



Individual and Social Decision-Making in the Brain

Ming Hsu

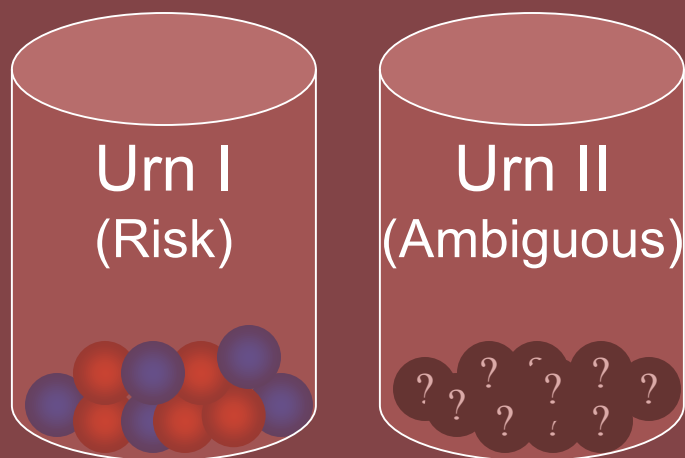




Plan

- Two studies: individual and social decision-making
 - Ellsberg Paradox
 - Other-regarding Preferences: Tradeoff between equity and efficiency

Choose Between Urns



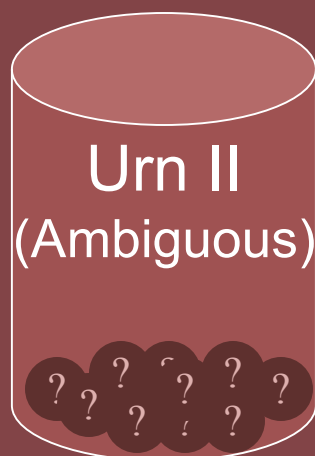
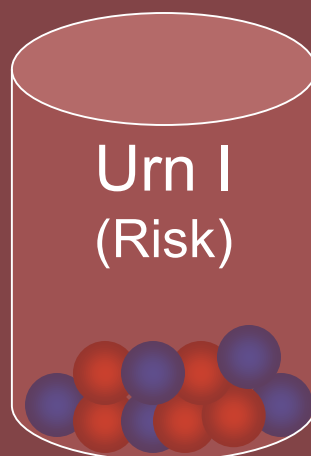
Many people prefer betting on Urn I over Urn II.

Ellsberg Paradox

$$P(\text{Red}_I) = P(\text{Blue}_I)$$

$$P(\text{Red}_I) = 0.5$$

$$P(\text{Blue}_I) = 0.5$$



$$P(\text{Red}_{II}) = P(\text{Blue}_{II})$$

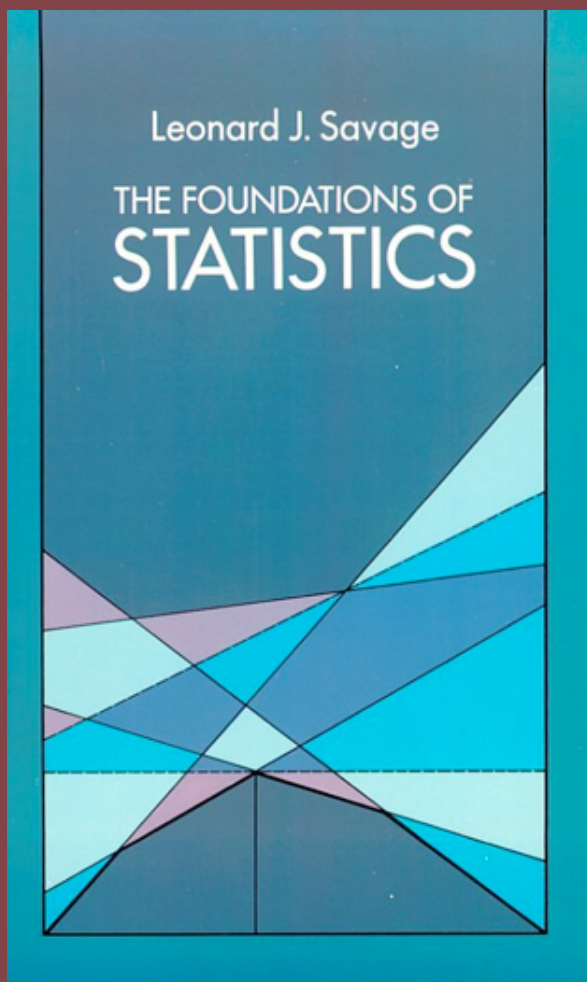
$$P(\text{Red}_{II}) < 0.5$$

$$P(\text{Blue}_{II}) < 0.5$$

$$P(\text{Red}_I) + P(\text{Blue}_I) = 1$$

$$P(\text{Red}_{II}) + P(\text{Blue}_{II}) = 1$$

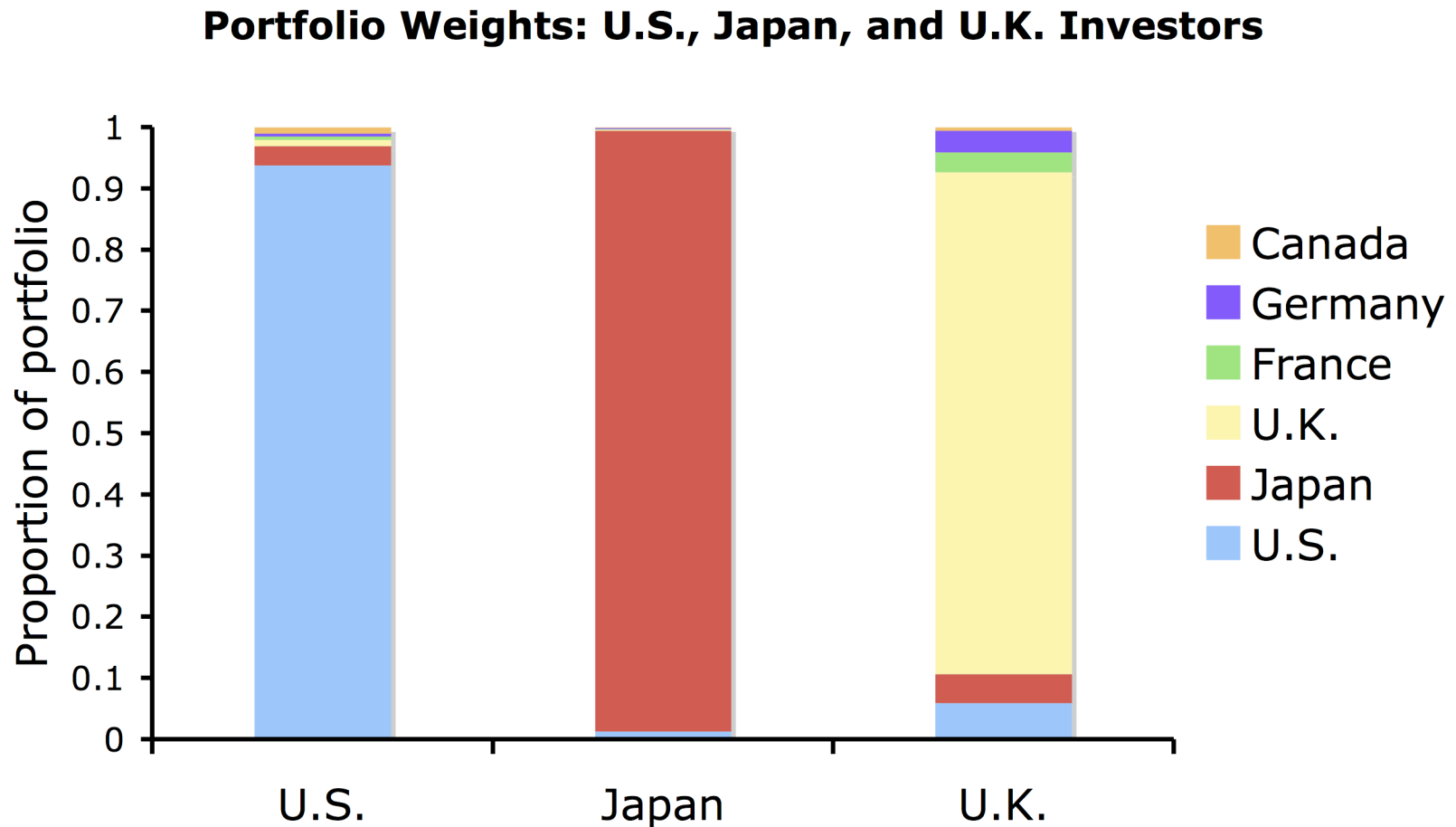
Where Is The Paradox?



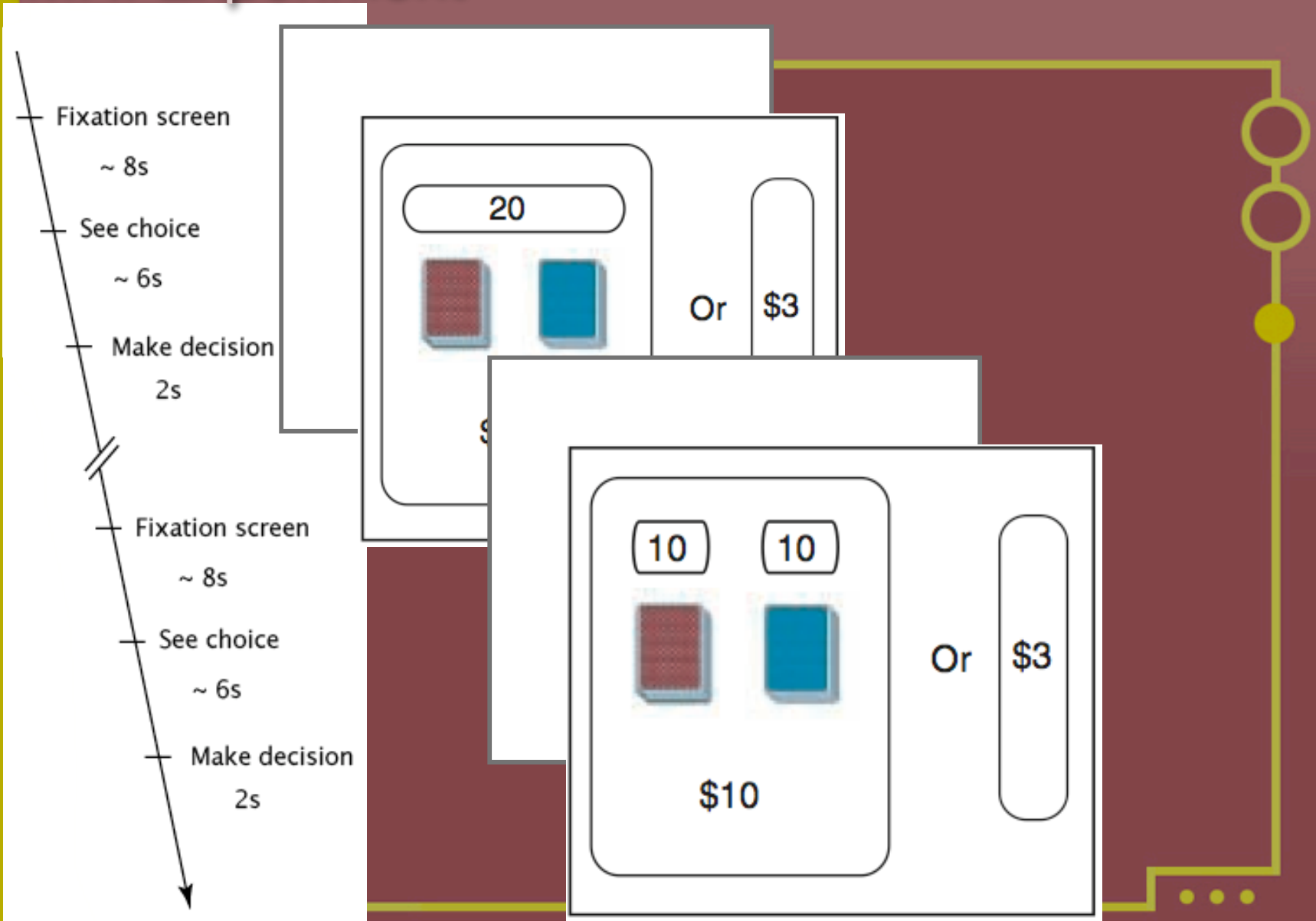
“...sadly but persistently, having looked into their hearts, found conflict with the axioms and decided ... **to satisfy their preferences and let the axioms satisfy themselves.**”

--Daniel Ellsberg, Quarterly Journal of Economics (1961)

Verizon or Deutsche Telecom?



fMRI Experiment



fMRI Experiment

The high temperature in Dushanbe, Tajikistan on November 7, 2003 is above 50 Fahrenheit.

Yes No

\$10

Or \$3

The high temperature in New York City, NY on November 7, 2003 is above 50 Fahrenheit.

Yes No

\$10

Or \$3

fMRI Experiment

Your opponent will draw 3

20




Or \$3

\$10

This panel shows a choice between two options. On the left, a rounded rectangle contains a score of '20' at the top, two cards (one red, one blue) in the middle, and '\$10' at the bottom. To the right of this rectangle is the word 'Or' followed by a vertical rounded rectangle containing '\$3'.

Your opponent will draw 0

20



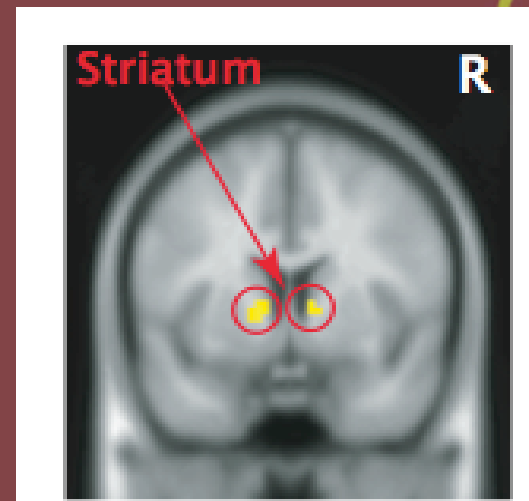
Or \$3

\$10

This panel shows a choice between two options. On the left, a rounded rectangle contains a score of '20' at the top, two cards (one red, one blue) in the middle, and '\$10' at the bottom. To the right of this rectangle is the word 'Or' followed by a vertical rounded rectangle containing '\$3'.

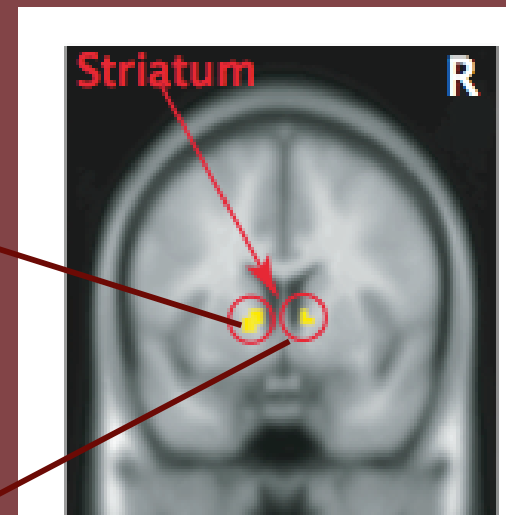
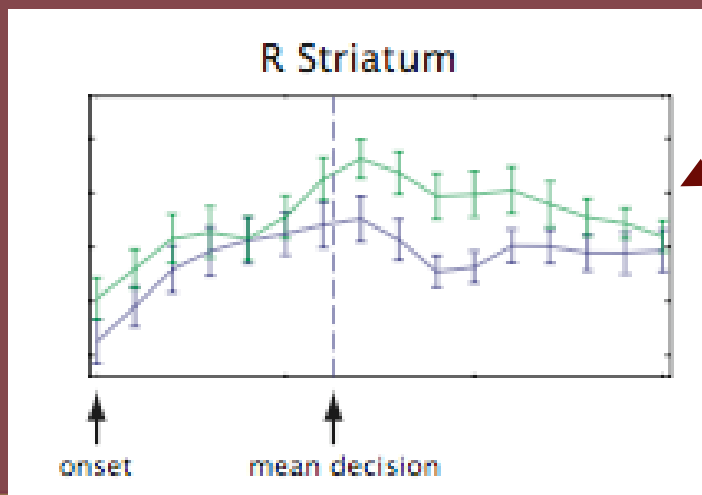
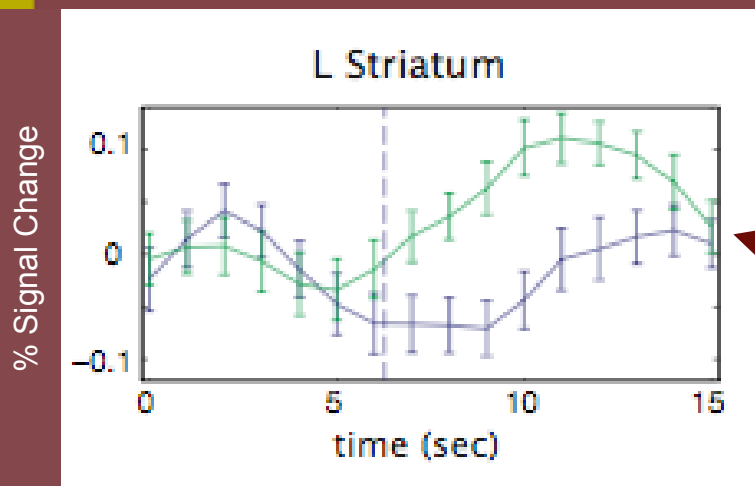
Expected Reward Region

$$y_{i,j}^{t,v} = \alpha + \beta^{amb} A(i,j,t) + \beta^{risk} R(i,j,t) + \delta E(i,j,t) + \pi W(i,j,t,v) + \varepsilon_{i,j}^{t,v}$$



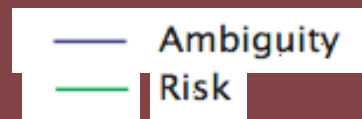
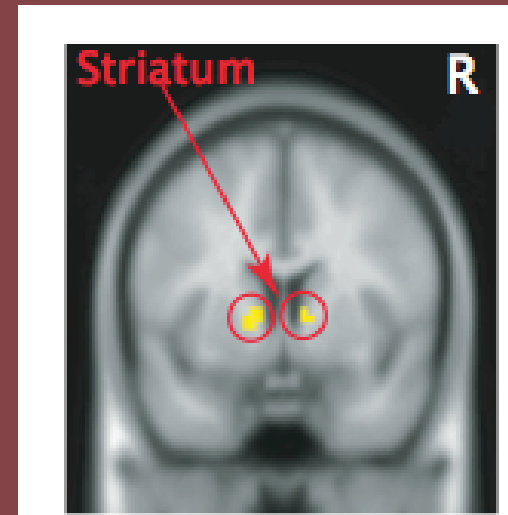
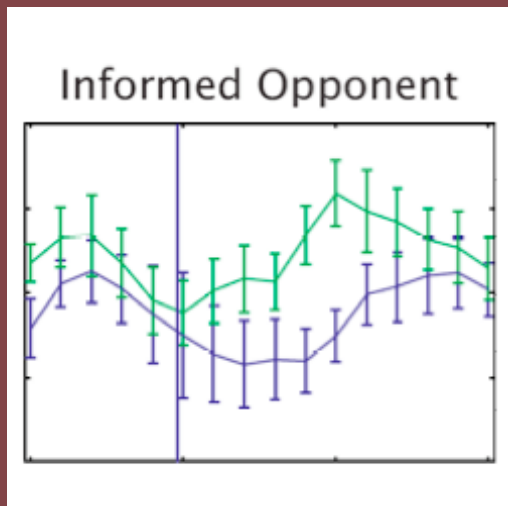
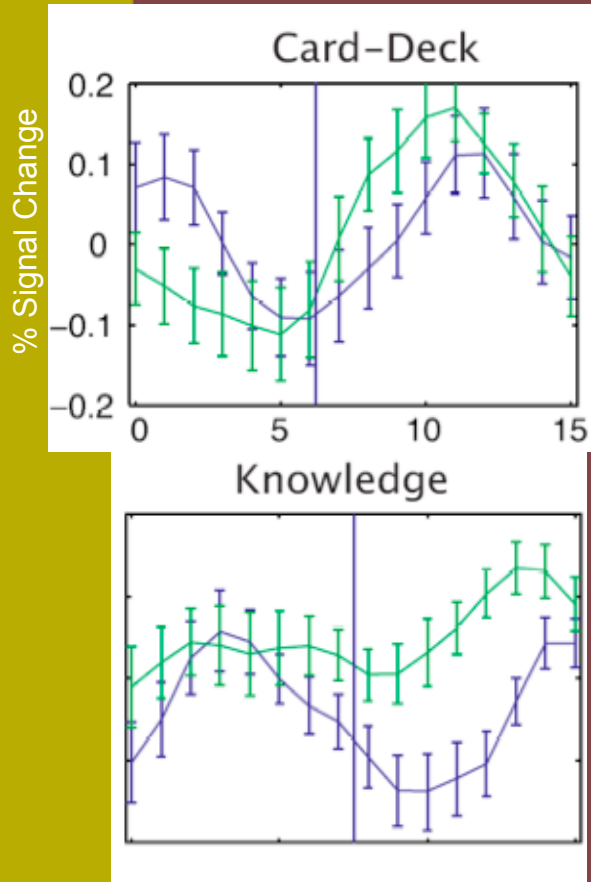
- y - Brain response
- $A(.)$ - Ambiguity trials
- $R(.)$ - Risk trials
- $E(.)$ - Expected value of choices
- $W(.)$ - Nuisance parameters

Lower Activity under Ambiguity



Ambiguity
Risk

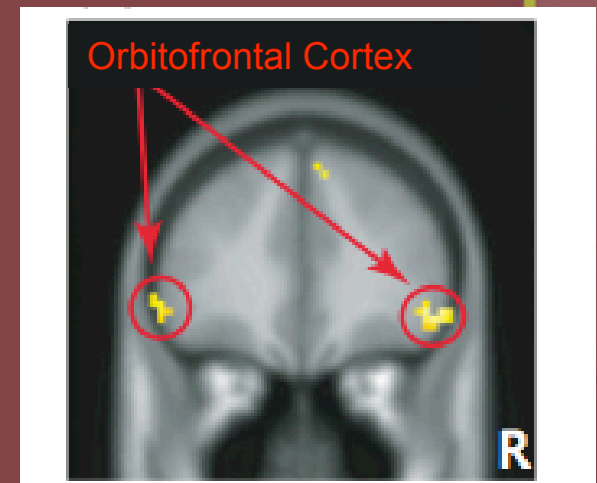
Lower Activity under Ambiguity



Region Reacting to Uncertainty

$$y_{i,j}^{t,v} = \alpha + \beta^{amb} A(i,j,t) + \beta^{risk} R(i,j,t) + \delta E(i,j,t) + \pi W(i,j,t,v) + \varepsilon_{i,j}^{t,v}$$

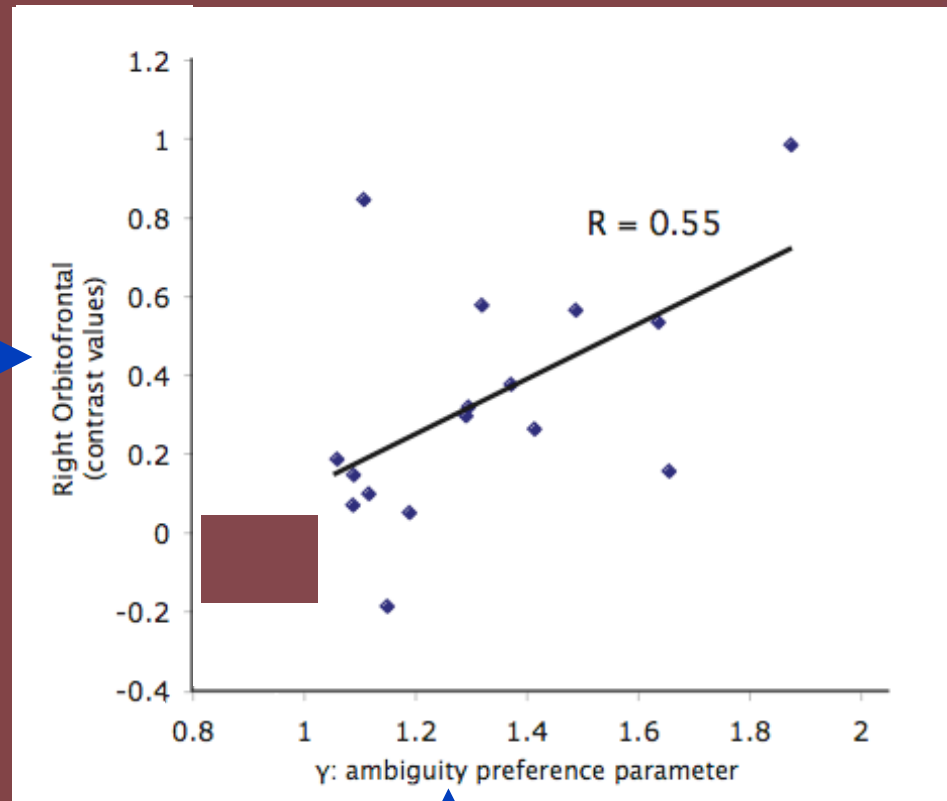
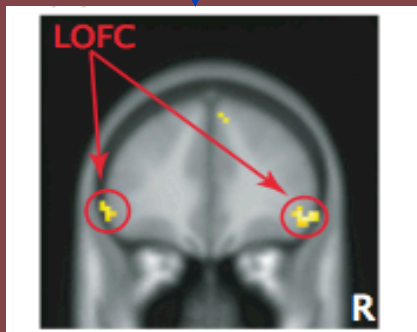
- y - Brain response
- $A(.)$ - Ambiguity trials
- $R(.)$ - Risk trials
- $E(.)$ - Expected value of choices
- $W(.)$ - Nuisance parameters



N.B. This region **does not** correlate with expected reward.

Link Between Brain and Behavior

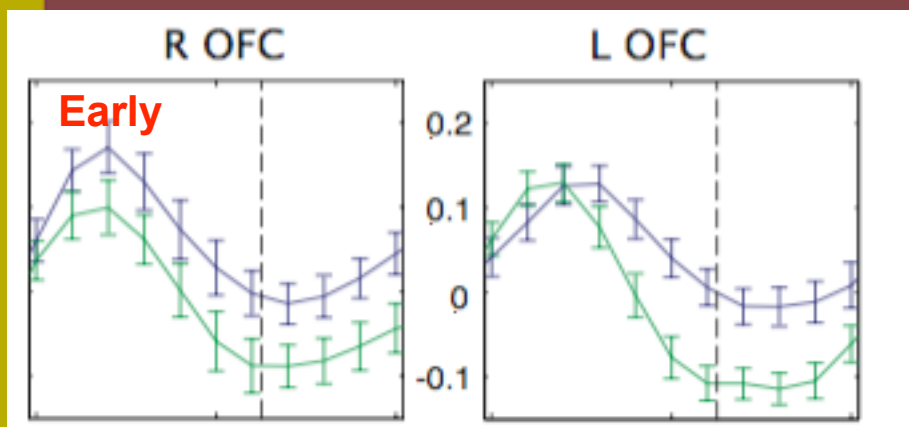
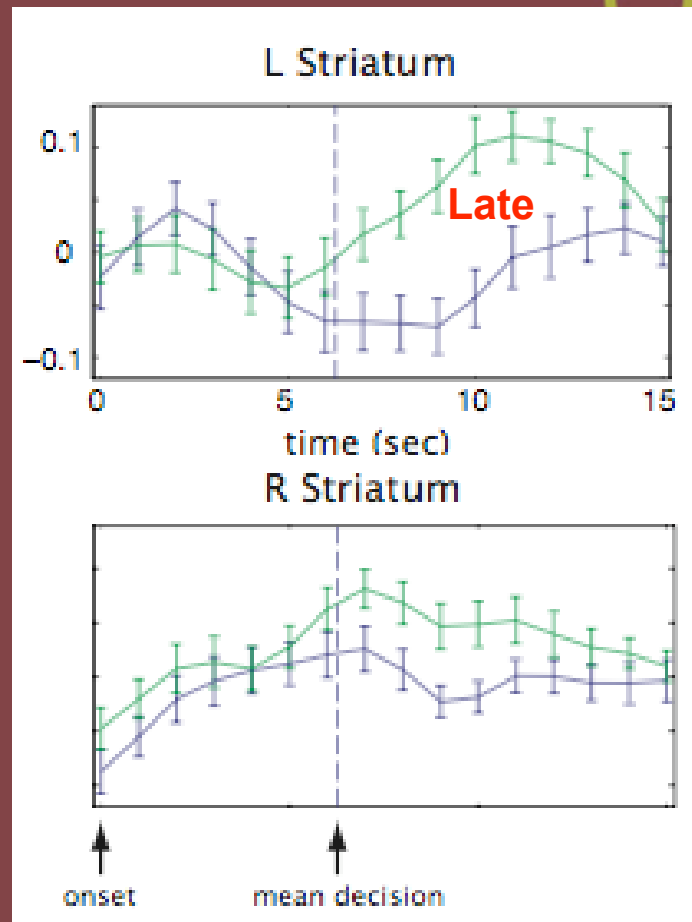
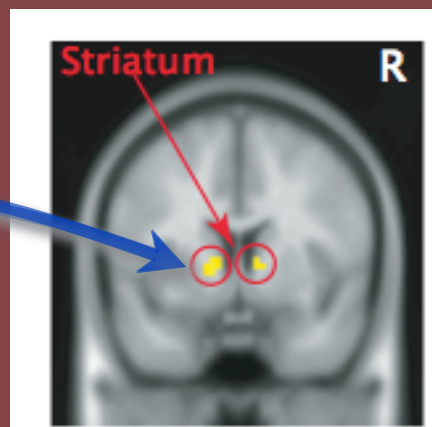
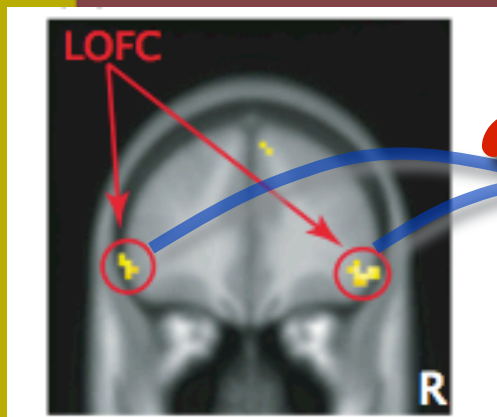
Brain Imaging Data



Behavioral Choice Data

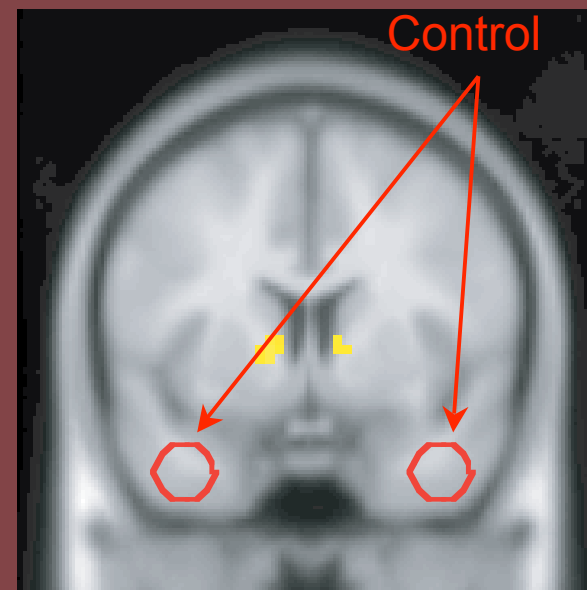
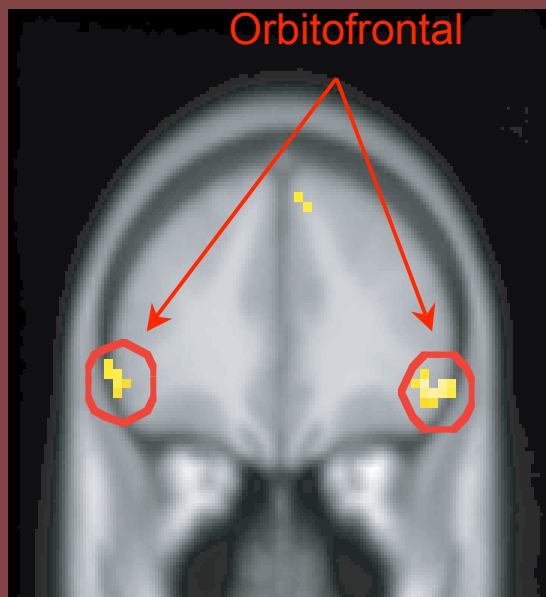
Stochastic Choice Model

A Signal for Uncertainty?



— Ambiguity
— Risk

Lesion Subjects



Lesion Experiment



100 Cards
50 Red
50 Black



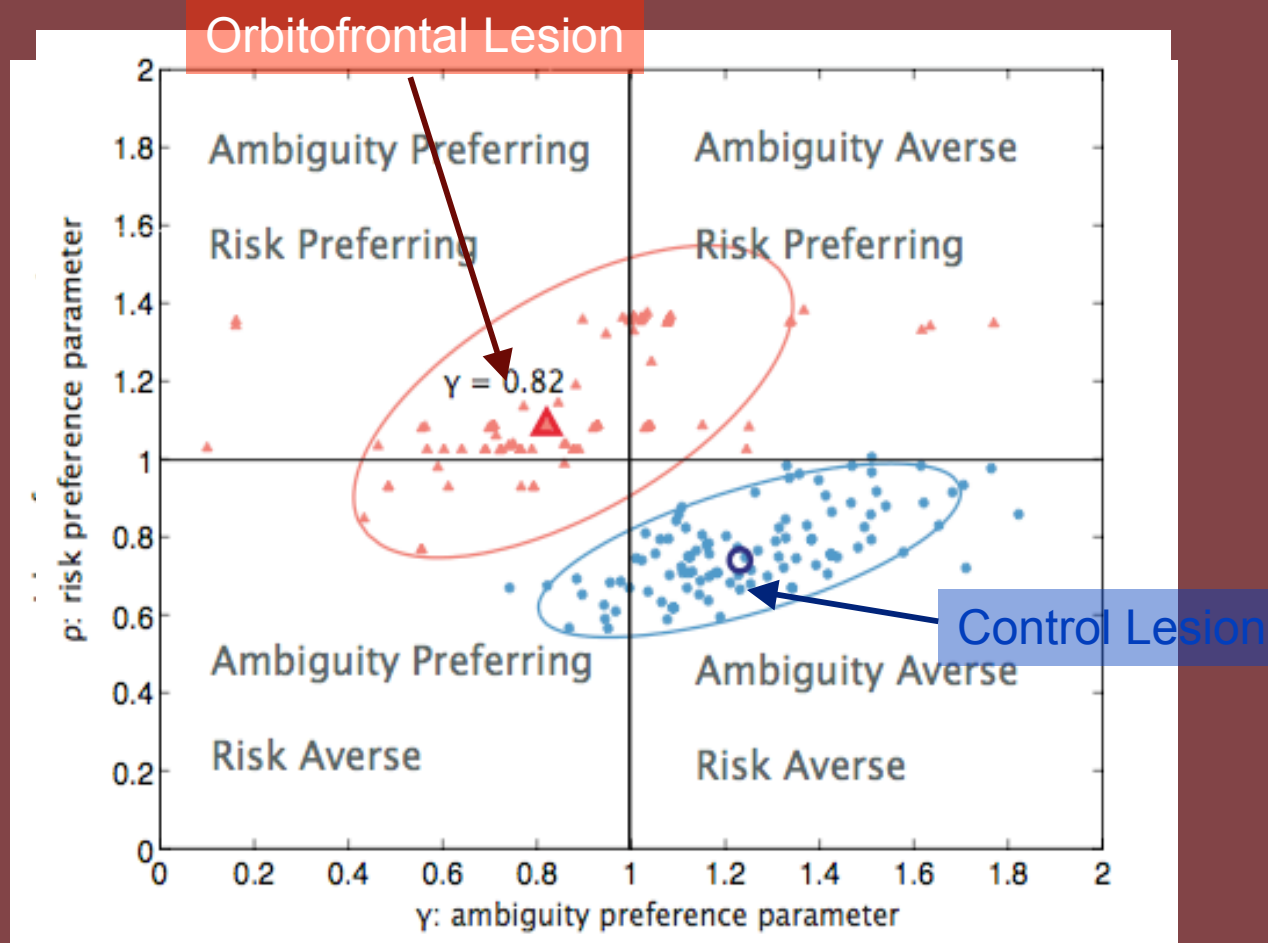
100 Cards
x Red
100-x Black

Choose between gamble worth 100 points
OR
Sure payoffs of 15, 25, 30, 40 and 60 points.

Lesion Patient Behavioral Data

Lesion	Certain Amt	Ambiguity	Risk
Control	15	.29	0
	25	.29	.14
	30	.57	.29
	40	.71	.57
	60	.71	.86
OFC	15	0	0
	25	0	0
	30	0	0
	40	.20	.20
	60	.40	.60

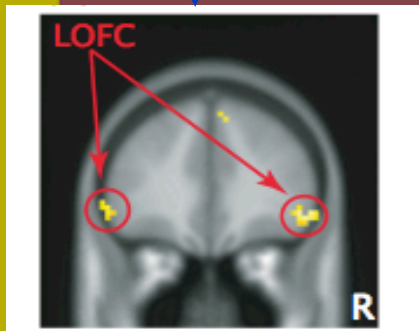
Estimated Risk and Ambiguity Attitudes



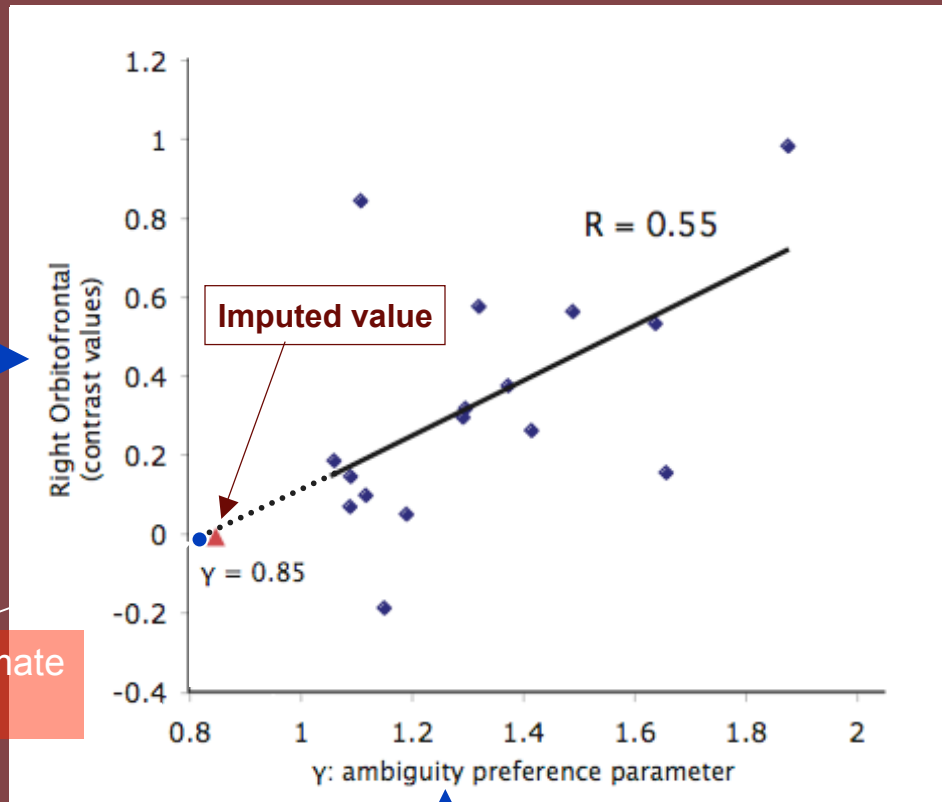
Orbitofrontal lesion patients more rational!

Linking Neural, Behavioral, and Lesion Data

Brain Imaging Data



OFC lesion estimate
 $\gamma = 0.82$

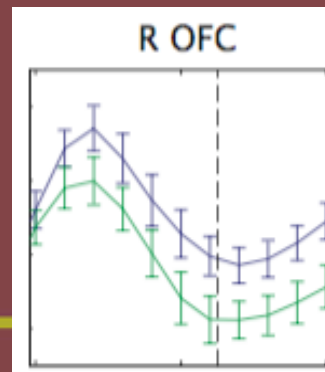
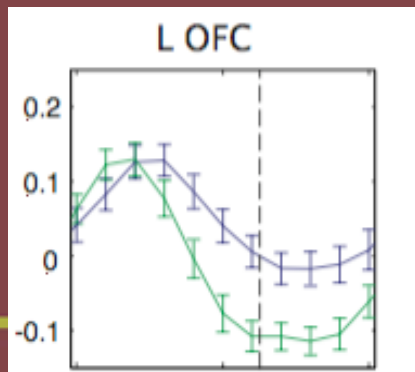
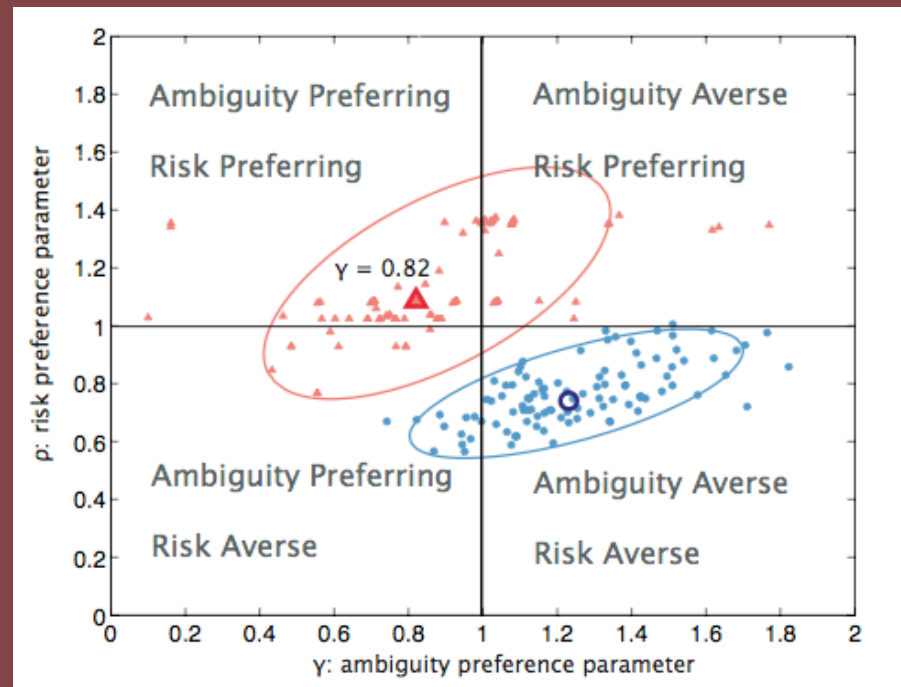
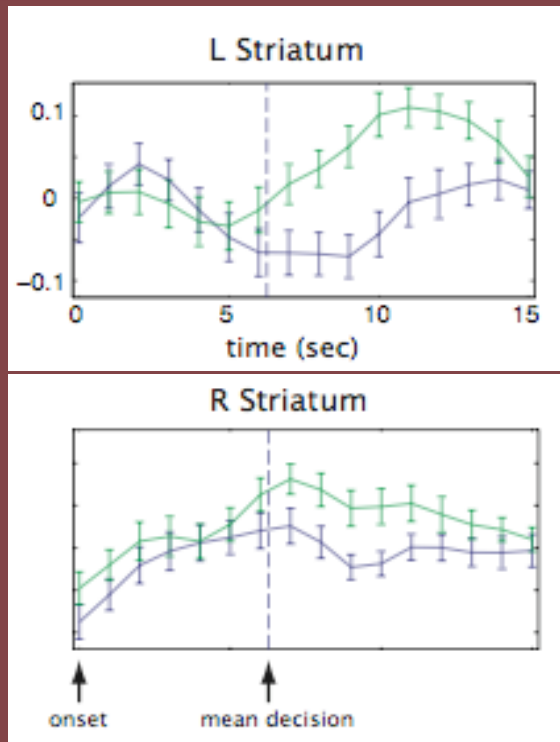


Behavioral Choice Data

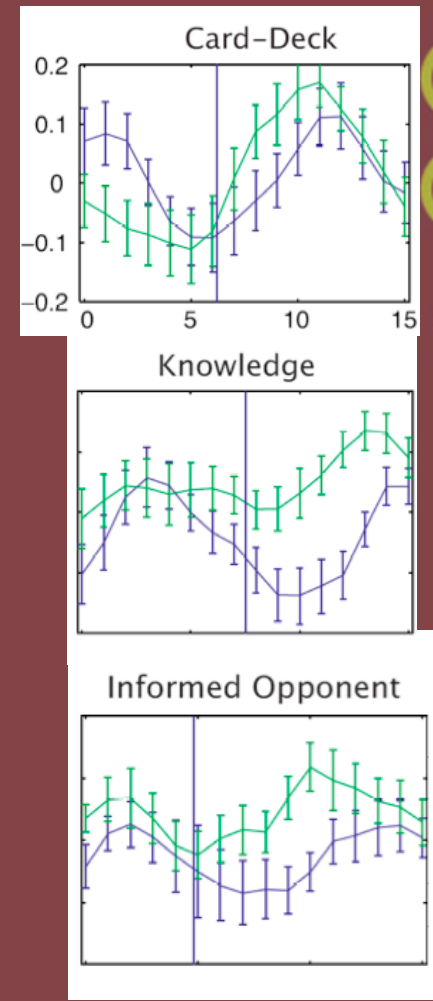
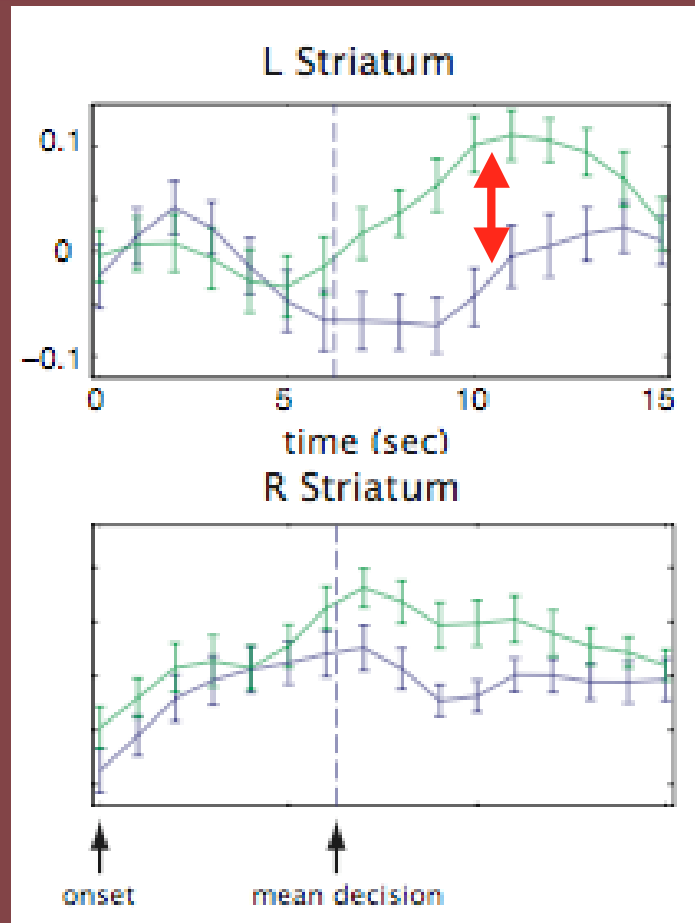
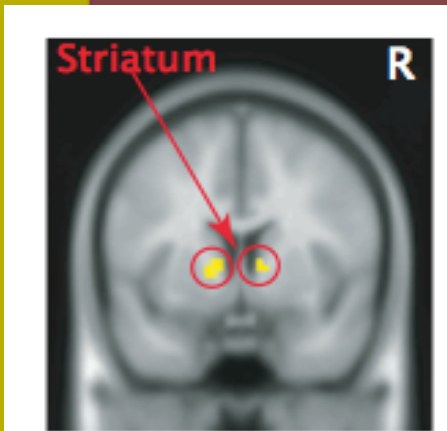
Stochastic Choice Model

One System, Not Two

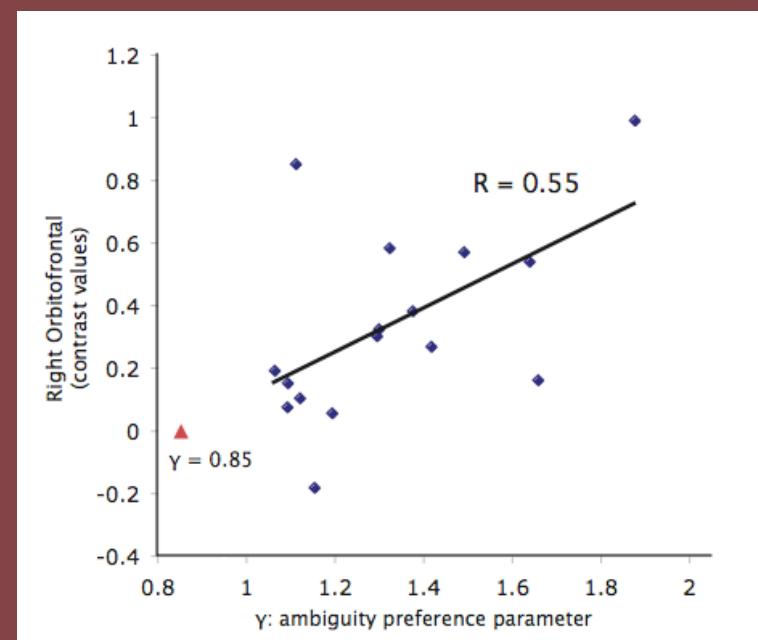
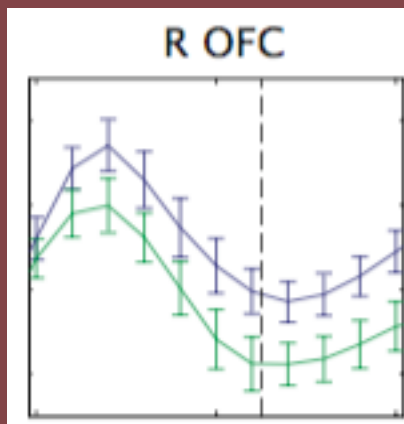
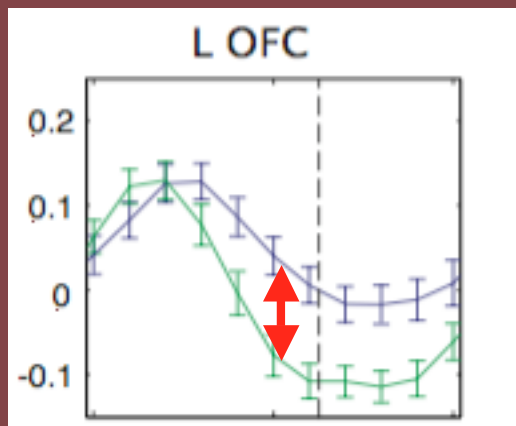
% Signal Change



Reward Value of Ambiguous Gambles



Signal for Uncertainty





Extension of Social Decision-Making

- Can the same processes extend to other types of decisions
 - Evolutionarily efficient
 - But is it a *just-so* story?

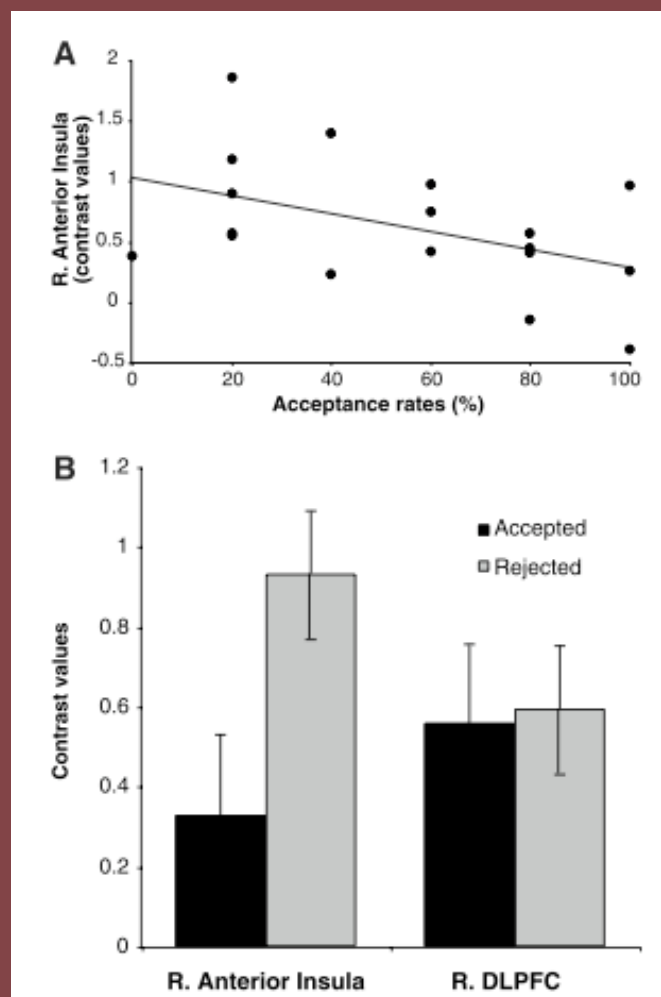
Ultimatum Game

- Unfair vs. Fair offers
 - Anterior insula
 - Anterior cingulate



Ultimatum Game

- Insula activity level
 - Correlated with rejection rate
 - Higher during rejection than acceptance
- Not true for other regions (DLPFC)



Not-So Dismal Science

- Tradeoff between efficiency and equity.
 - “Political Economy you think is an enquiry into the nature and causes of wealth - I think it should rather be called an enquiry into the laws which determine the division of the produce industry amongst the classes who concur in its formation.” (Letter from Ricardo to Malthus)
- Theory
 - Measurement of inequity and decision-making under risk
 - Stochastic/distributional dominance

Moral Philosophy

- Scenarios that probe moral intuition.
 - Much used in moral philosophy
 - One of the most famous is the “trolley” dilemma
- A runaway trolley is about to kill 5 people
 - Push lever to change track -- kill 1 to save 5.
 - Push man down foot bridge -- kill 1 to save 5.





Experiment

- **Real outcomes:** Subjects make choices that we implement.
 - Literature mostly surveys or as-if scenarios
- **Vary outcomes**
 - To estimate weights placed on efficiency and equity
- **Partition temporal sequence** (start, decision, outcome, etc).
 - Important for the brain

Design

- What is the worst thing we can do within the constraints of IRB?
 - Taking money from children.
 - Taking money from orphans.
 - Taking money from African orphans.
- Distributing meals to the children: either give or take.
 - 24 meals correspond to \$5.
 - Donate average of \$60 according to children
 - Total of around \$2,500 over course of experiment



Intuition

- Choose between the following
 - Give 1 orphan \$10
 - Give 2 orphans \$4 each

- Or the following
 - Take away \$10 from 1 orphan
 - Take away \$6 from 2 orphans each



Experiment

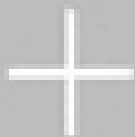
➤ Sequence

- Subjects recruited from Craigslist.com: 28-55 yr, at least college education.
- Paid \$50 upon completion of experiment.
- Subject comes in to reception room
- Given brochure with description of charity and short bios of all 60 kids
- Left alone for up to 10min with brochure
- Instructed on task
- Stressed throughout that this is a real charity, with real children, for real money, and we donate according to their choices.
- Post-experiment questionnaire.



Experimental Sequence

Act



You chose to give:



Dick **-7 meals**



Enoch **-7 meals**



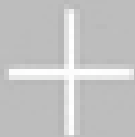
Joshua **0 meals**

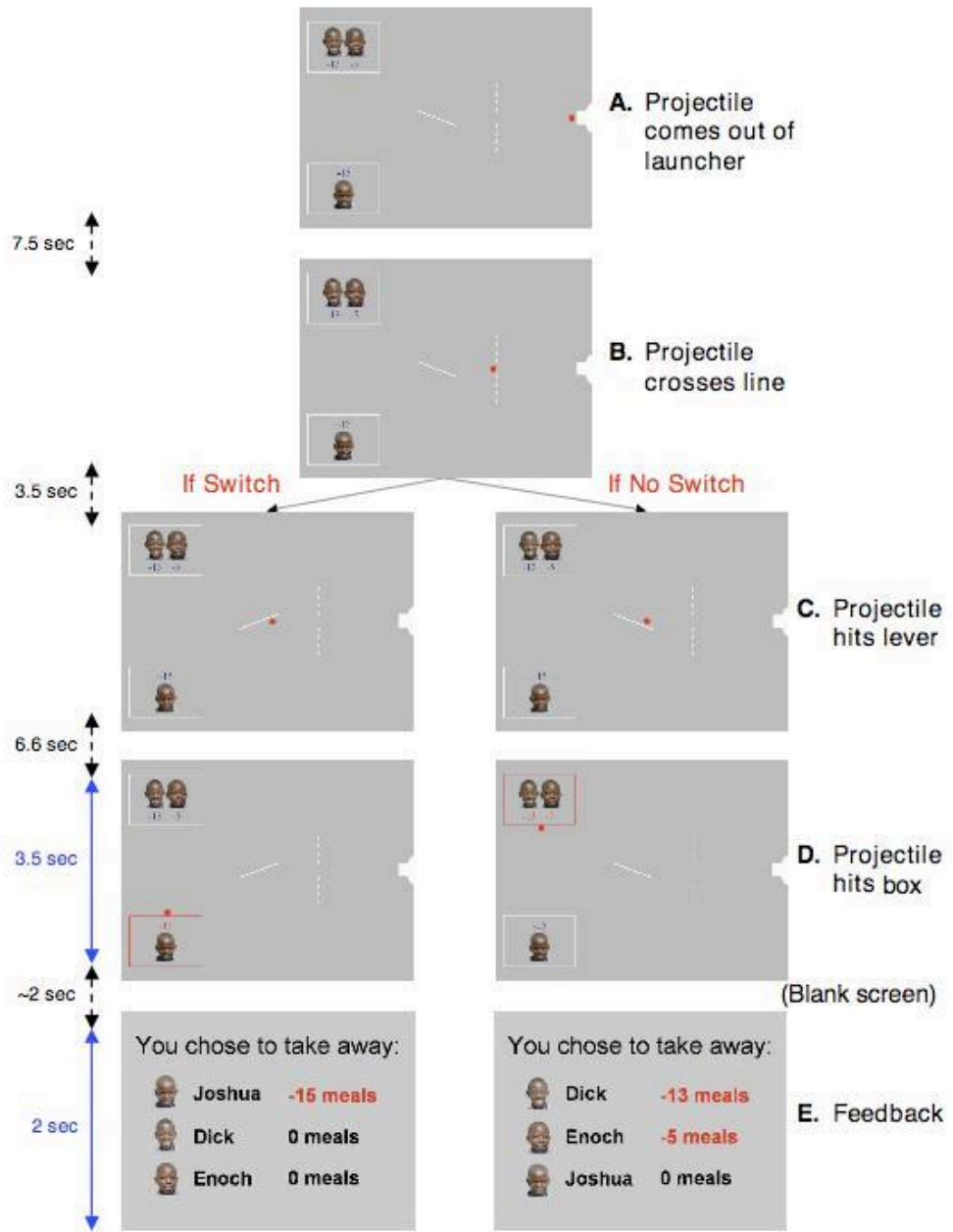


Experimental Sequence

Omit









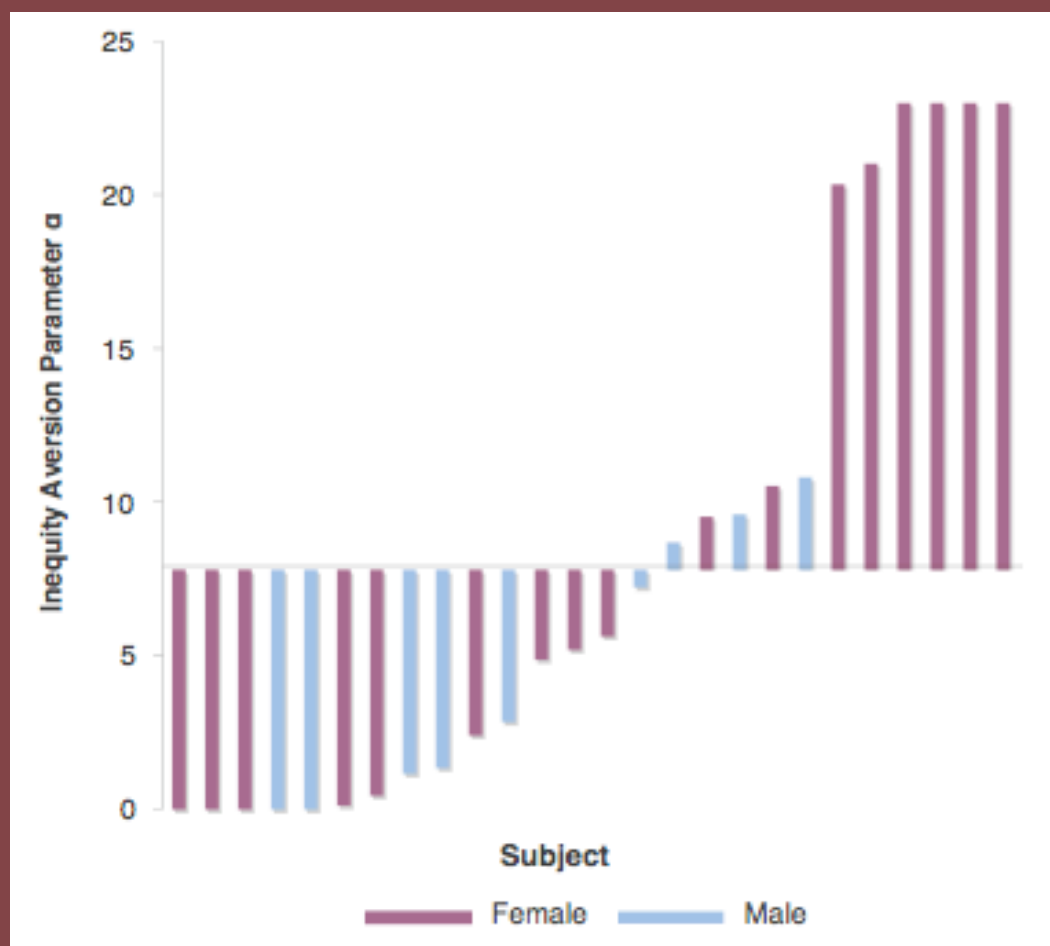
Experimental Design

- There are 36 trials, 18 gain and 18 loss.
 - Gain: give to 1 kid or 2 kids.
 - Loss: take from 1 kid or 2 kids.
- The gain (loss) amounts for 1 kid is
 - {15, 19, 23}
 - {-15, -19, -23}
- Kids endowed with 24 meals to start.

Behavioral Model Selection

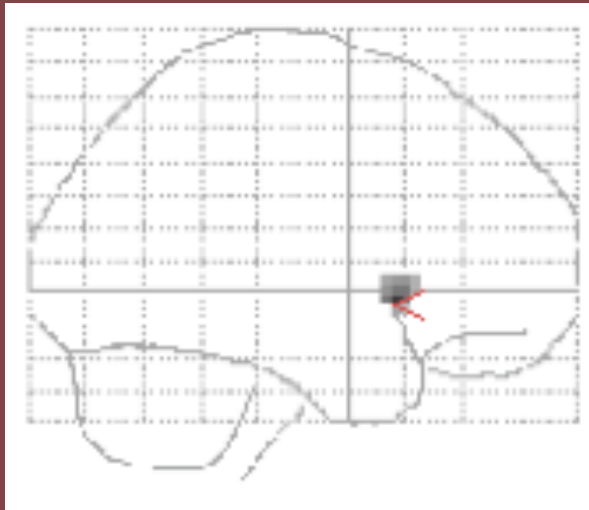
- Inequity aversion model
 - $U(x) = \text{sum}(x) - \alpha \cdot \text{gini}(x)$
 - Gain: $\alpha = 15.3$
 - Loss: $\alpha = 6.96$
- Prospect theory-ish utility
 - $U(x) = x^\gamma$ (gain); $\gamma = 0.79$
 - $U(x) = -(-x)^{\gamma'}$; $\gamma' = 1.14$
- Can reject utility functions such as
 - Rawlsian (leximin)
 - Cobb-Douglas

Inequity Aversion Estimate



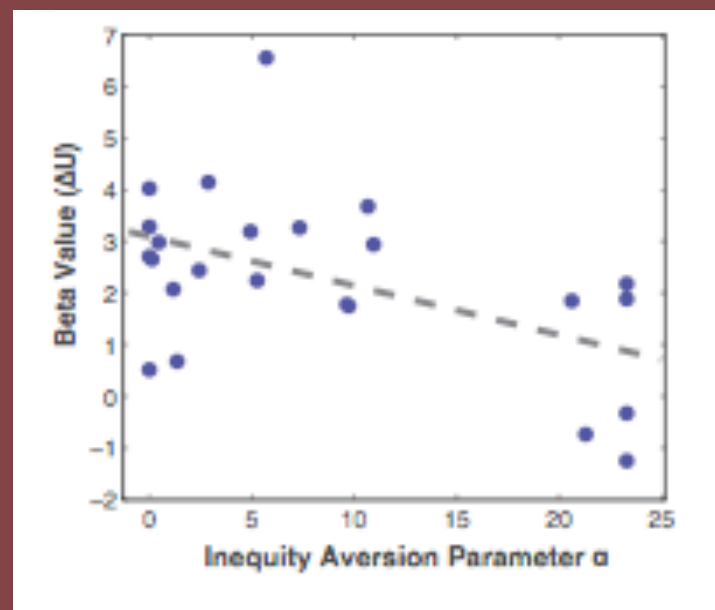


Hit Kid: Chosen Utility - Unchosen Utility

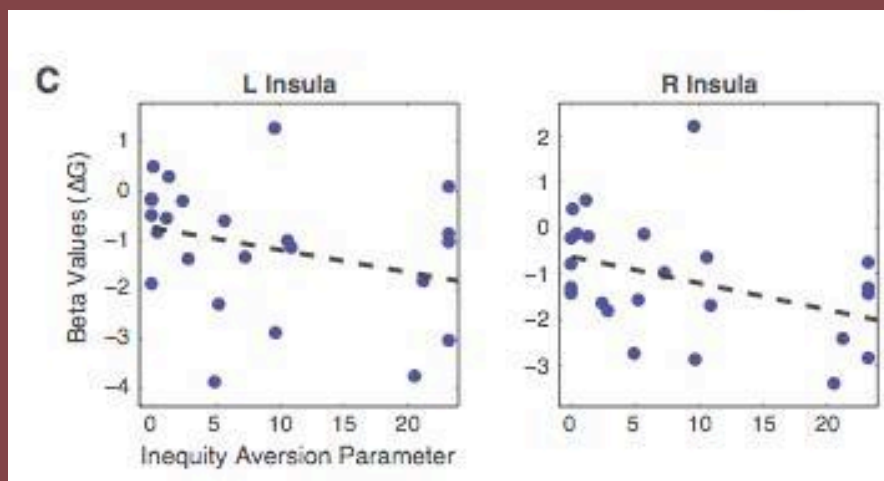
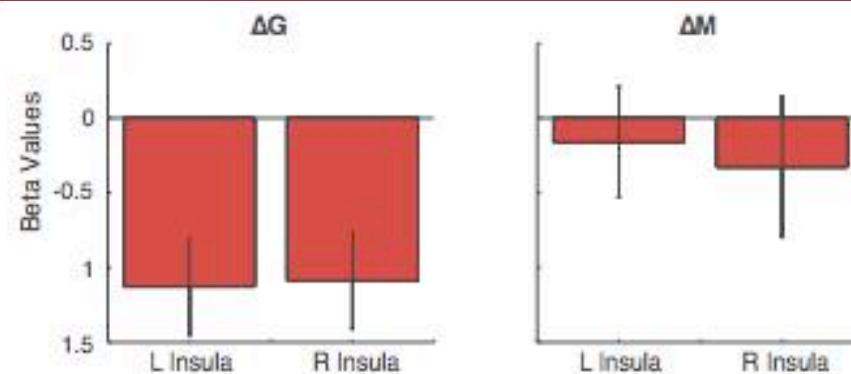
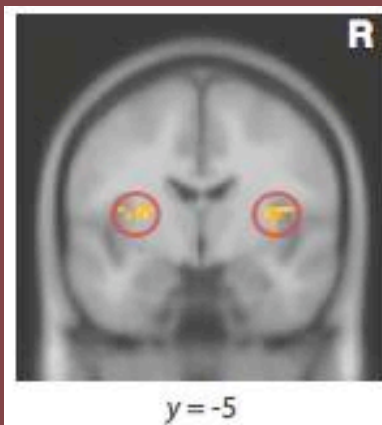


Variations in Coefficients

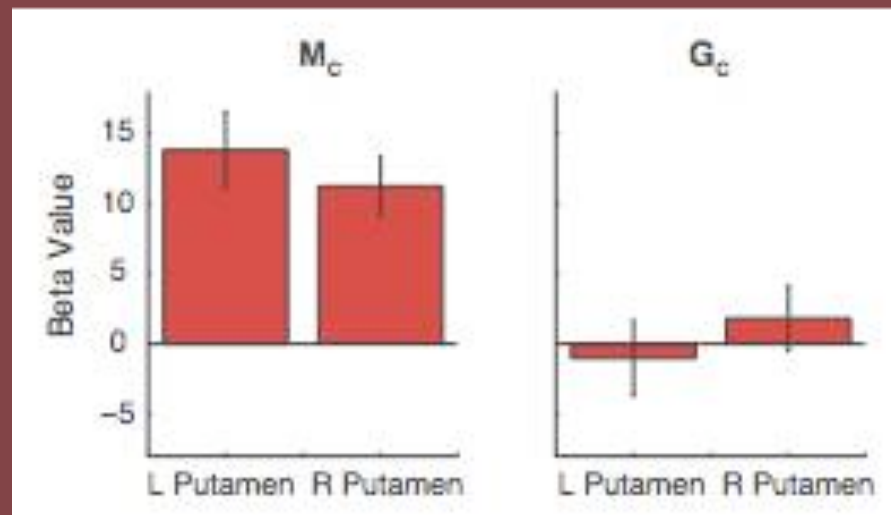
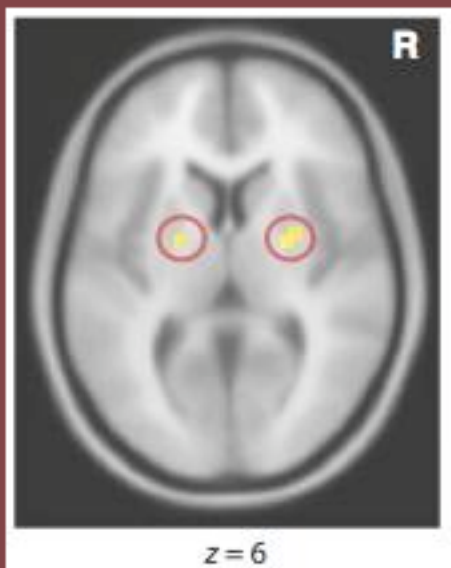
- Utilities calculated with group α
- Therefore estimated coefficients should vary with individual α negatively.
 - Pearson $\rho = -0.502$, $p < 0.0125$, two-tailed.



Display: Chosen Gini - Unchosen Gini



Display: Chosen Meals



Uncorrelated with inequity aversion parameter

Interim Conclusions

- People trade off between *equity* and *efficiency*
 - Brain regions appear to encode the two separately
 - Used gini but Theil, Atkinson, or something else.
- Involvement of emotions in other-regarding preferences
 - Both separate and unified encoding of equity and efficiency
 - Appears to affect utility through weighting of inequity rather than efficiency.



Extensions and Future Research

- Separation of perception and choice
 - Most results in current use marginal measures.
 - Cross cultural differences:
 - Europeans more concerned about inequity than Americans on average
 - Rich in America are more concerned about inequity than European counterparts
 - Introduction of risk and uncertainty
 - Ex-ante vs. ex-post fairness
 - Procedural vs. Distributive Fairness
- 