavioral sessions (1 practice, 2 paid) before scanning
- 144 choices/session
- 6 delays ranging 6 hrs-180 days; 6 amounts scaled for each subject (max ~ $120); delay/amount pairs change across sessions
- in paid sessions, 4 trials randomly selected by dice roll & subjects paid according to their choice
- all payments made using pre-paid debit cards

Estimating a Discount Function from Choice: Single Subject Example (RA)

Choice Data

Discount Function

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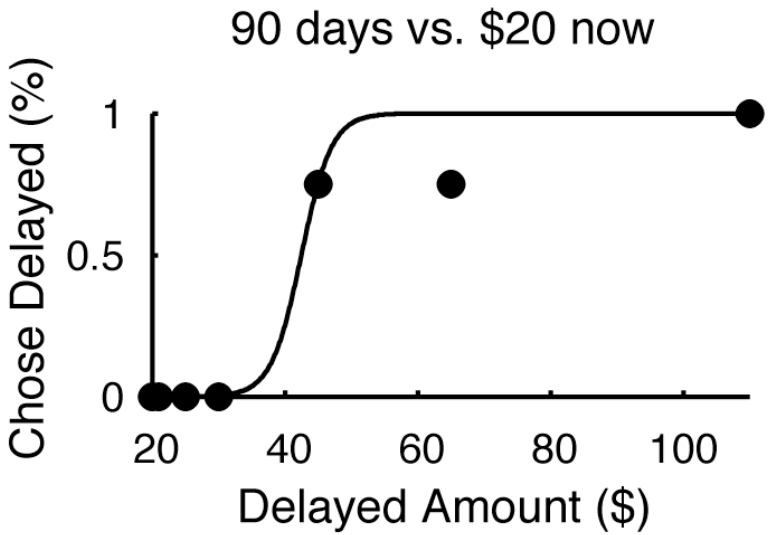
Choice Data

Discount Function



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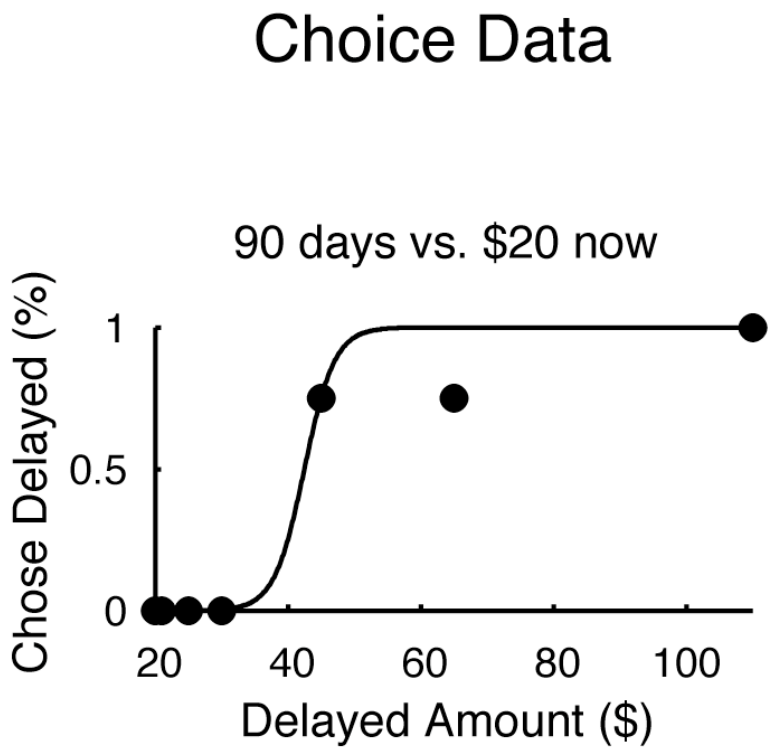
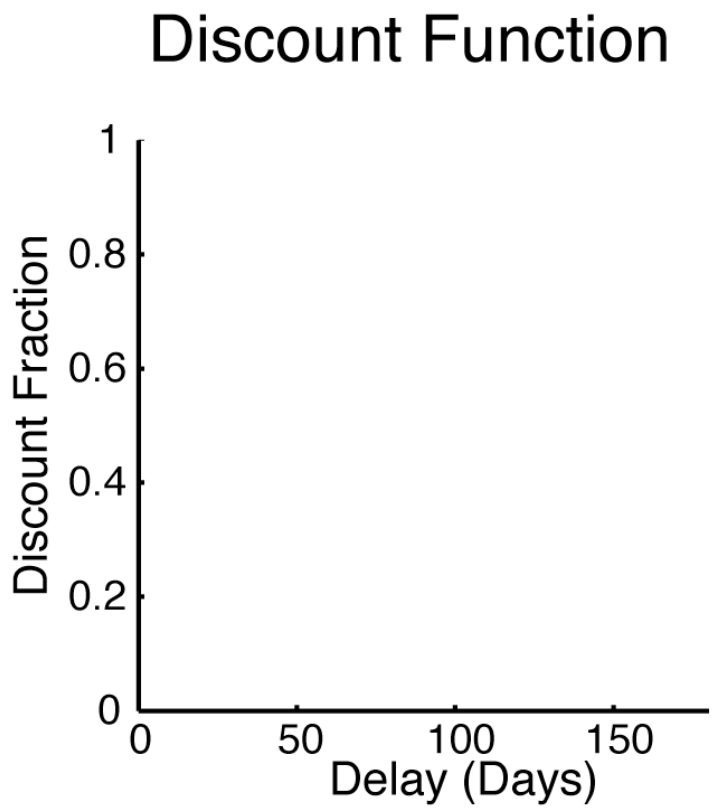
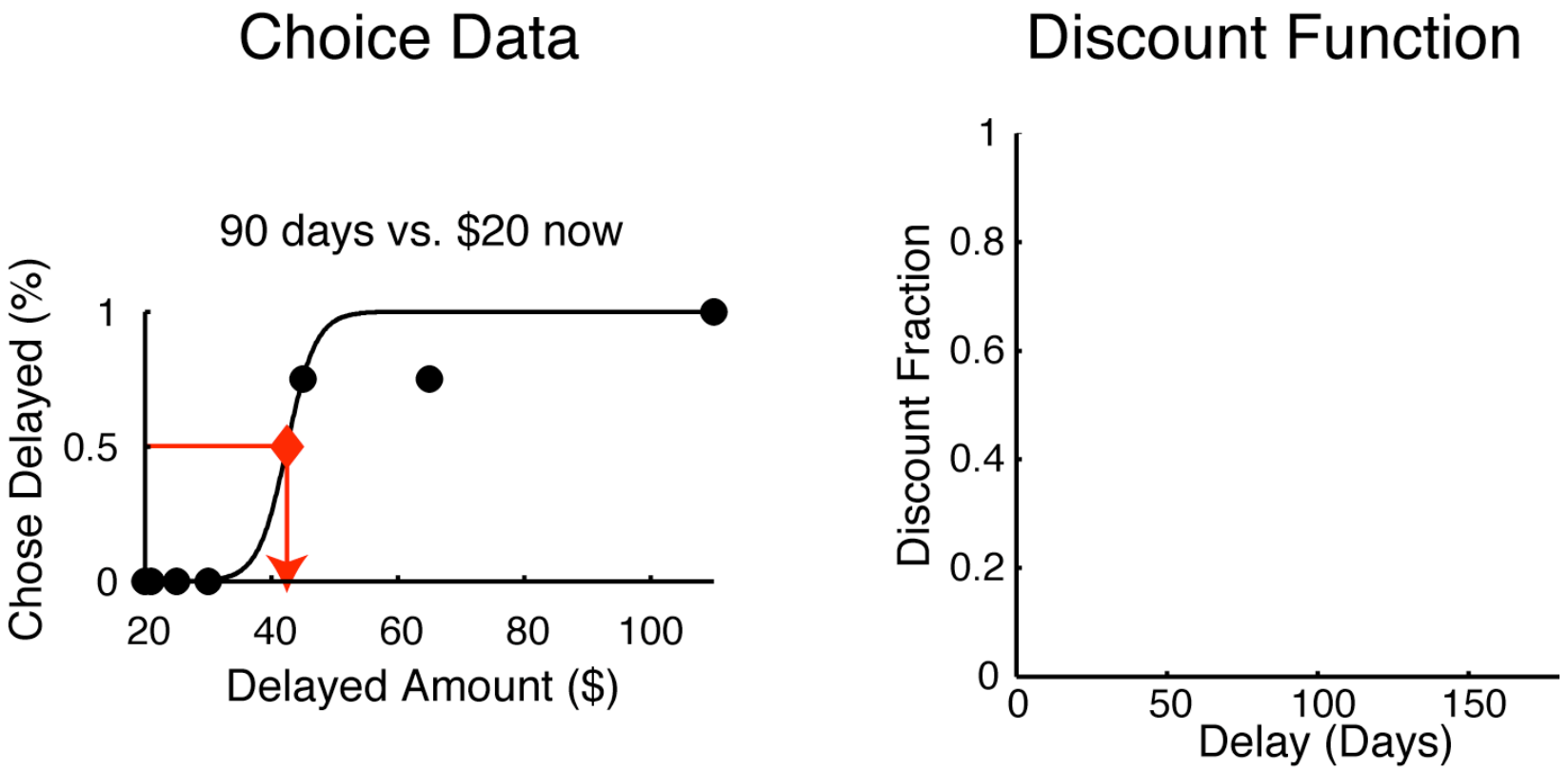




Estimating a Discount Function from Choice: Single Subject Example (RA)



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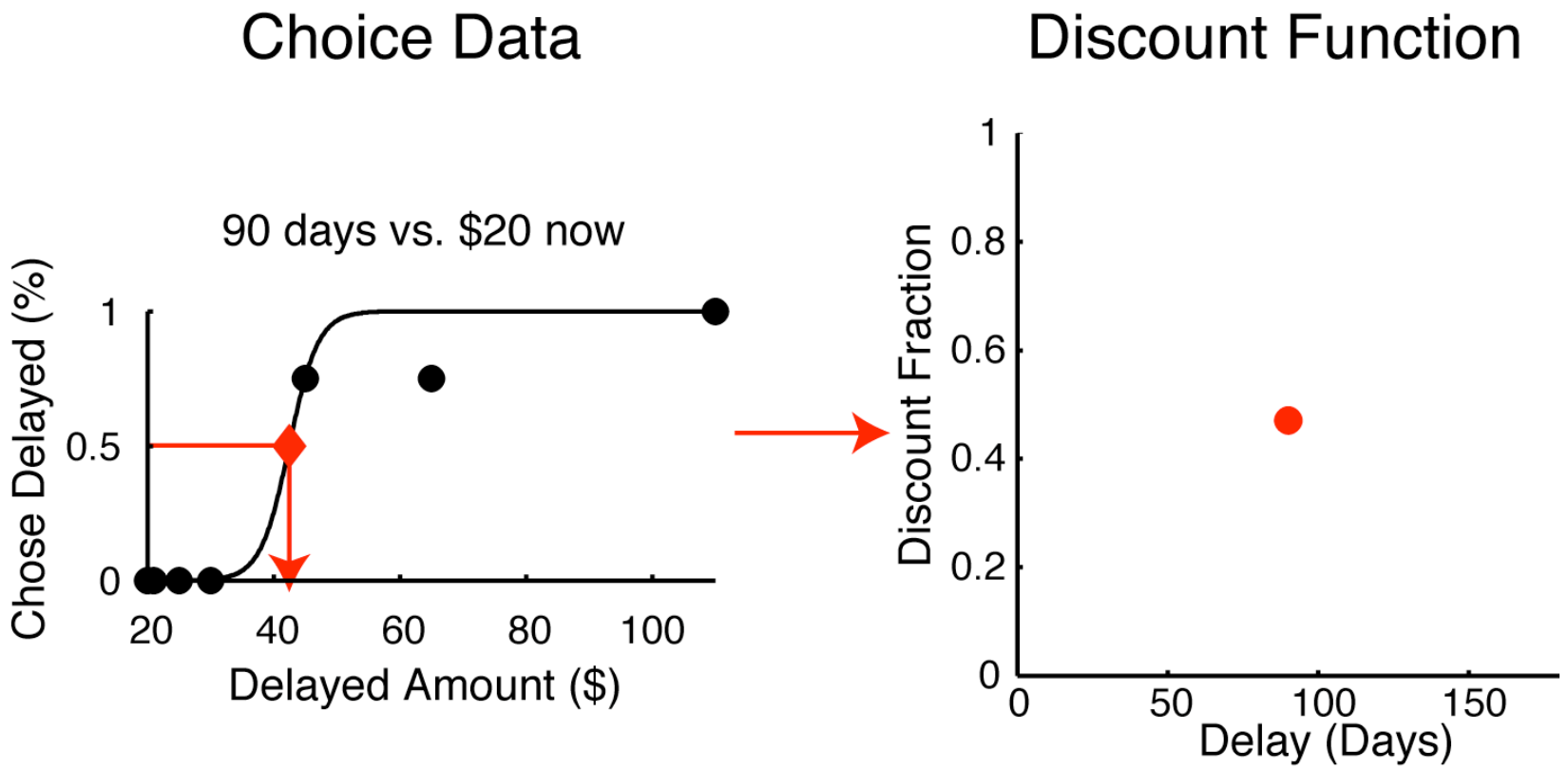

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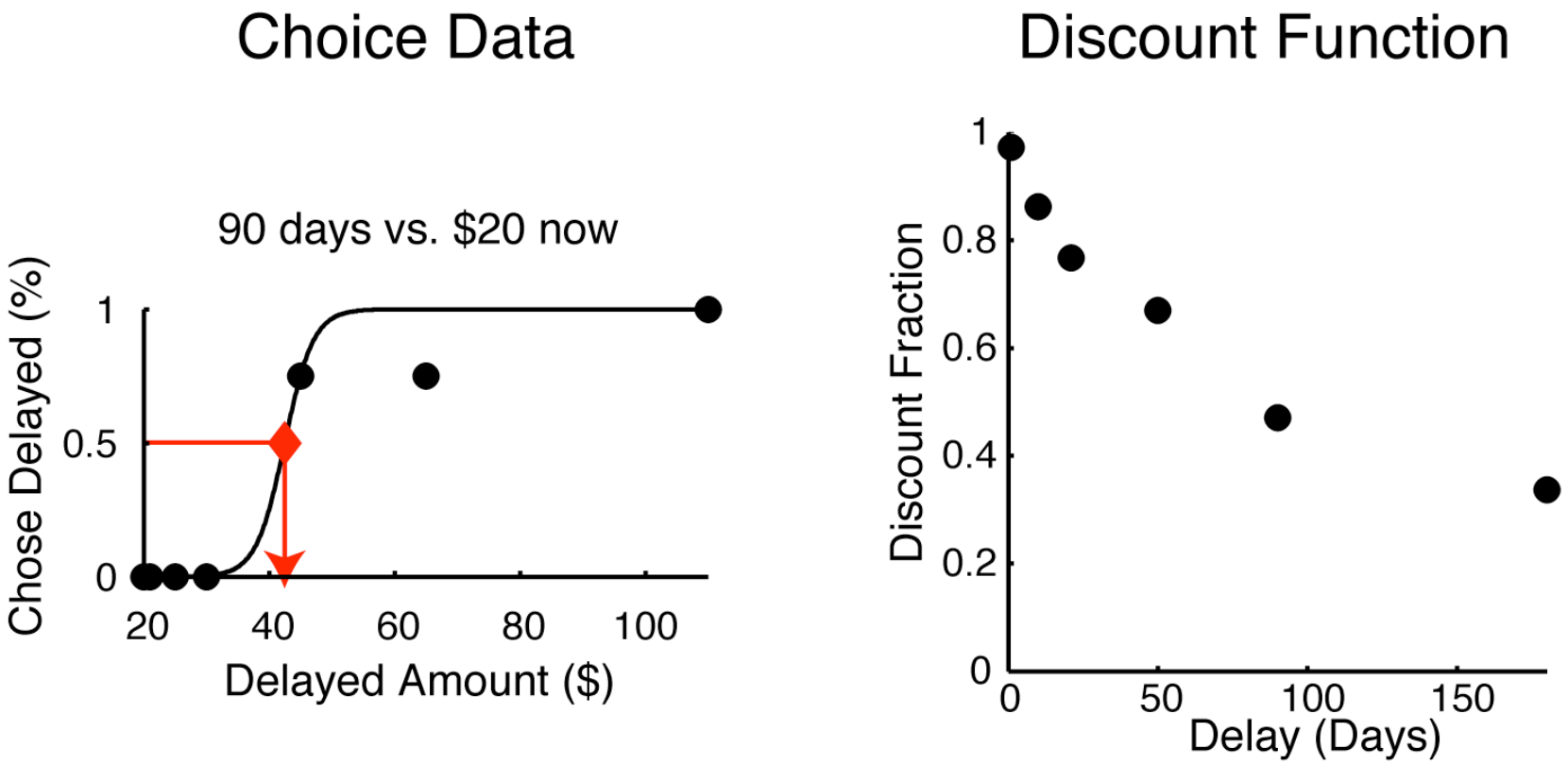

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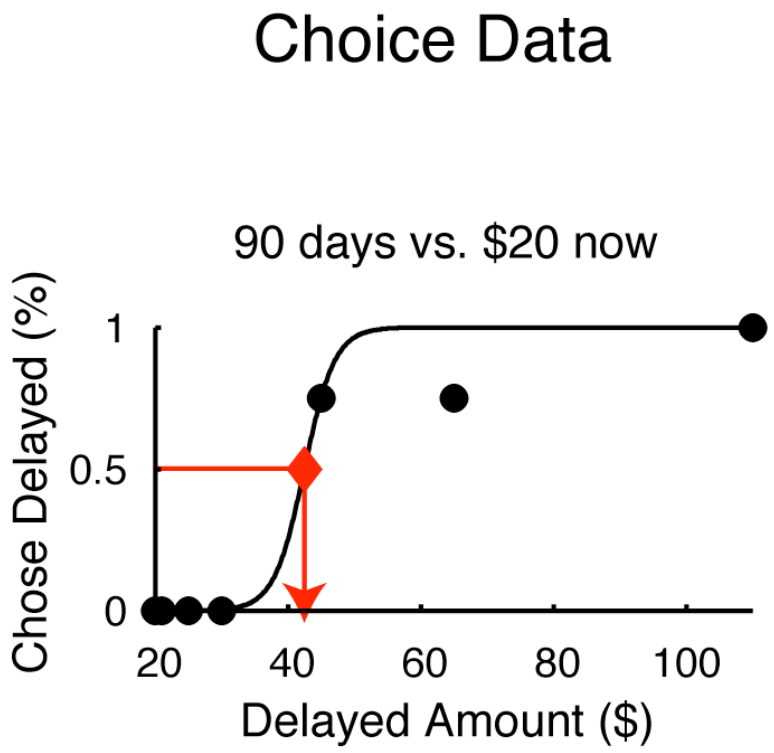
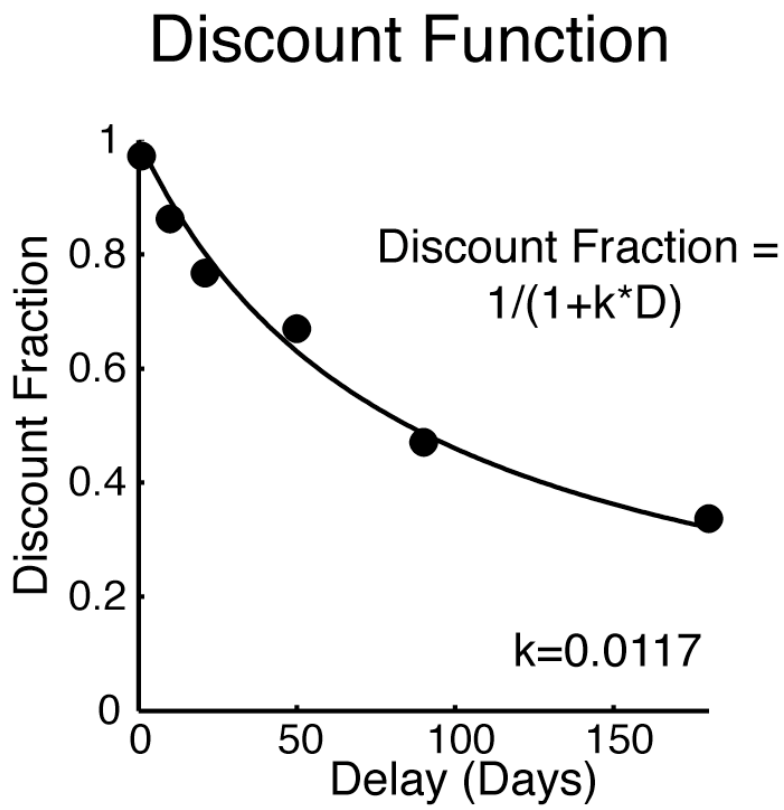
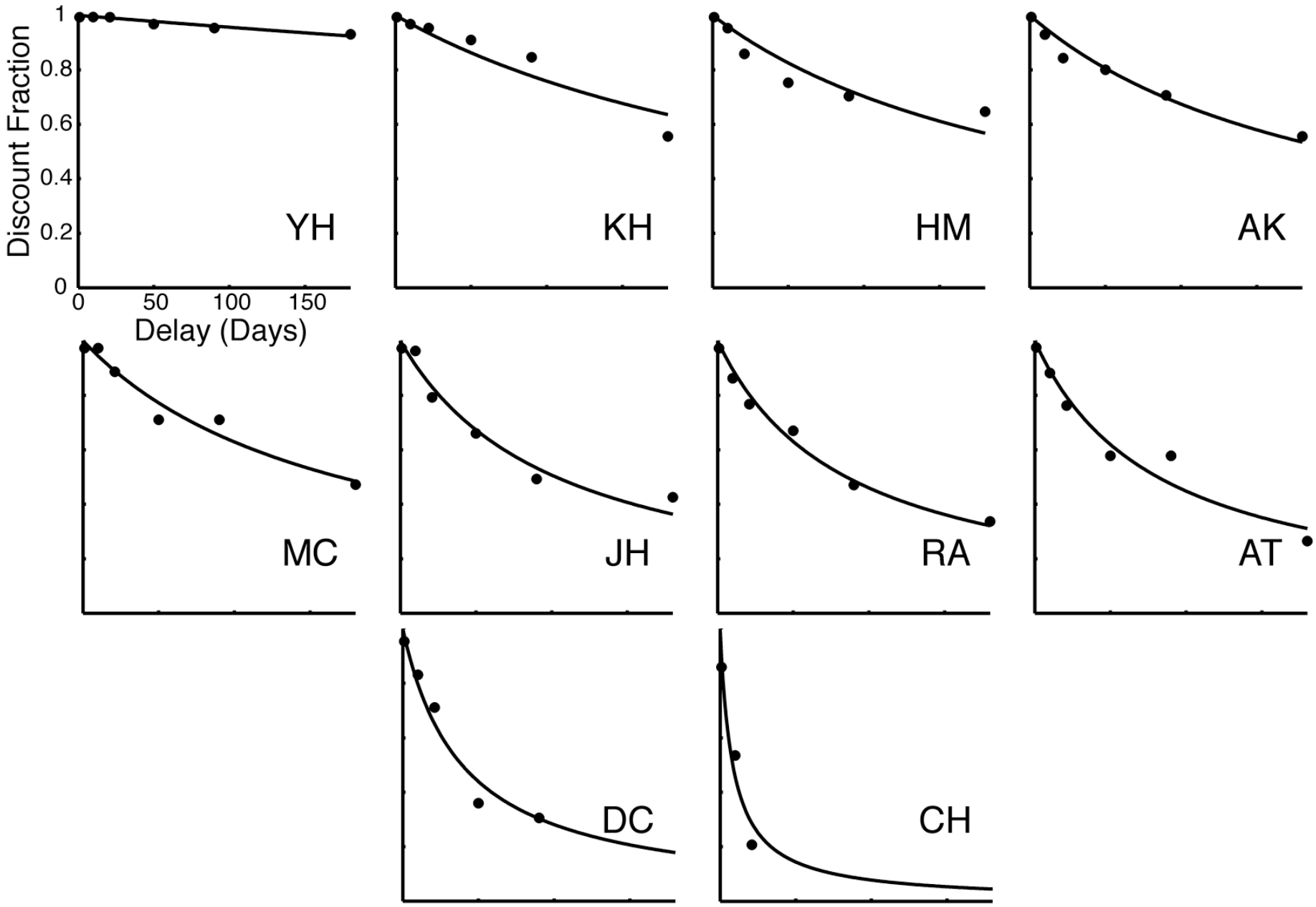


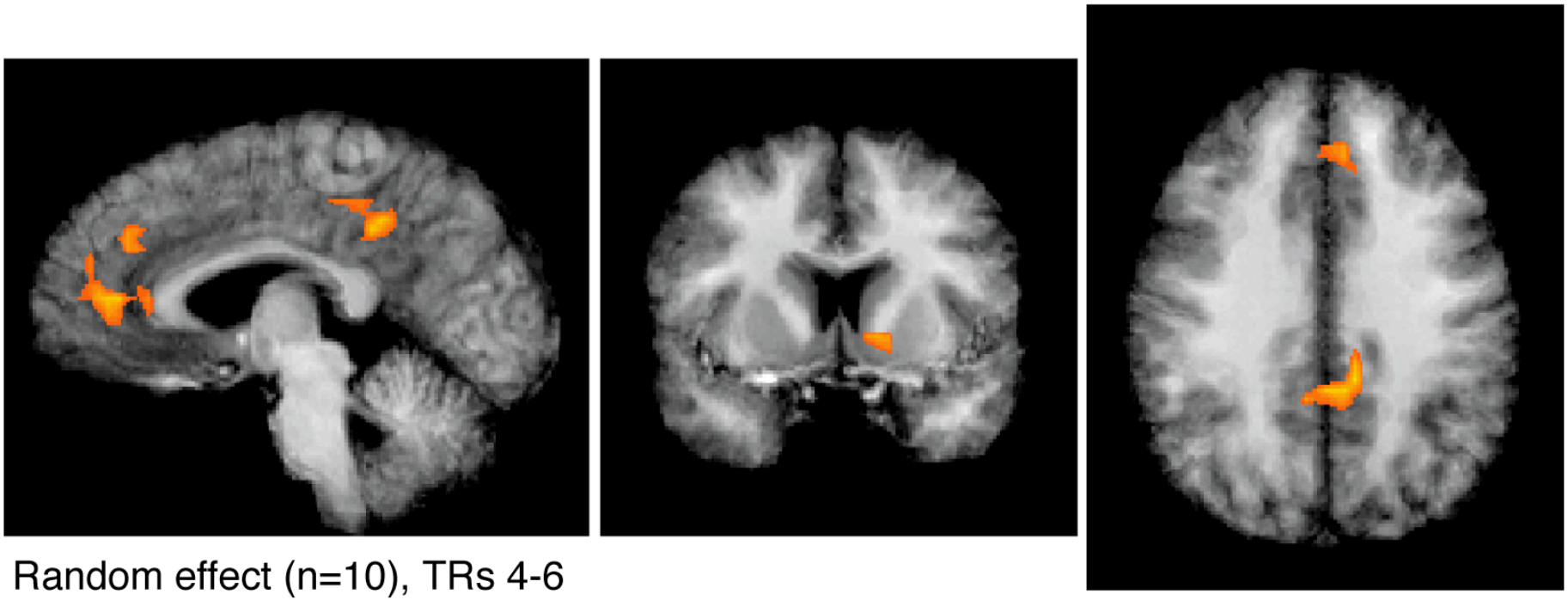


Discount Function: All Subjects (n=10)



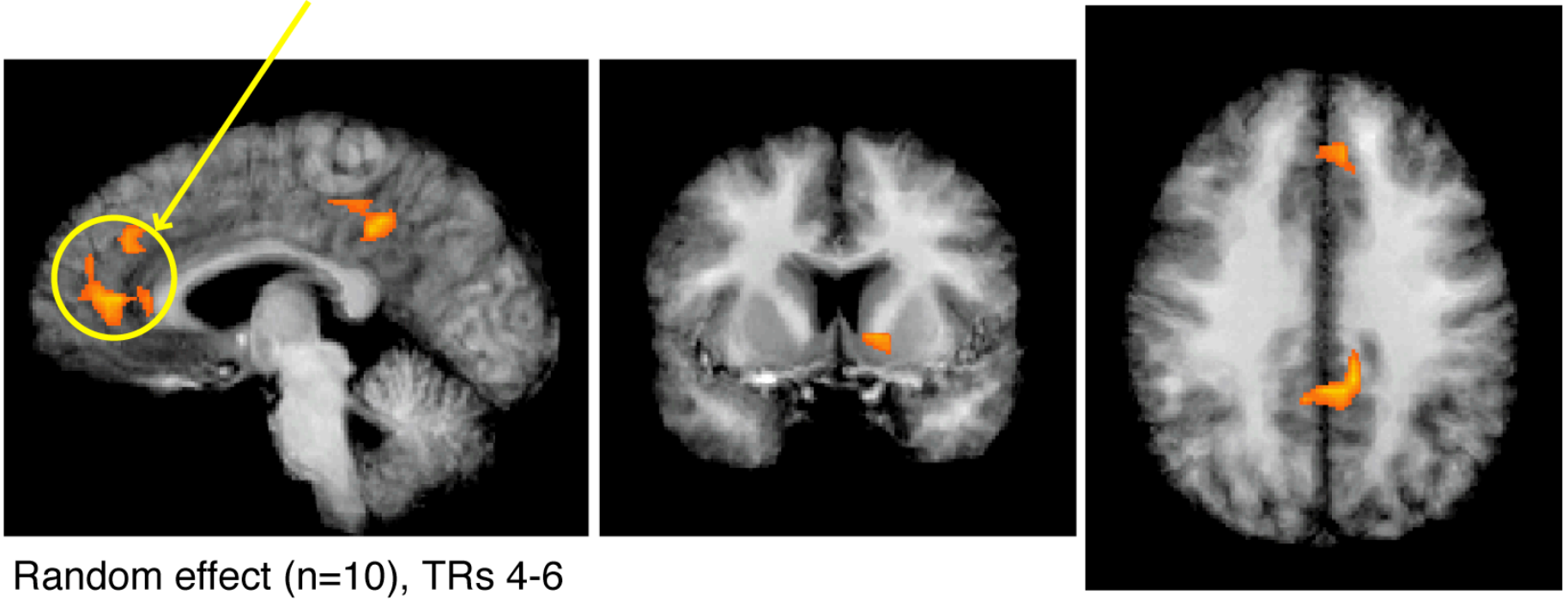
Immediate or Delayed?

Correlation with Subjective Value



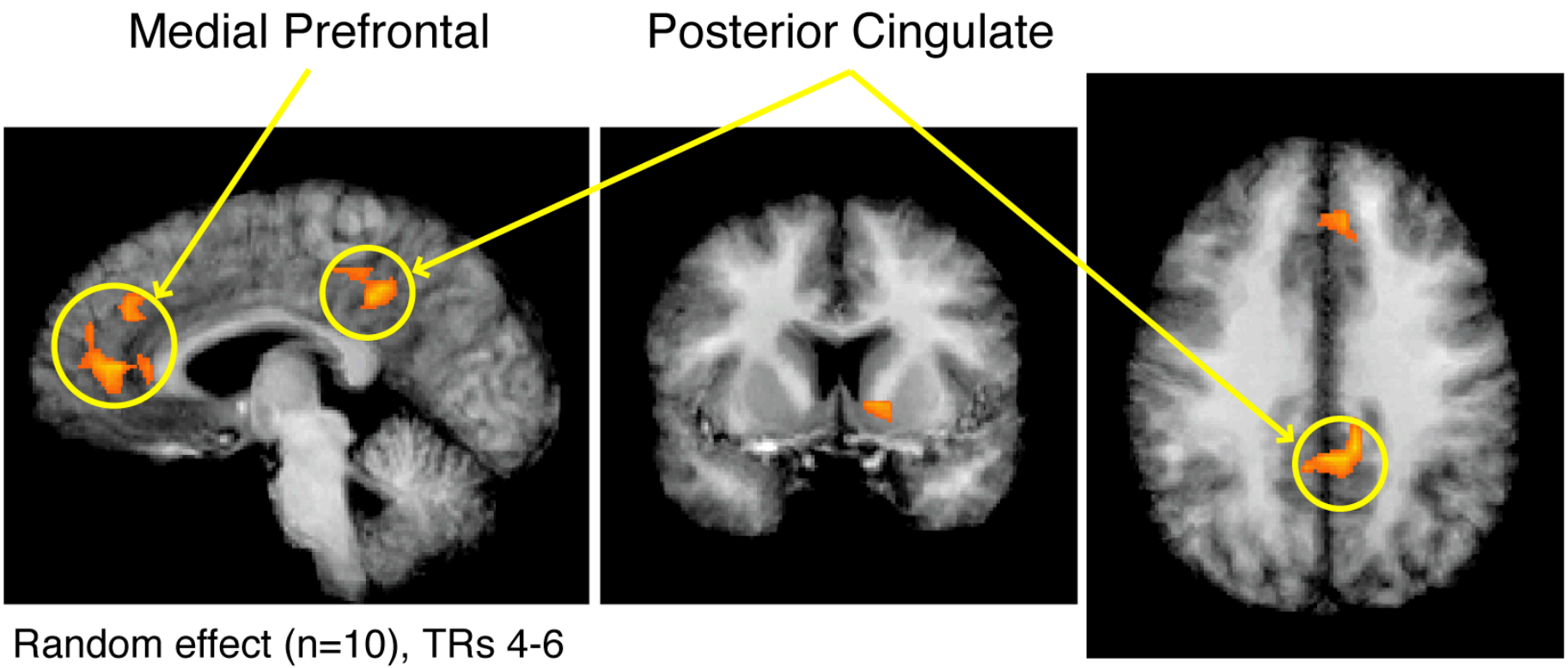
Random effect (n=10), TRs 4-6

Correlation with Subjective Value



Random effect (n=10), TRs 4-6

Correlation with Subjective Value

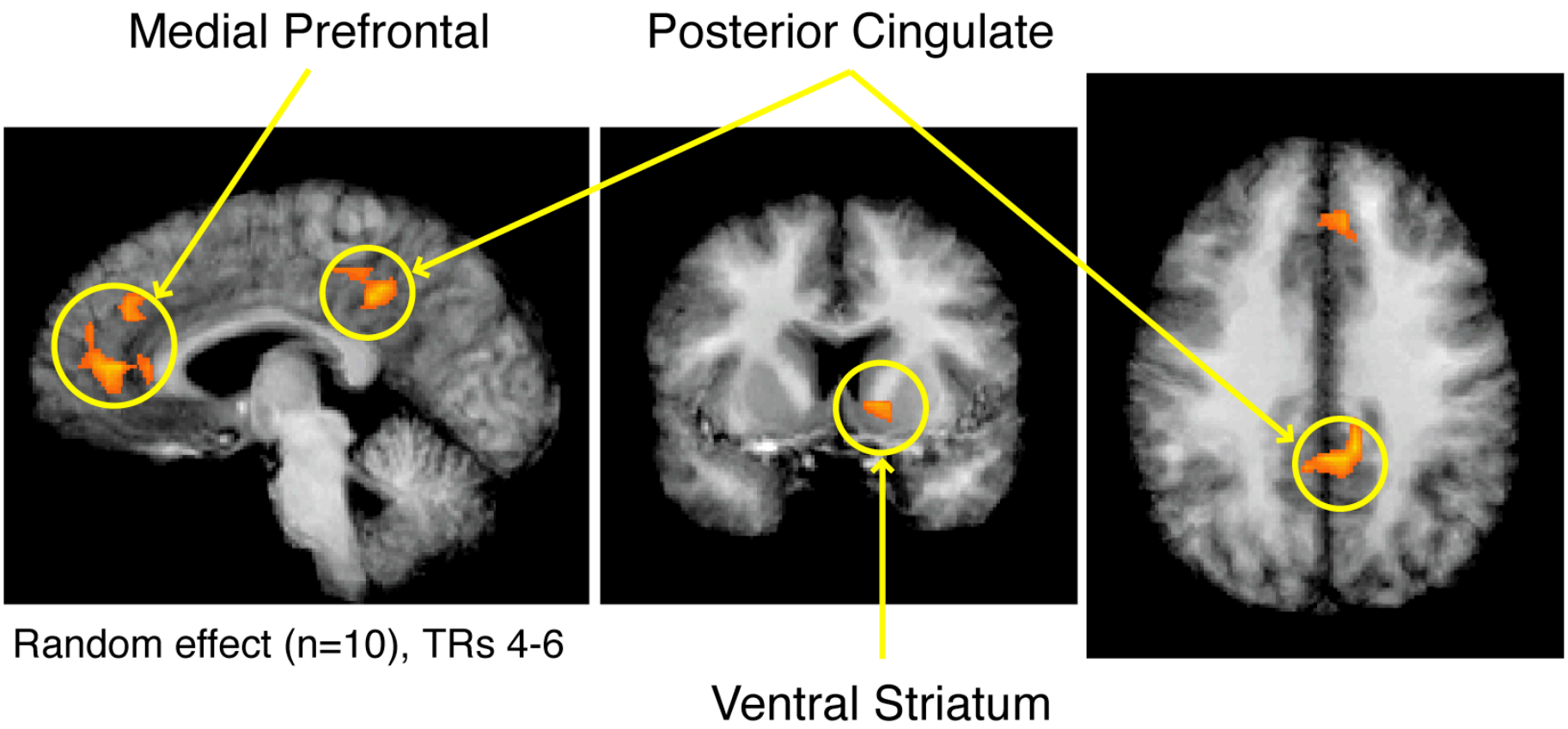


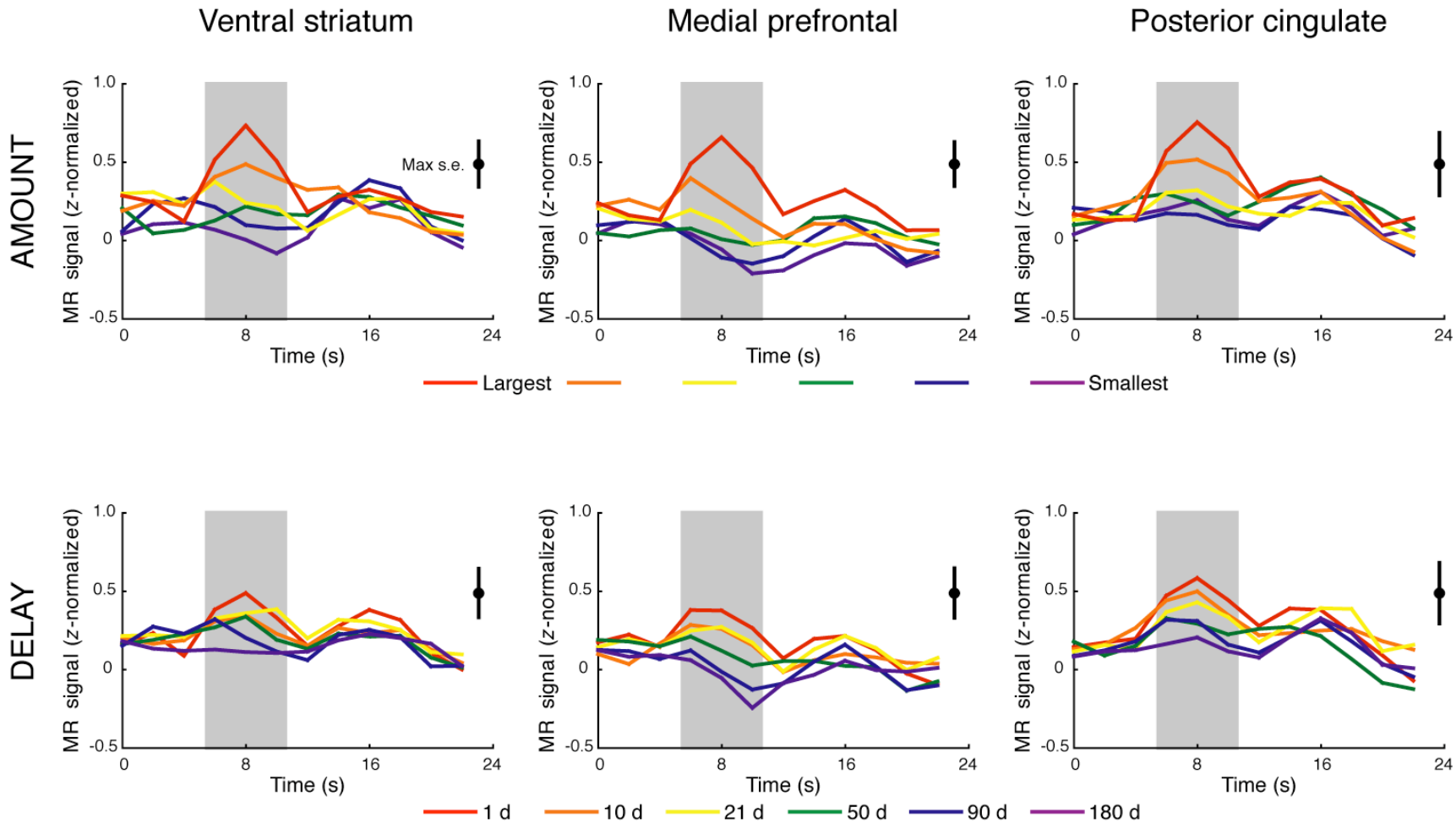
Random effect (n=10), TRs 4-6

p<.005
(uncorrected)

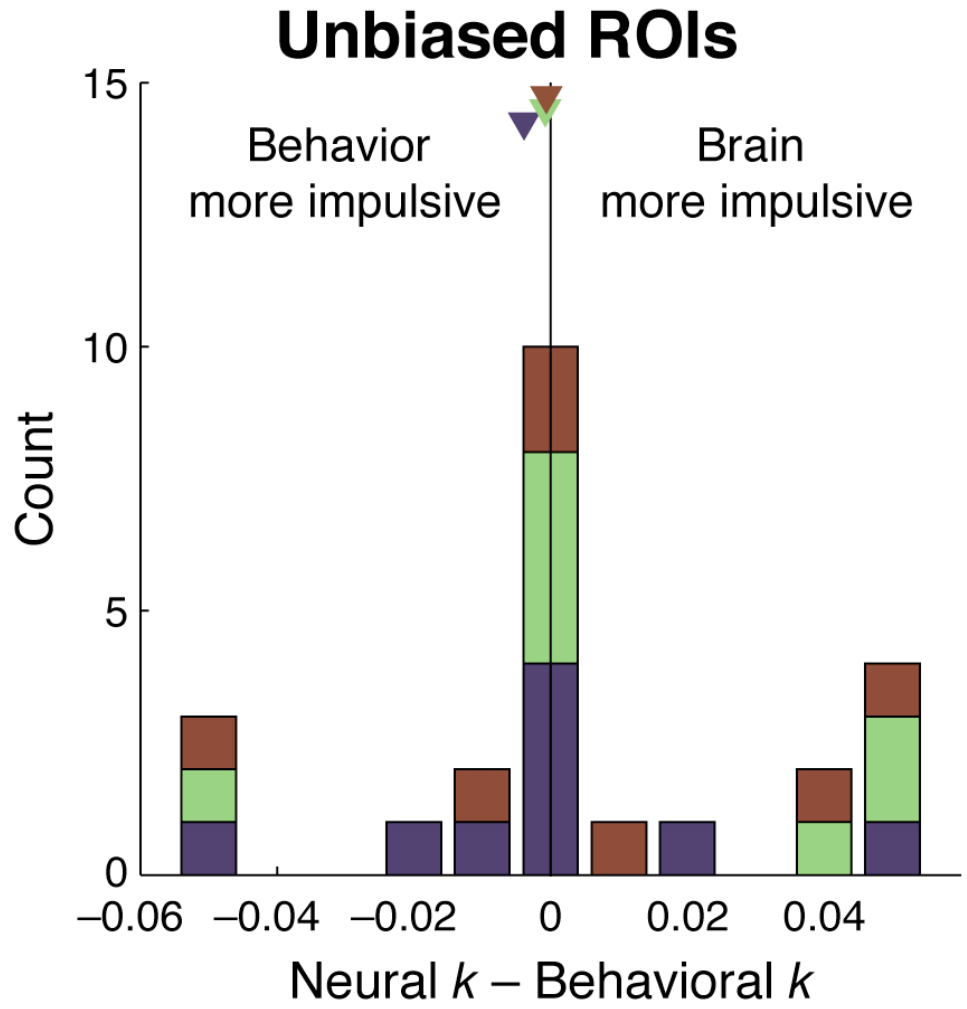
p<.05,
(corrected, FDR)

Correlation with Subjective Value




Ventral striatum
Medial prefrontal
Posterior cingulate
AMOUNT
DELAY
MR signal (z-normalized)
Time (s)
Max s.e.
Largest
Smallest
1 d
10 d
21 d
50 d
90 d
180 d

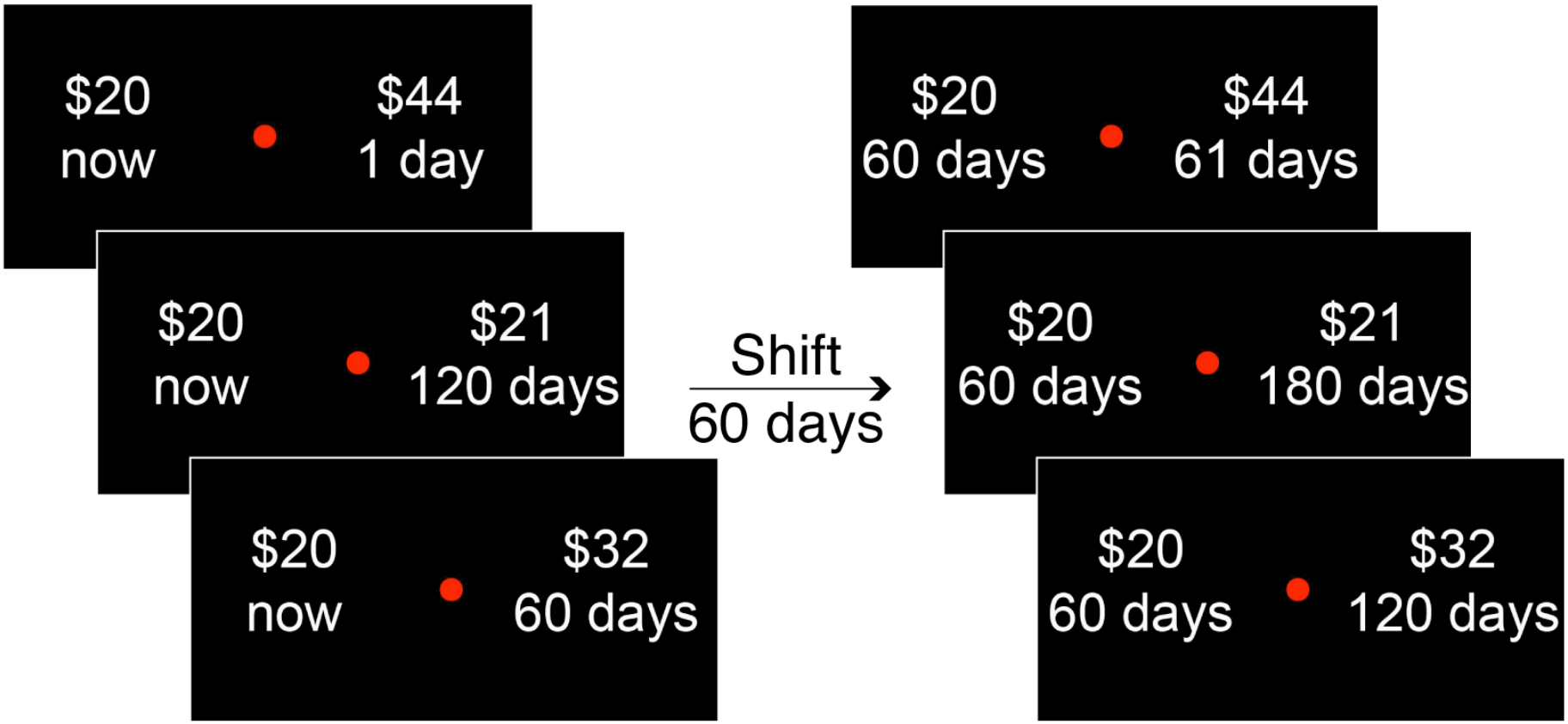
Neural Discount Rates Match Behavior



Wilcoxon signed rank test versus zero: $P = 0.93$

Ventral Striatum Medial Prefrontal Posterior Cingulate

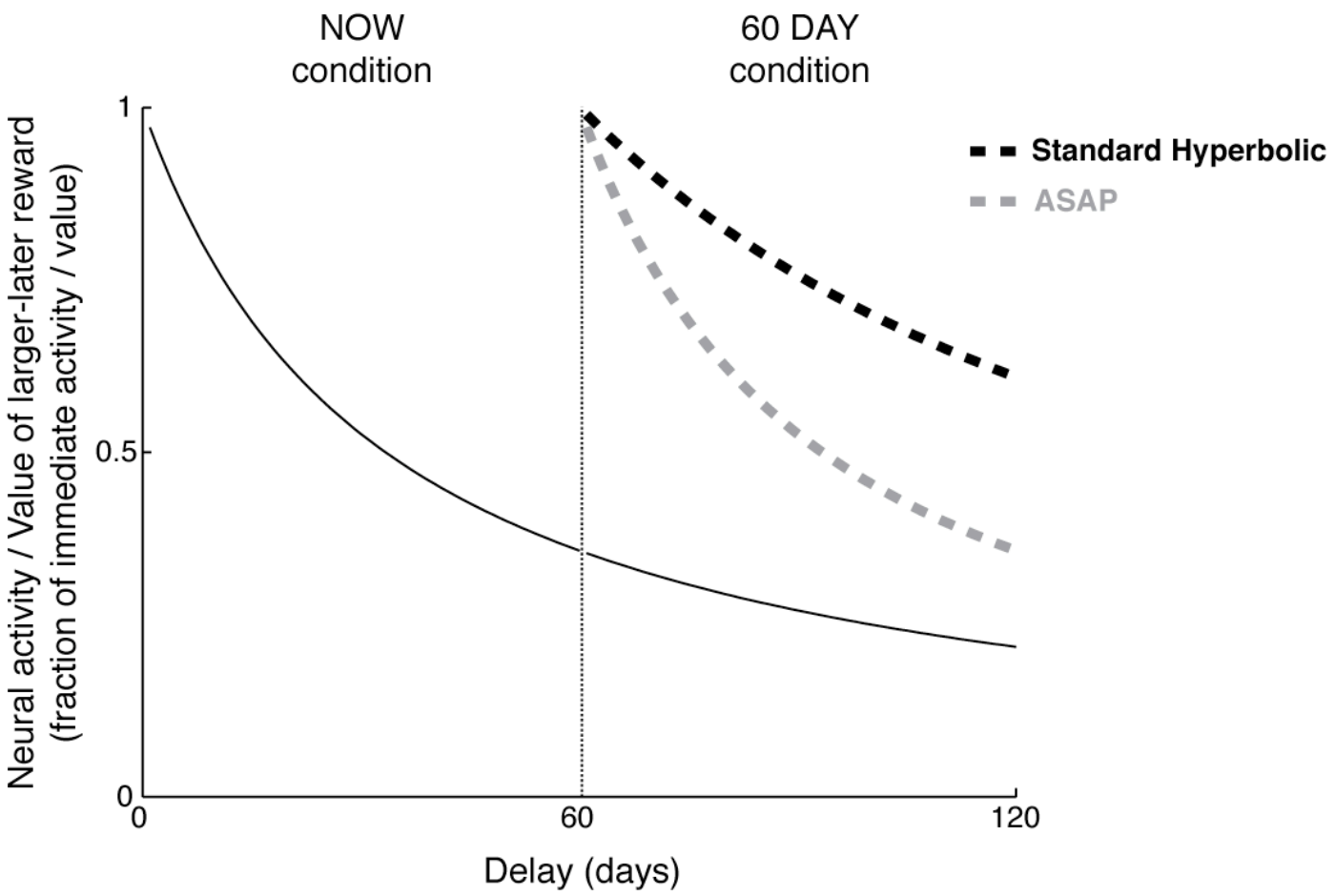
Experimental Design



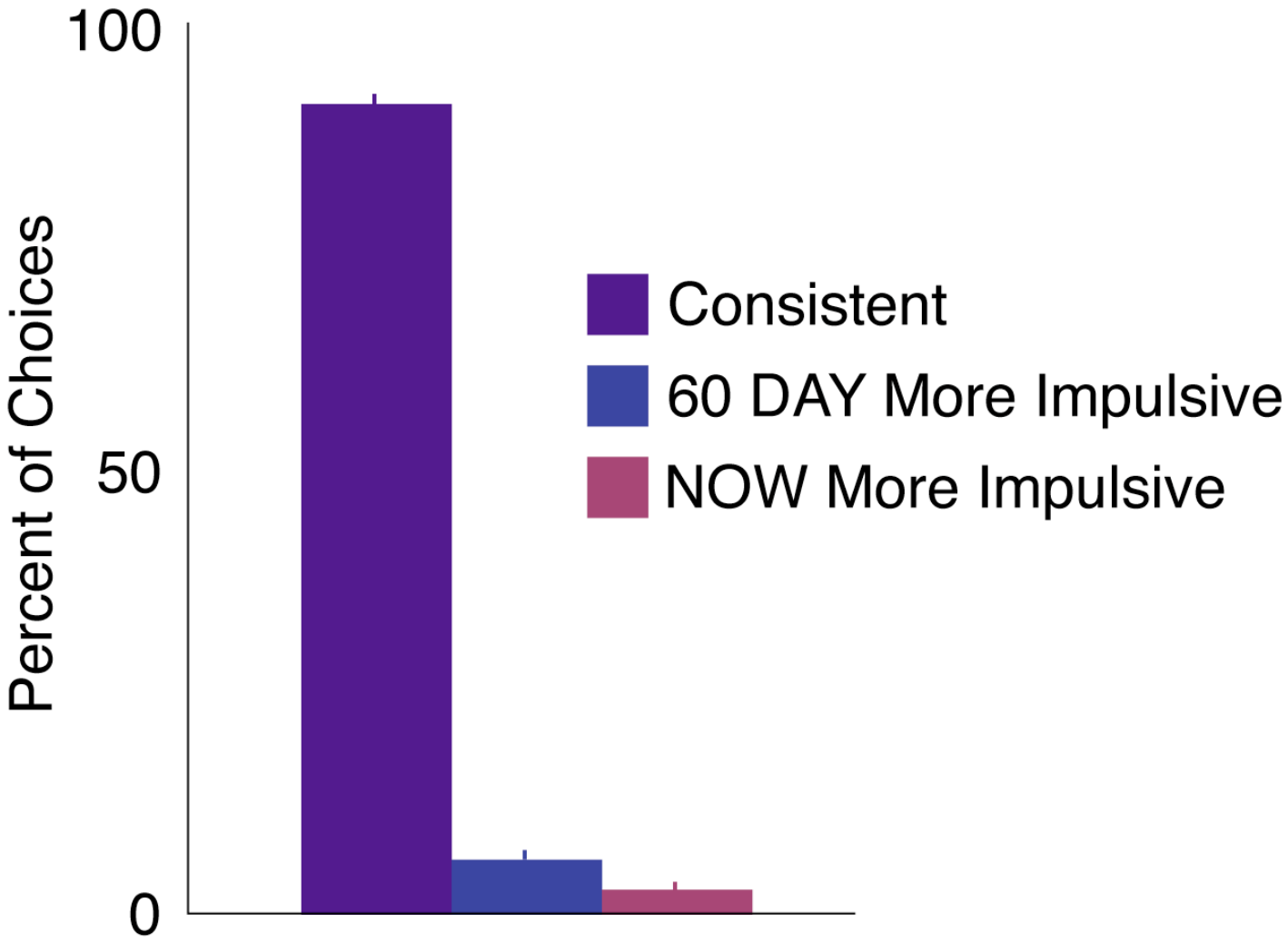
NOW reference

60 DAY reference

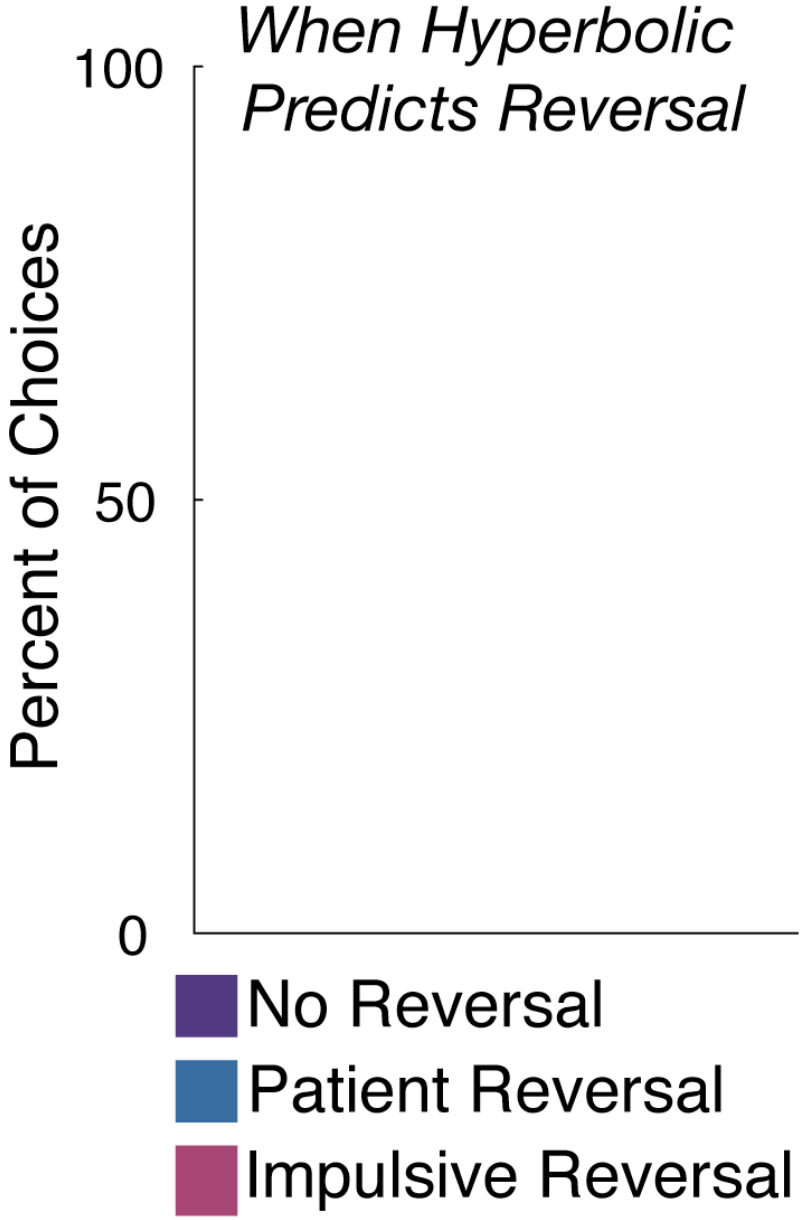
-choices from both conditions are randomly intermixed-

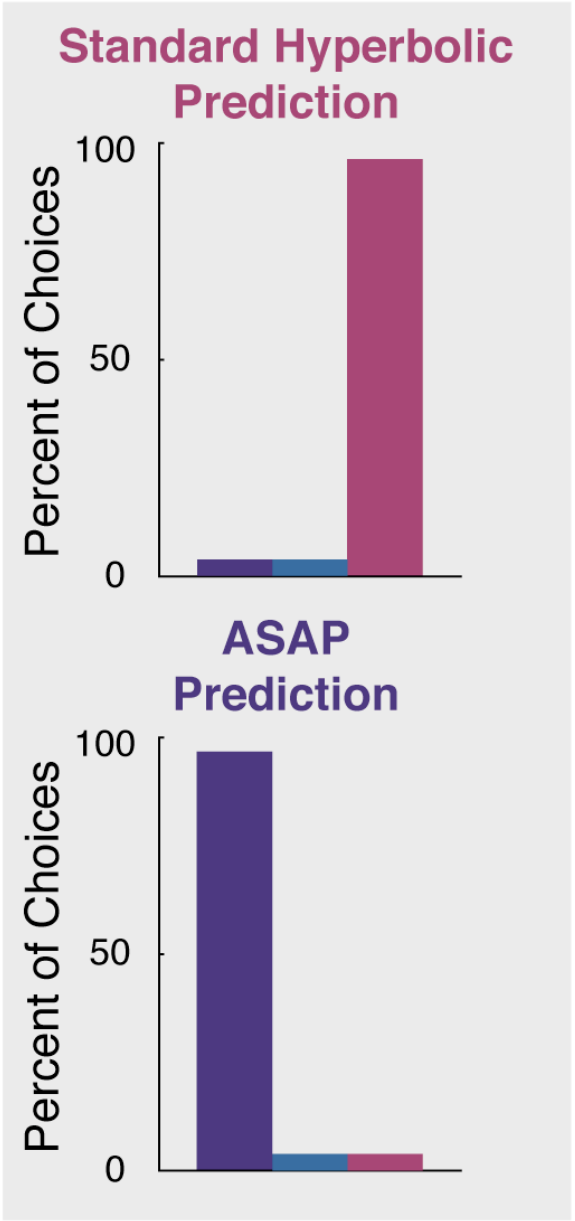

NOW
condition
60 DAY
condition
Standard Hyperbolic
ASAP
Neural activity / Value of larger-later reward
(fraction of immediate activity / value)
1
0.5
0
0
60
120
Delay (days)

Behavioral Results

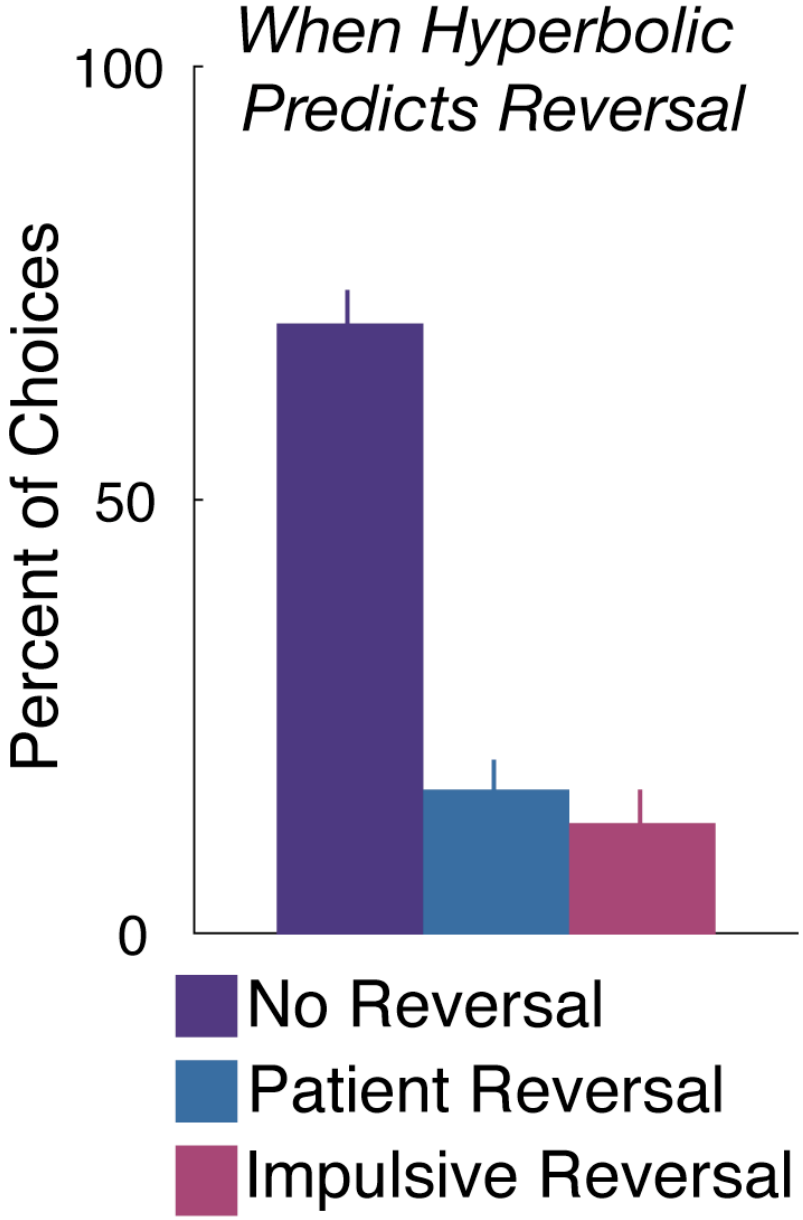


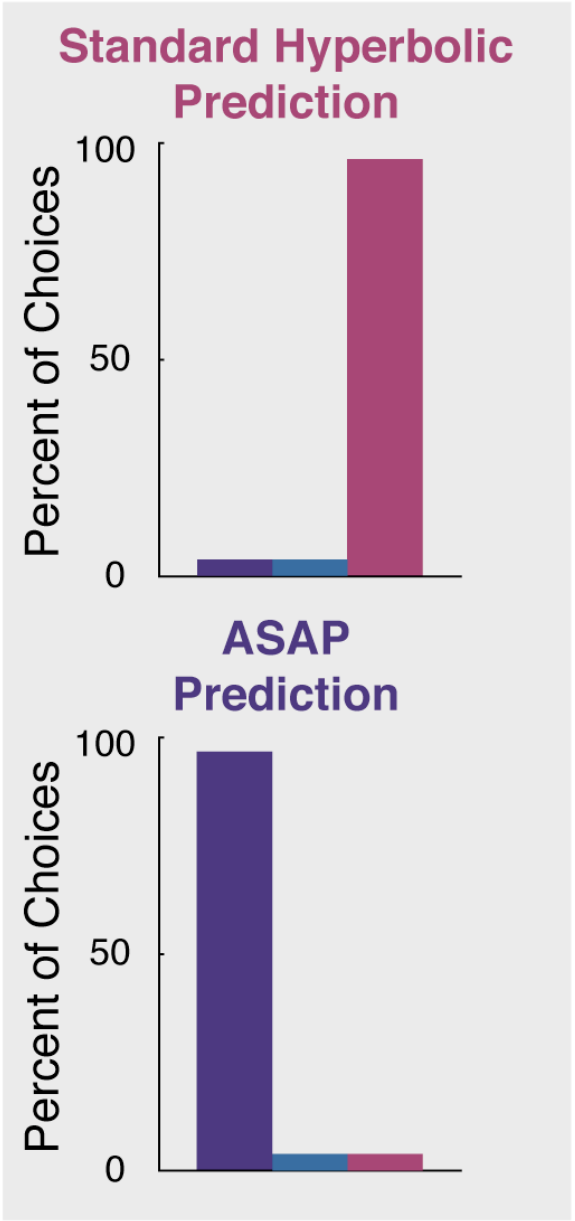
Group Behavior: Choices

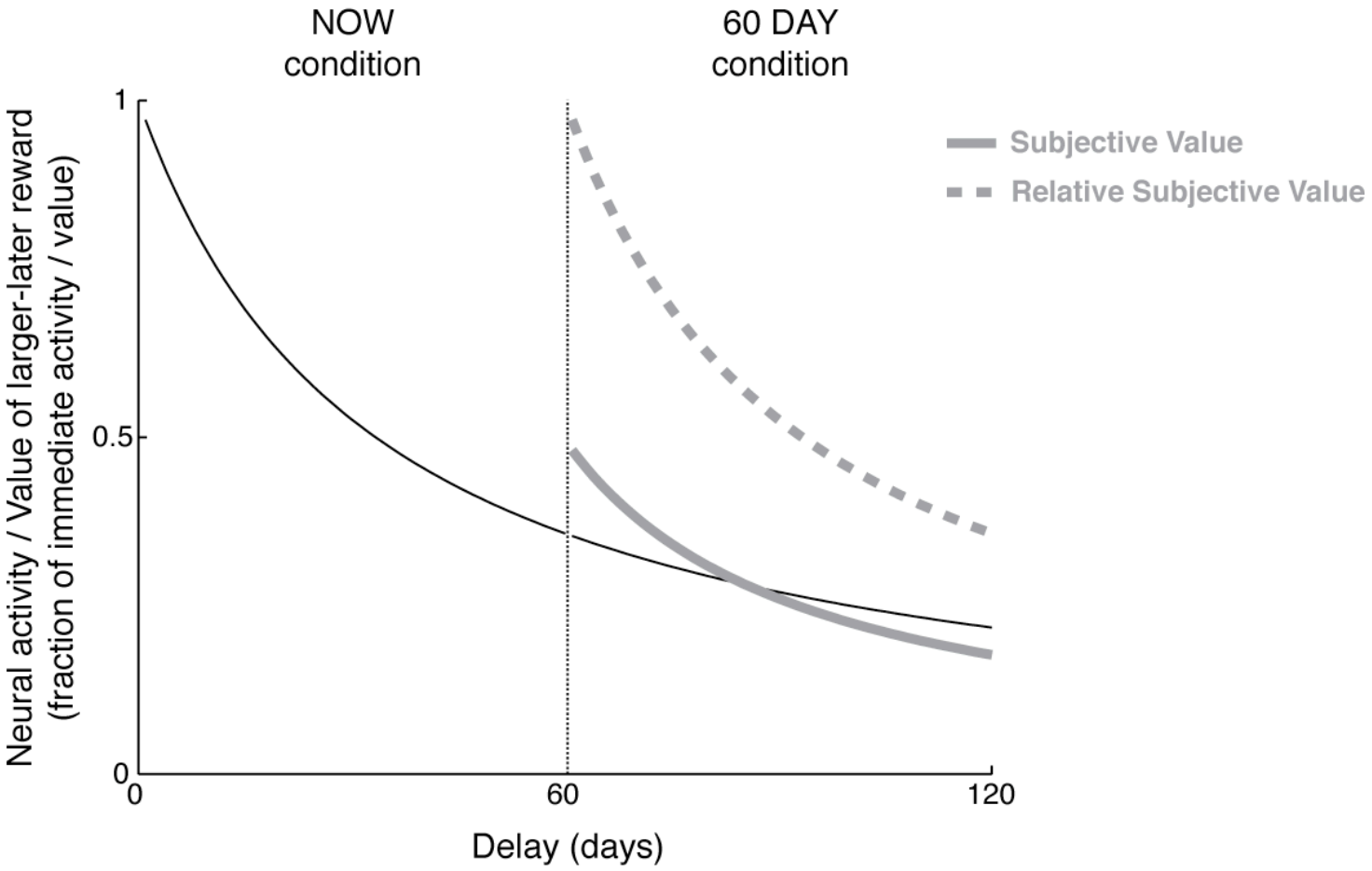




Group Behavior: Choices






NOW
condition
60 DAY
condition
Subjective Value
Relative Subjective Value
Neural activity / Value of larger-later reward
(fraction of immediate activity / value)
1
0.5
0
0
60
120
Delay (days)

Neural Results

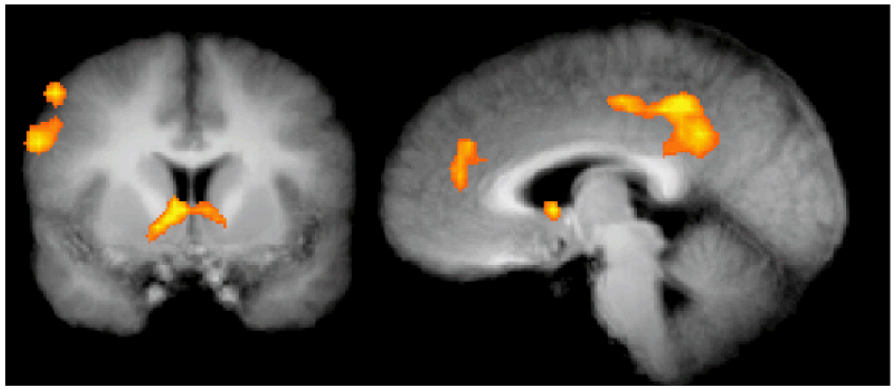
CORRELATIONS

Neural Results

CORRELATIONS

Relative Value, NOW?

YES



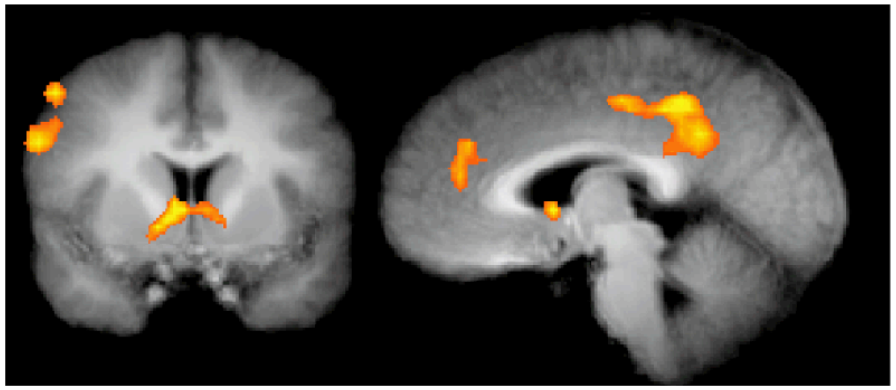
Random effects, n=22, TRs 4-6
Voxel-wise p<.005 (uncorr.), Cluster-wise p<.05 (corr.)

Neural Results

CORRELATIONS

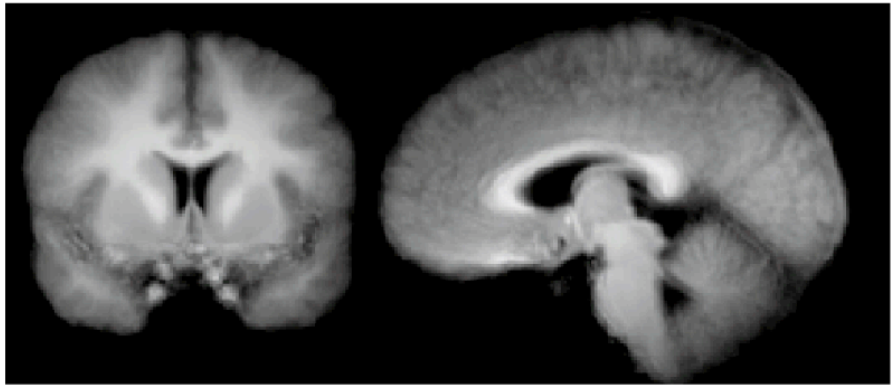
Relative Value, NOW?

YES



Relative Value, 60 DAY?

WEAK or NO



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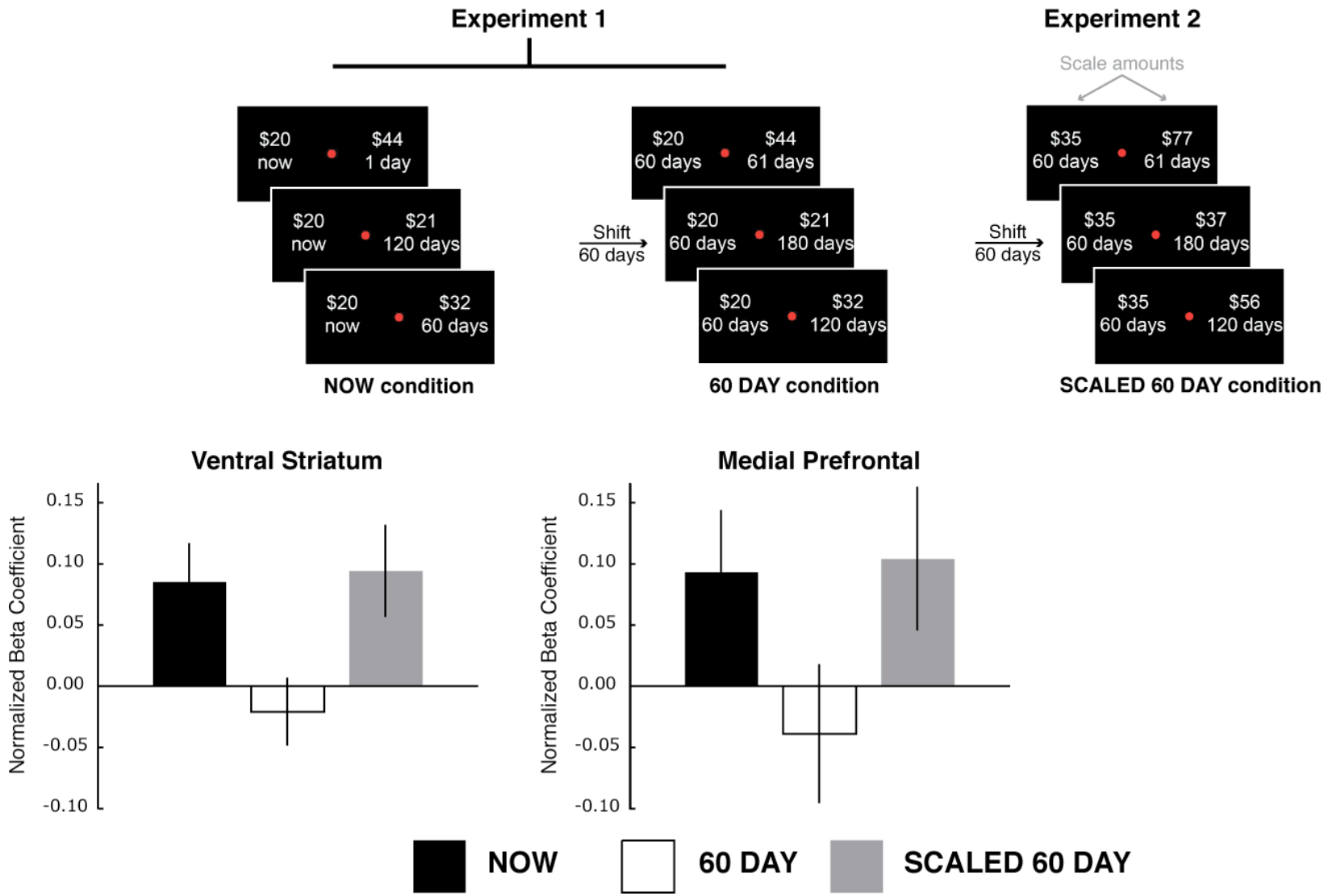
Experiment 1
$20 now
$44 1 day
$20 now
$21 120 days
$20 now
$32 60 days
NOW condition
Shift 60 days
$20 60 days
$44 61 days
$20 60 days
$21 180 days
$20 60 days
$32 120 days
60 DAY condition
Experiment 2
Scale amounts
Shift 60 days
$35 60 days
$77 61 days
$35 60 days
$37 180 days
$35 60 days
$56 120 days
SCALED 60 DAY condition
Ventral Striatum
Medial Prefrontal
Normalized Beta Coefficient
0.15
0.10
0.05
0.00
-0.05
-0.10
NOW
60 DAY
SCALED 60 DAY

But what happens when you move subjective value around?

Acknowledgements

NYU

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Cindy Kim

Khoi Vo