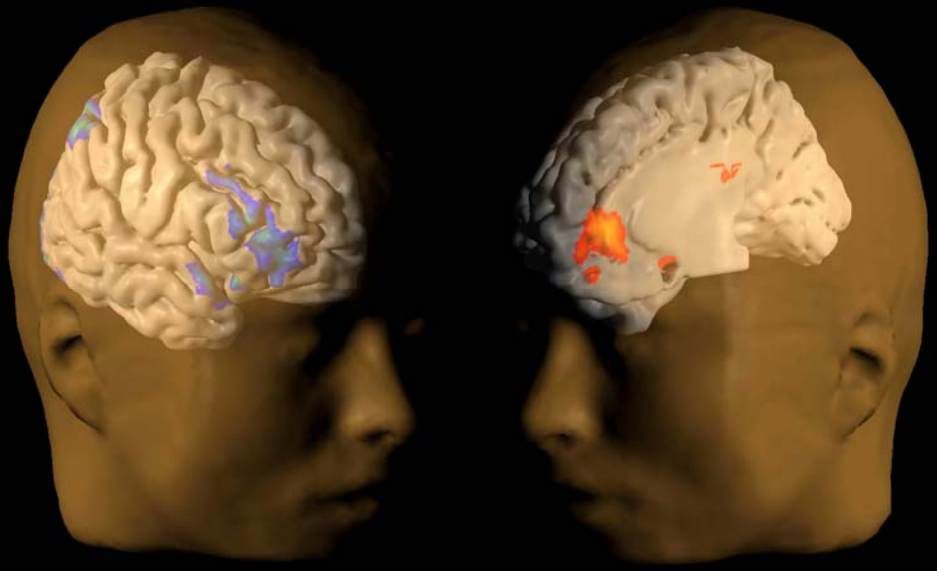
Neuroeconomics:
The Multiple Systems Hypothesis



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September 29, 2008

Neuroeconomics: definition.

Definition: Neuroeconomics is the study of the *biological microfoundations* of *economic cognition*.

- *Biological microfoundations* are neurochemical mechanisms and pathways, like brain systems, neurons, genes, and neurotransmitters.
- *Economic cognition* is cognitive activity that is associated with economic perceptions, beliefs and decisions, including mental representations, emotions, expectations, learning, memory, preferences, decision-making, and behavior.

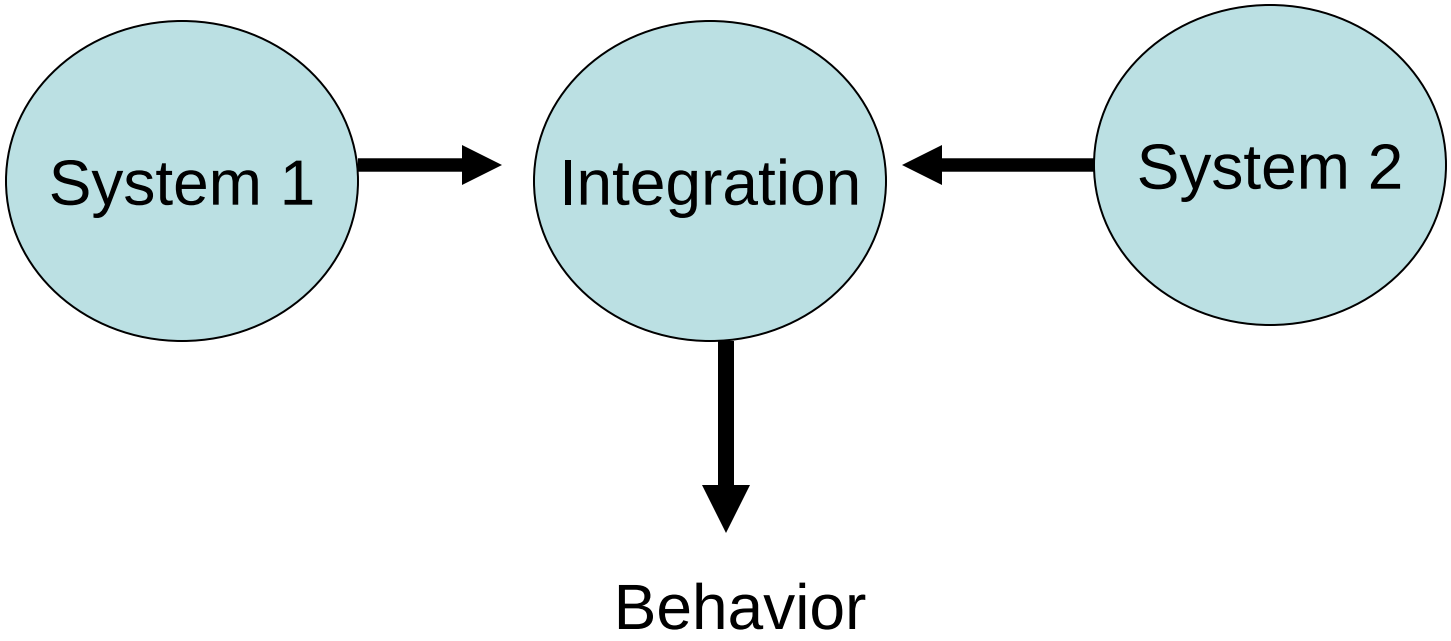
The Multiple Systems Hypothesis

- Statement of Hypothesis
- Variations on a theme
- Caveats
- Illustrative predictions
  - Cognitive load manipulations
  - Willpower manipulations
  - Affect vs. analytic manipulations
  - Cognitive Function
  - Development
  - Neuroimaging
- Directions for future research

Statement of Multiple Systems Hypothesis (MSH)

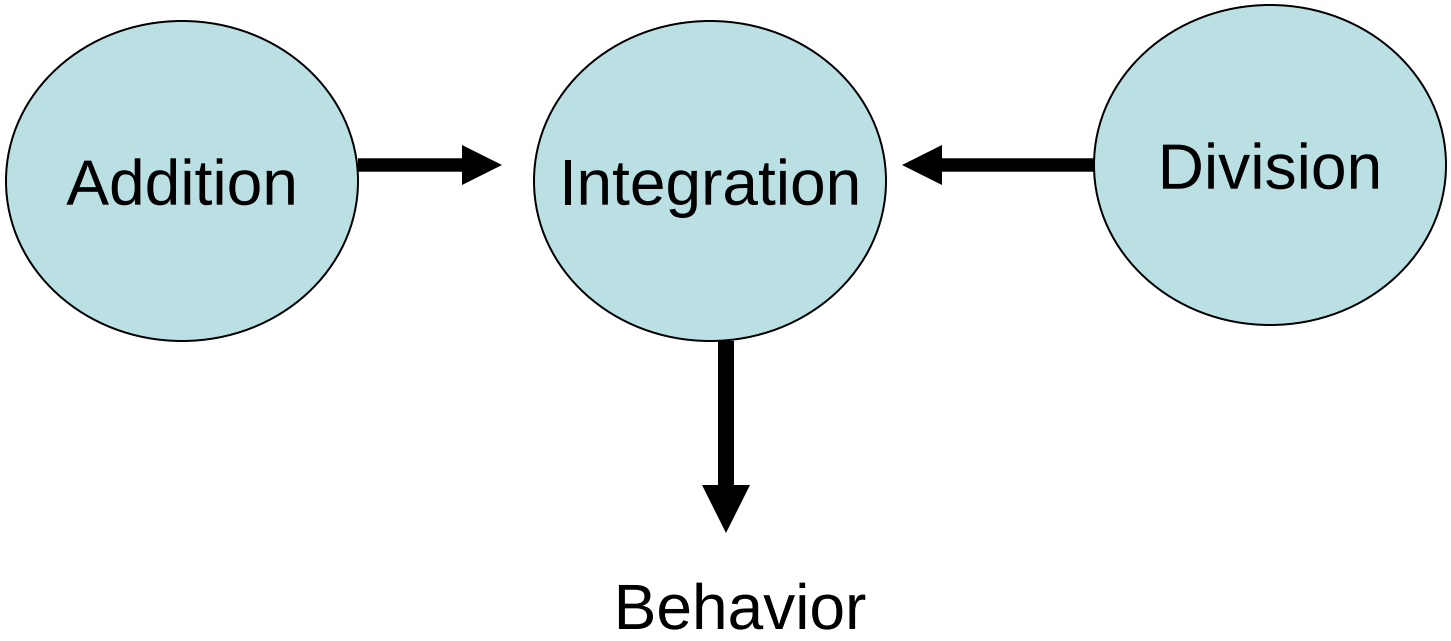
- The brain makes decisions (e.g. constructs value) by integrating signals from multiple systems
- These multiple systems process information in qualitatively different ways and in some cases differentially weight attributes of rewards (e.g., time delay)

An (oversimplified) multiple systems model



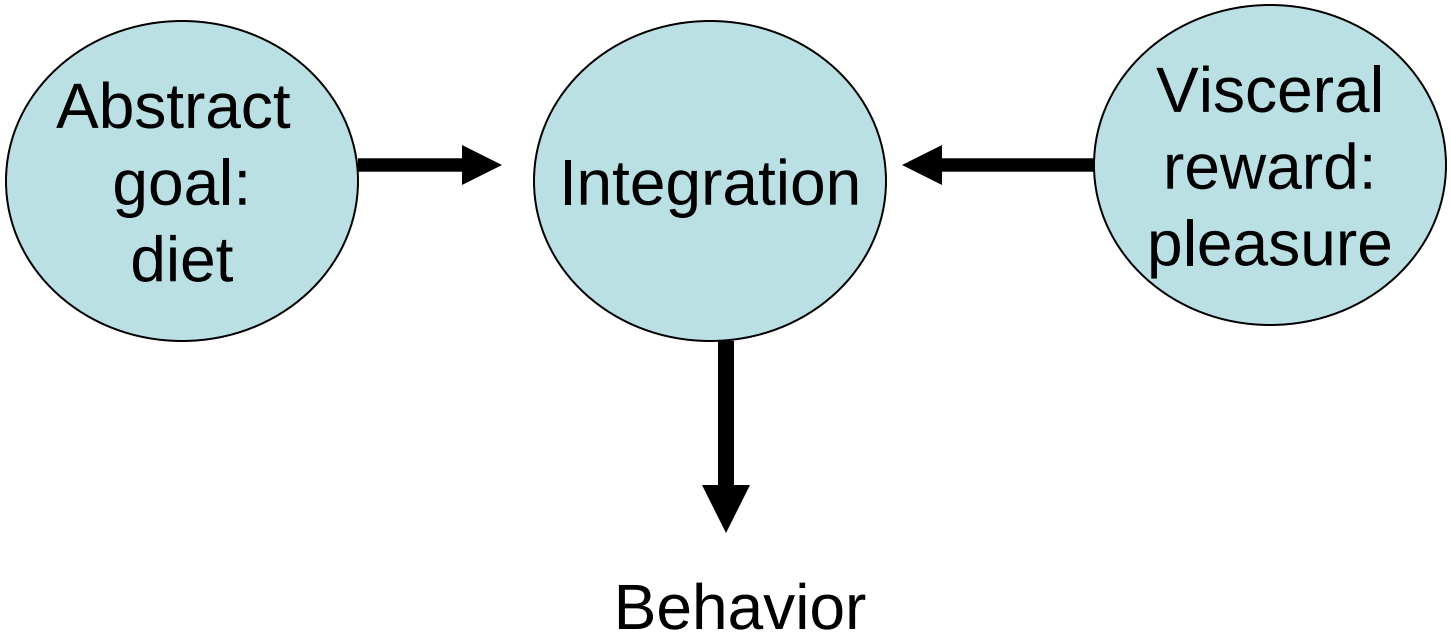
An uninteresting example

What is 6 divided by 3?



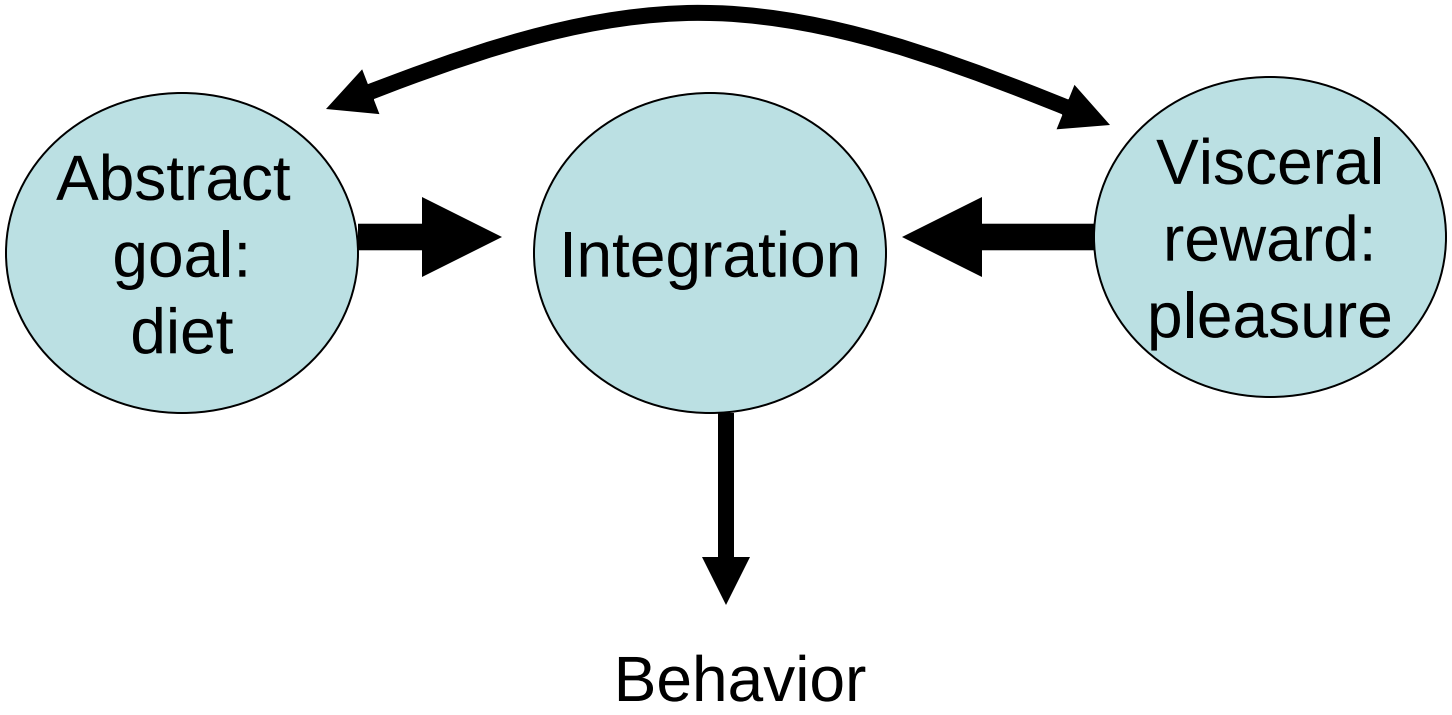
A more interesting example

Would you like a piece of chocolate?



A more interesting example

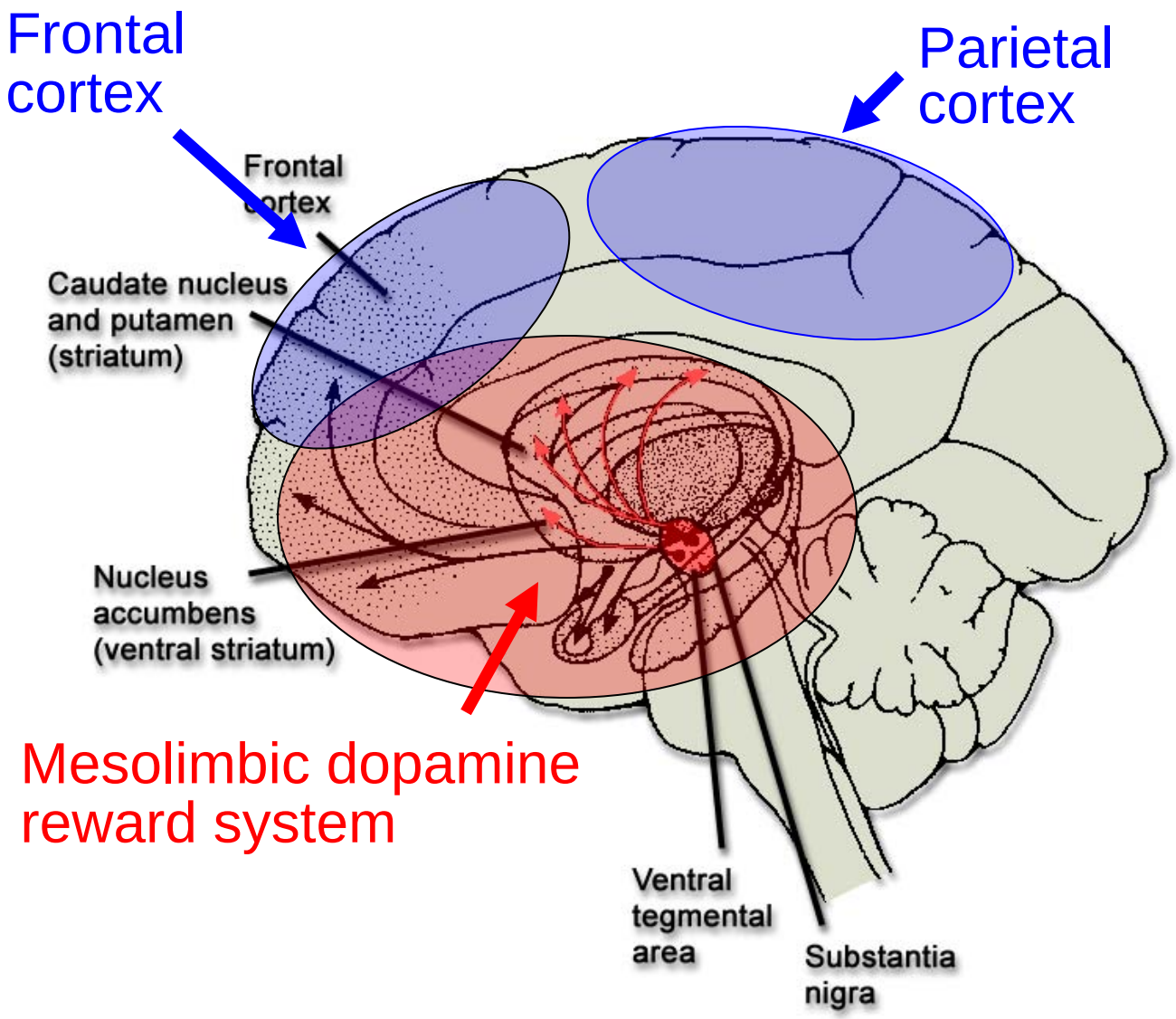
Would you like a piece of chocolate?



Variations on a theme

- Interests vs passions (Smith)
- Superego vs Ego vs Id (Freud)
- Controlled vs Automatic (Schneider & Shiffrin, 1977; Benhabib & Bisin, 2004)
- Cold vs Hot (Metcalfe and Mischel, 1979)
- System 2 vs System 1 (Frederick and Kahneman, 2002)
- Deliberative vs Impulsive (Frederick, 2002)
- Conscious vs Unconscious (Damasio, Bem)
- Effortful vs Effortless (Baumeister)
- Planner vs Doer (Shefrin and Thaler, 1981)
- Patient vs Myopic (Fudenburg and Levine, 2006)
- Abstract vs Visceral (Loewenstein & O'Donoghue 2006; Bernheim & Rangel, 2003)
- PFC & parietal cortex vs Mesolimbic dopamine (McClure et al, 2004)

Affective vs. Analytic Cognition



Commonalities between classification schemes

Affective system

- fast
- unconscious
- reflexive
- myopic

Analytic system

- slow
- conscious
- reflective
- forward-looking

Caveats

- $N \geq 2$
- The systems do not have well-defined boundaries (they are densely interconnected)
- Maybe we should not say “system,” but should instead say “multiple processes”
- Some systems may not have a value/utility representation
  - Making my diet salient is not the same as assigning utils/value to a Devil Dog
- If you look downstream enough, you’ll find what looks like an integrated system

Predictions

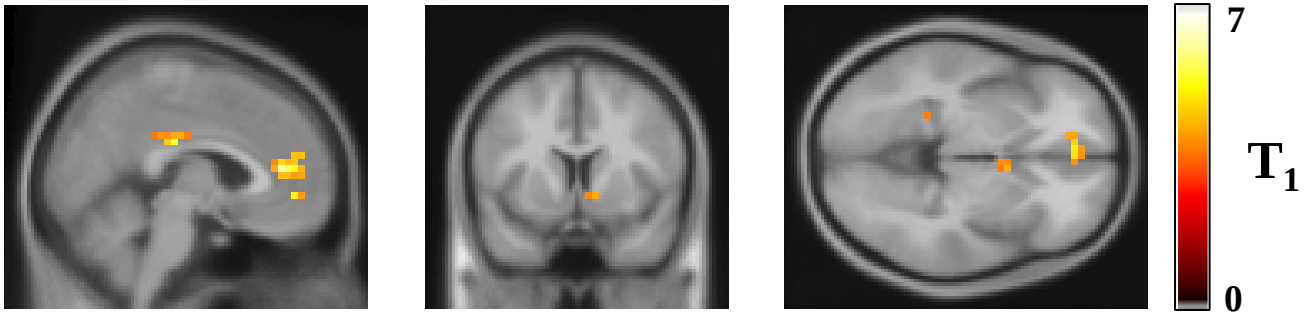
- **Cognitive Load Manipulations**
  - Shiv and Fedorikhin (1999), Hinson, Jameson, and Whitney (2003)
- **Willpower manipulations**
  - Baumeister and Vohs (2003)
- **Affect vs. analytic manipulations**
  - Rodriguez, Mischel and Shoda (1989)
- **Cognitive Function**
  - Benjamin, Brown, and Shapiro (2006), Shamosh and Gray (forth.)
- **Developmental Dynamics**
  - Green, Fry, and Myerson (1994), Krietler and Zigler (1990)
- **Neuroimaging Studies**
  - Tanaka et al (2004), McClure et al (2004), Hariri et al (2006), McClure et al (2007), Kabel and Glimcher (2007)

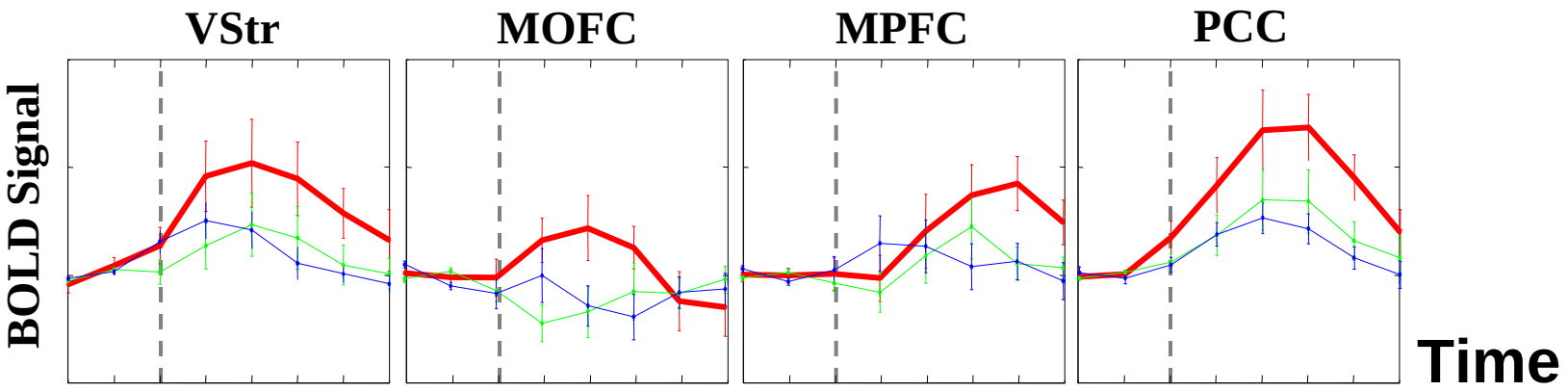
McClure, Laibson, Loewenstein, Cohen (Science, 2004)

- Intertemporal choice with time-dated Amazon gift certificates.
- Subjects make binary choices:

$20 now	**or**	**$30 in two weeks**
$20 in two weeks	**or**	**$30 in four weeks**
$20 in four weeks	**or**	**$30 in six weeks**

β areas respond "only" to immediate rewards



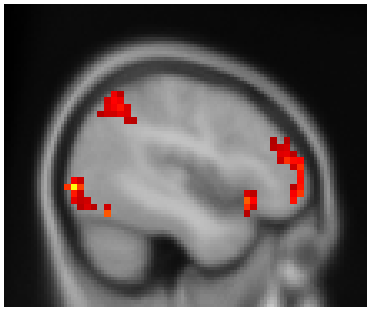


— $20 now or $30 in two weeks

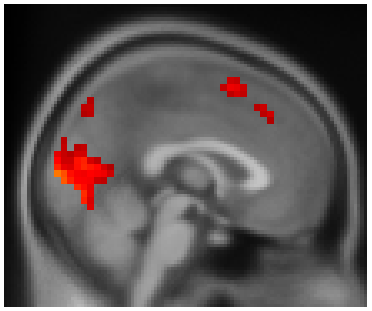
— $20 in two weeks or $30 in four weeks

— $20 in four weeks or $30 in six weeks

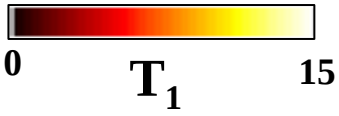
δ Areas respond equally to all rewards

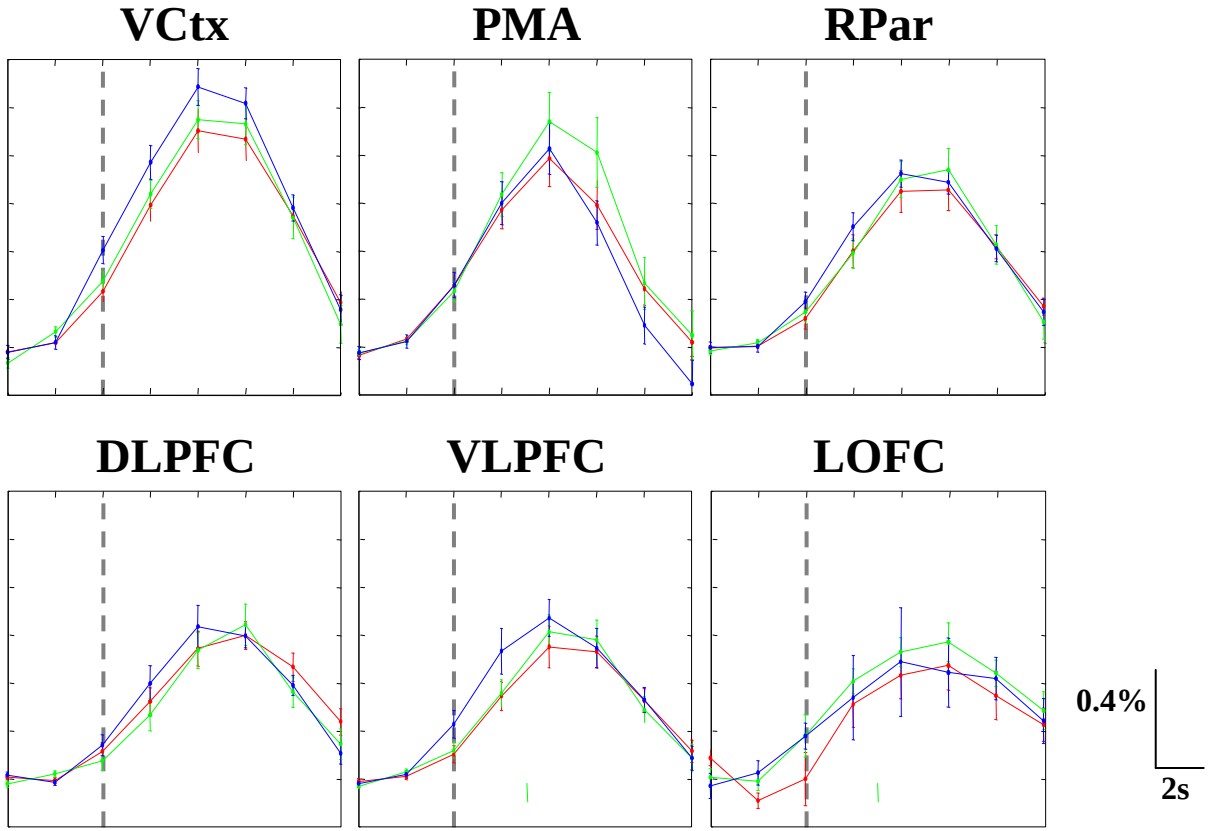


x = 44mm



x = 0mm



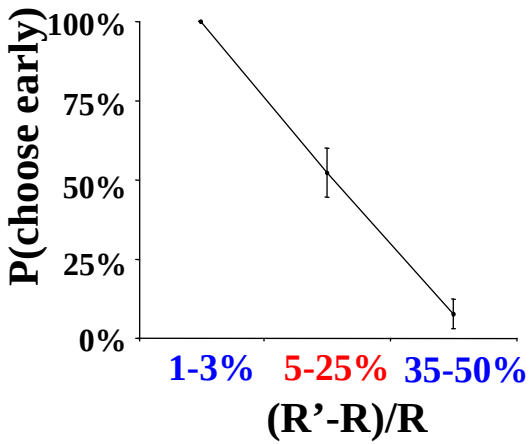


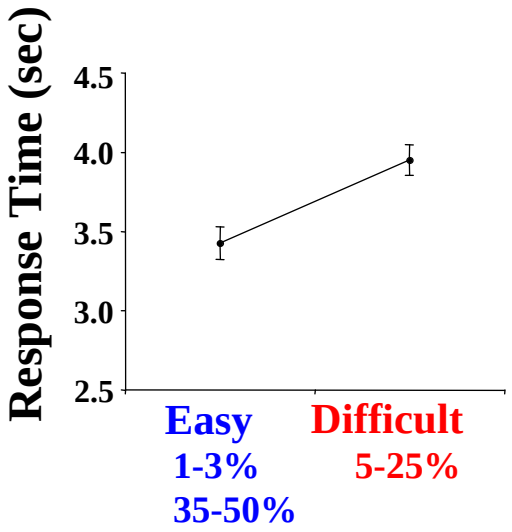
— $20 now or $30 in two weeks

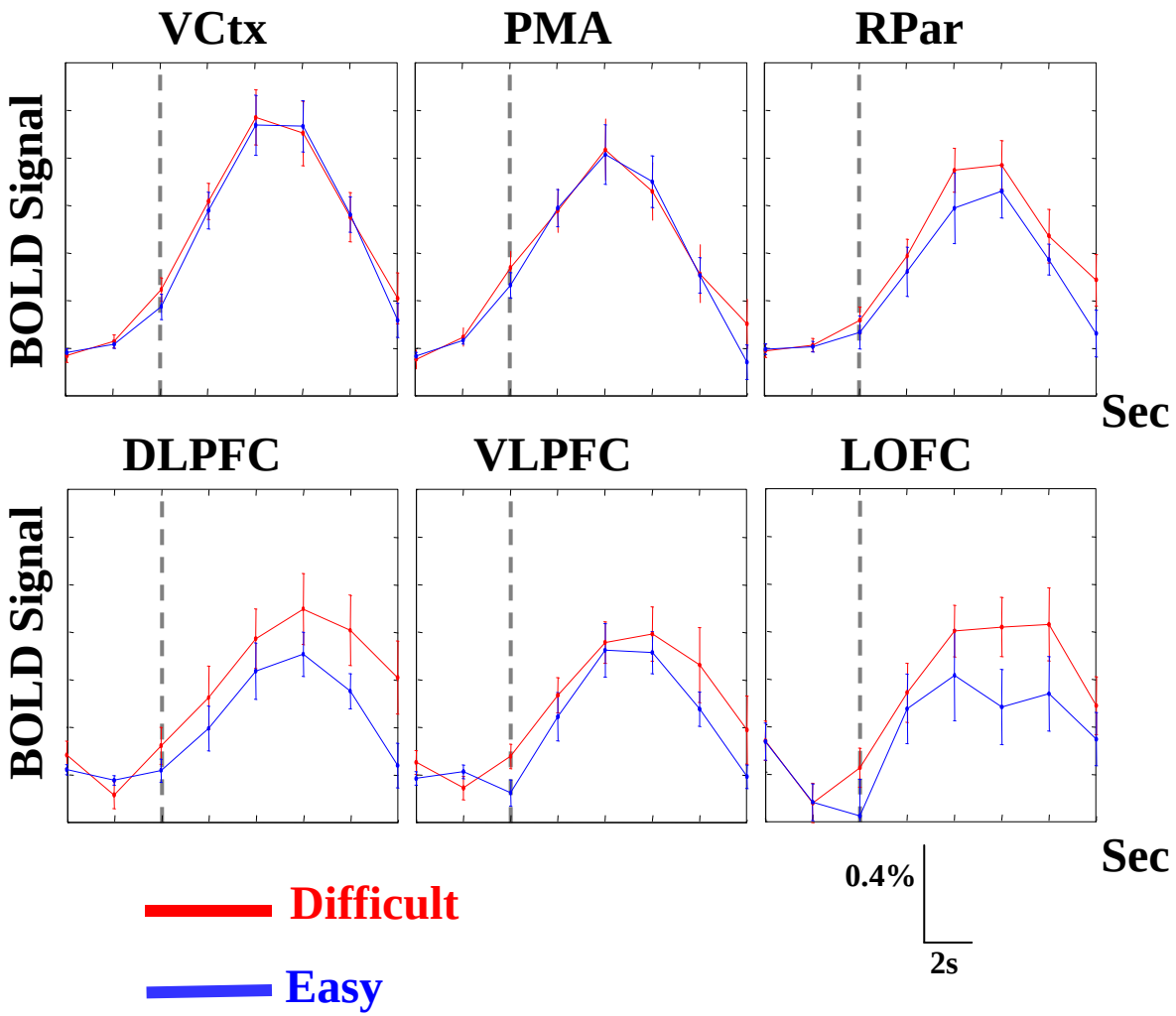
— $20 in two weeks or $30 in four weeks

— $20 in four weeks or $30 in six weeks

Effect of Difficulty

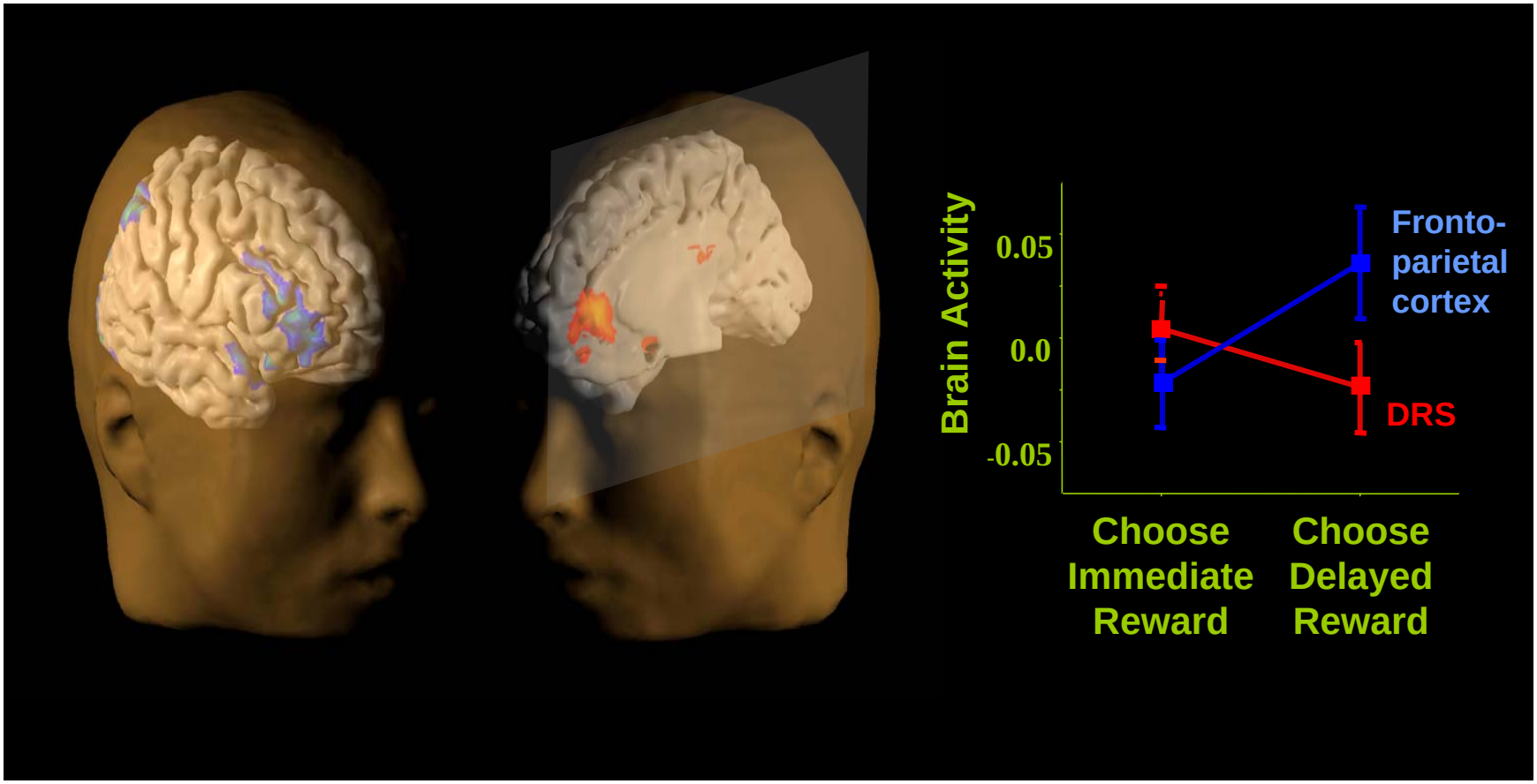






Brain activity in the frontoparietal system and mesolimbic dopamine reward system predict behavior

(Data for choices with an immediate option.)



McClure, Ericson, Laibson, Loewenstein, Cohen (Journal of Neuroscience, 2007)

Subjects water deprived for 3hr prior to experiment

(a subject scheduled for 6:00)

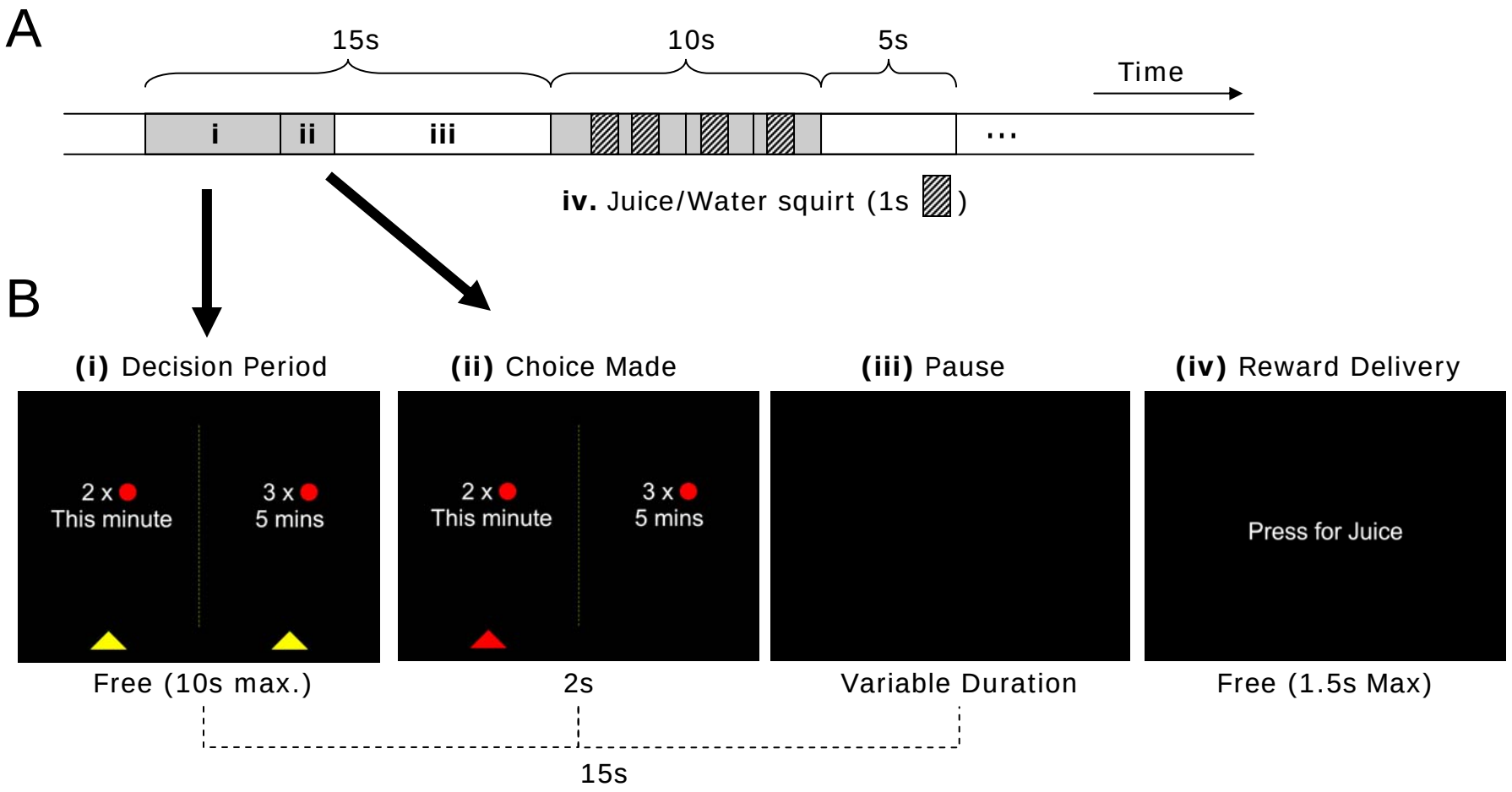
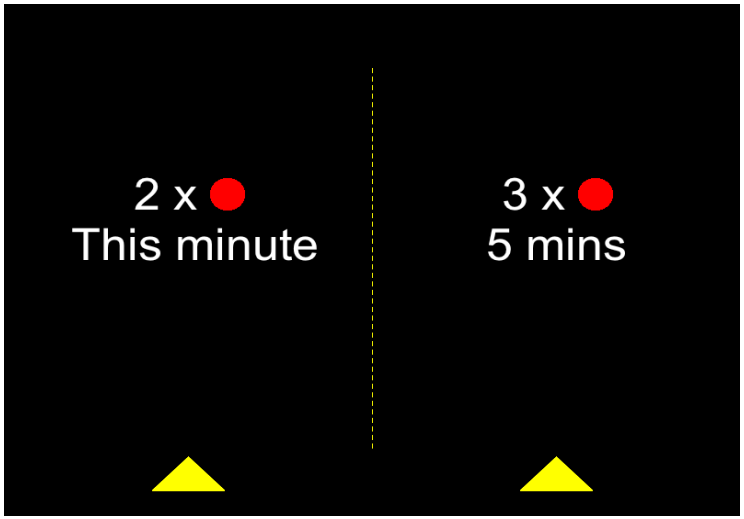

A
15s
10s
5s
Time
i
ii
iii
...
iv. Juice/Water squirt (1s)
B
(i) Decision Period
(ii) Choice Made
(iii) Pause
(iv) Reward Delivery
2 x
This minute
3 x
5 mins
2 x
This minute
3 x
5 mins
Press for Juice
Free (10s max.)
2s
Variable Duration
Free (1.5s Max)
15s

Figure 1

Experiment Design

d $\in$ { This minute, 10 minutes, 20 minutes }
d'-d $\in$ { 1 minute, 5 minutes }
(R, R') $\in$ {(1,2), (1,3), (2,3)}

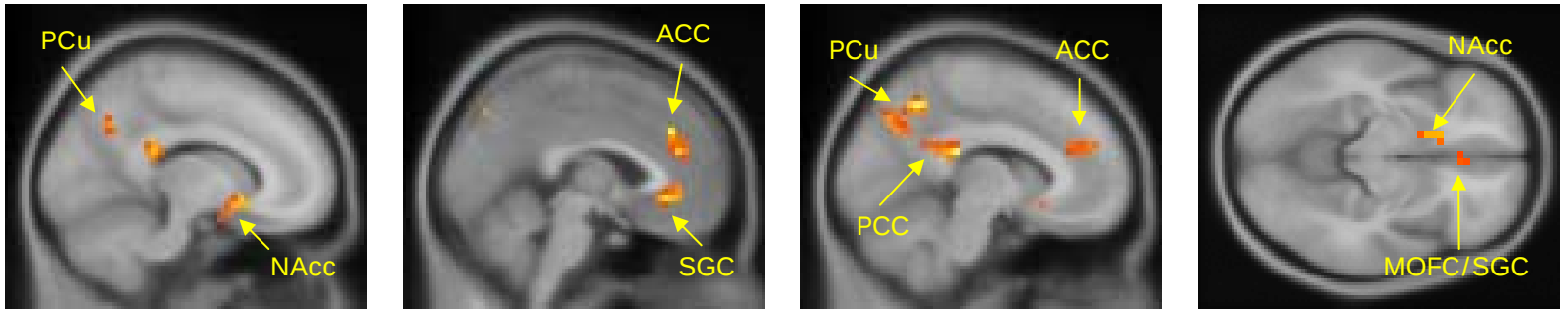


d = This minute
d'-d = 5 minutes
(R, R') = (2,3)

Neuroimaging data estimated with general linear model.

A

β areas: respond only to immediate rewards



B

δ areas: respond to all rewards

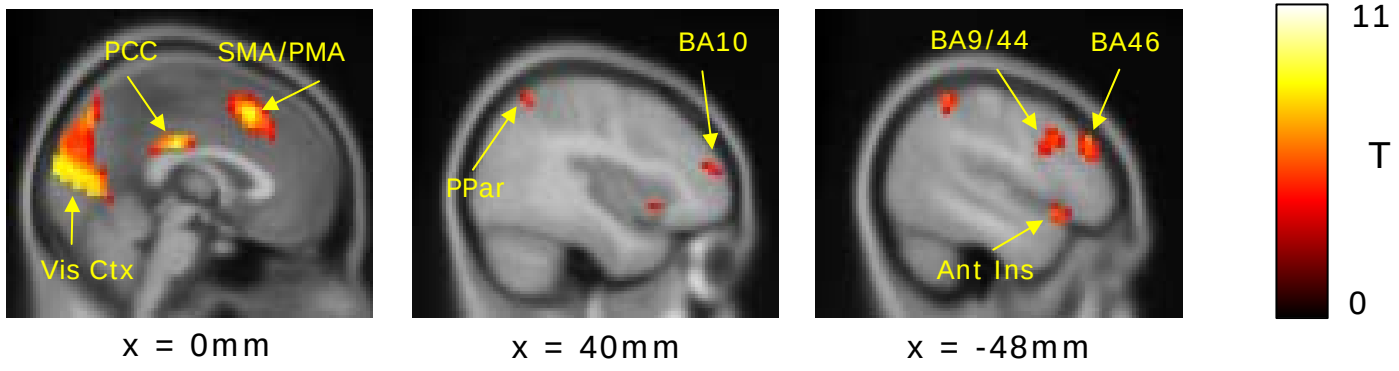
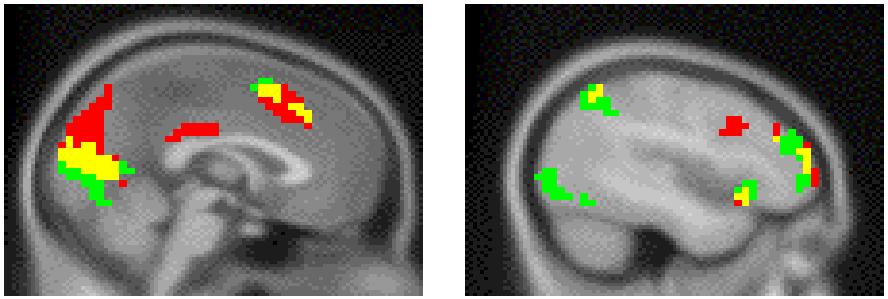


Figure 4

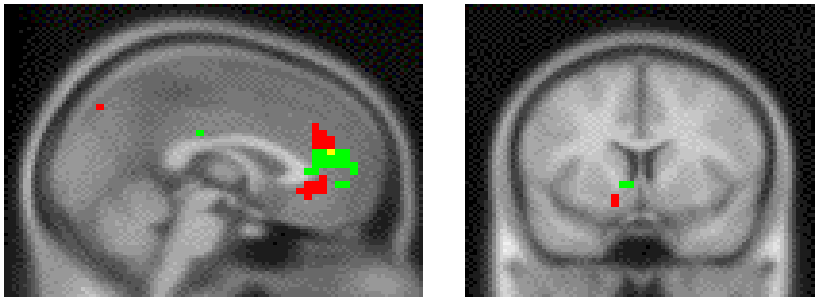
Relationship to Amazon experiment:

δ areas ($p < 0.001$)



x = 0mm x = -48mm

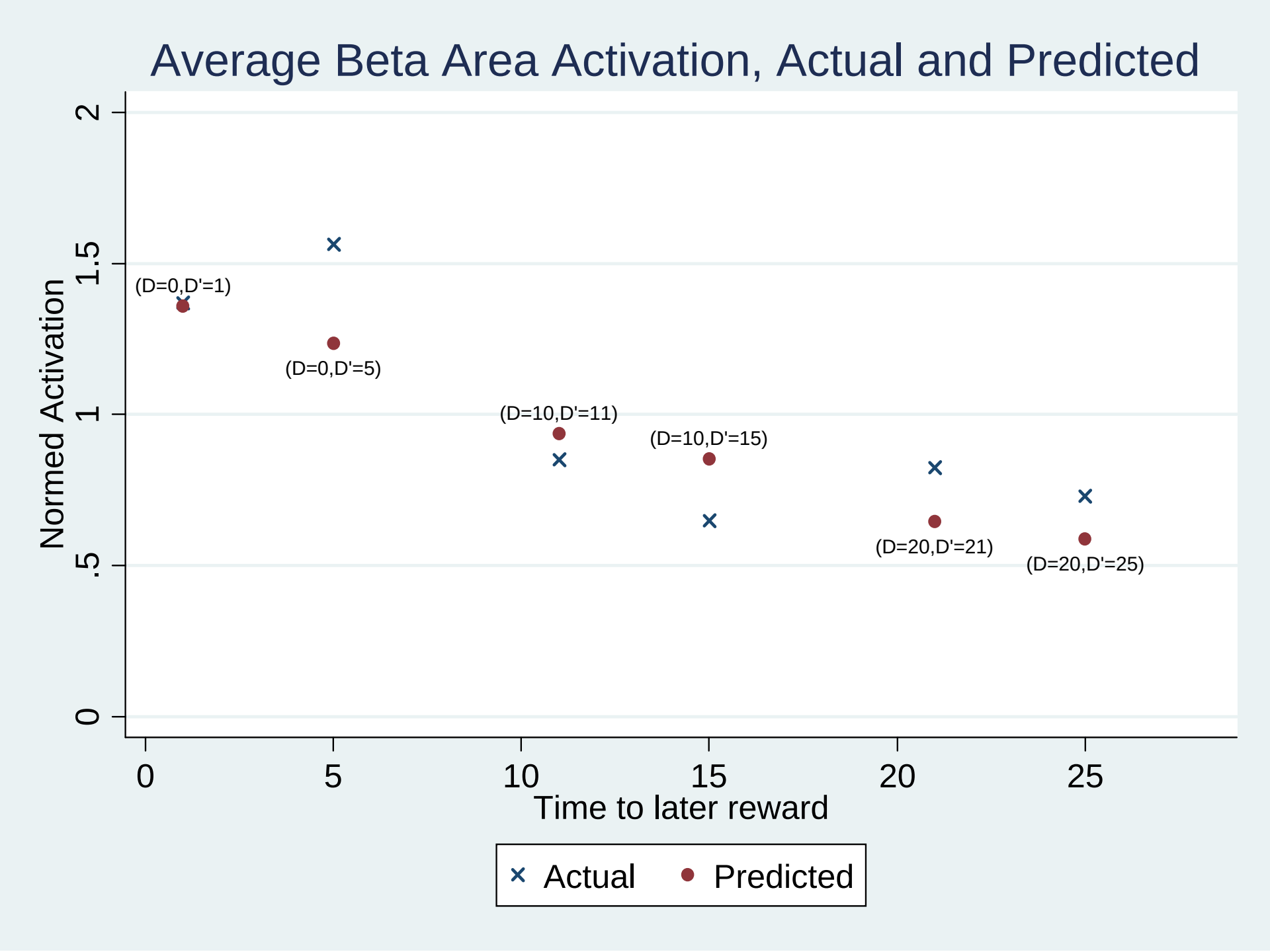
β areas ($p < 0.001$)

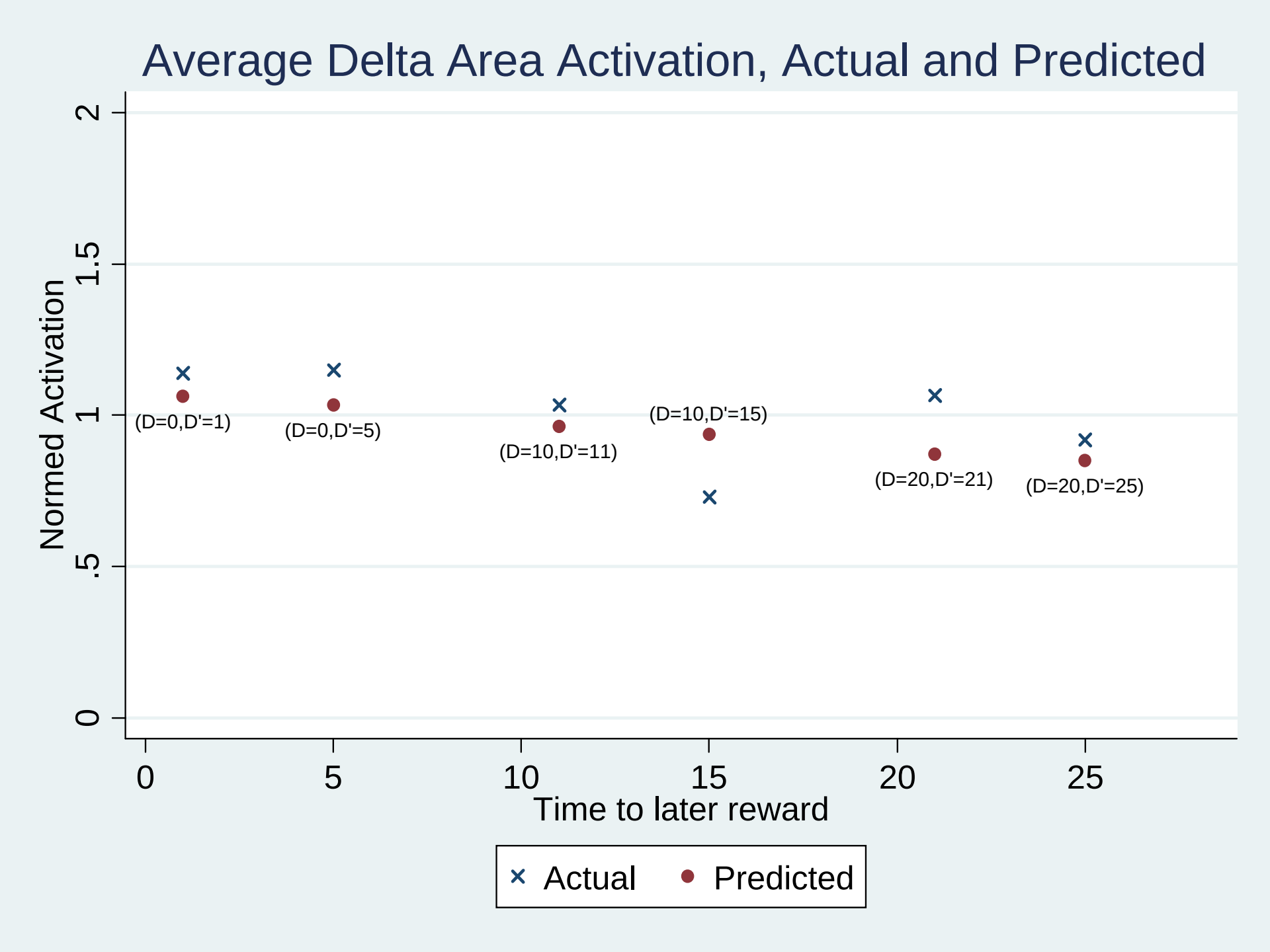


x = 0mm y = 8mm

Primary only Money only Both

Figure 5


Average Beta Area Activation, Actual and Predicted
Normed Activation
0
.5
1
1.5
2
0
5
10
15
20
25
Time to later reward
(D=0,D'=1)
(D=0,D'=5)
(D=10,D'=11)
(D=10,D'=15)
(D=20,D'=21)
(D=20,D'=25)
Actual
Predicted


Average Delta Area Activation, Actual and Predicted
Normed Activation
0
.5
1
1.5
2
0
5
10
15
20
25
Time to later reward
(D=0,D'=1)
(D=0,D'=5)
(D=10,D'=11)
(D=10,D'=15)
(D=20,D'=21)
(D=20,D'=25)
Actual
Predicted

Future work:

1. Are multiple system models a useful way of generating new hypotheses and models?
2. Are these systems localized? If so, where?
3. How do the systems communicate?
4. How are the inputs integrated?
5. When are the systems cooperative and when conflictual?
6. When they are in conflict, are they strategic?
7. What manipulations enhance or weaken the signals coming from these systems?
8. Can we influence individual systems in the lab?
9. Can we influence individual systems in the field?
10. Can we produce useful formalizations of their operation?