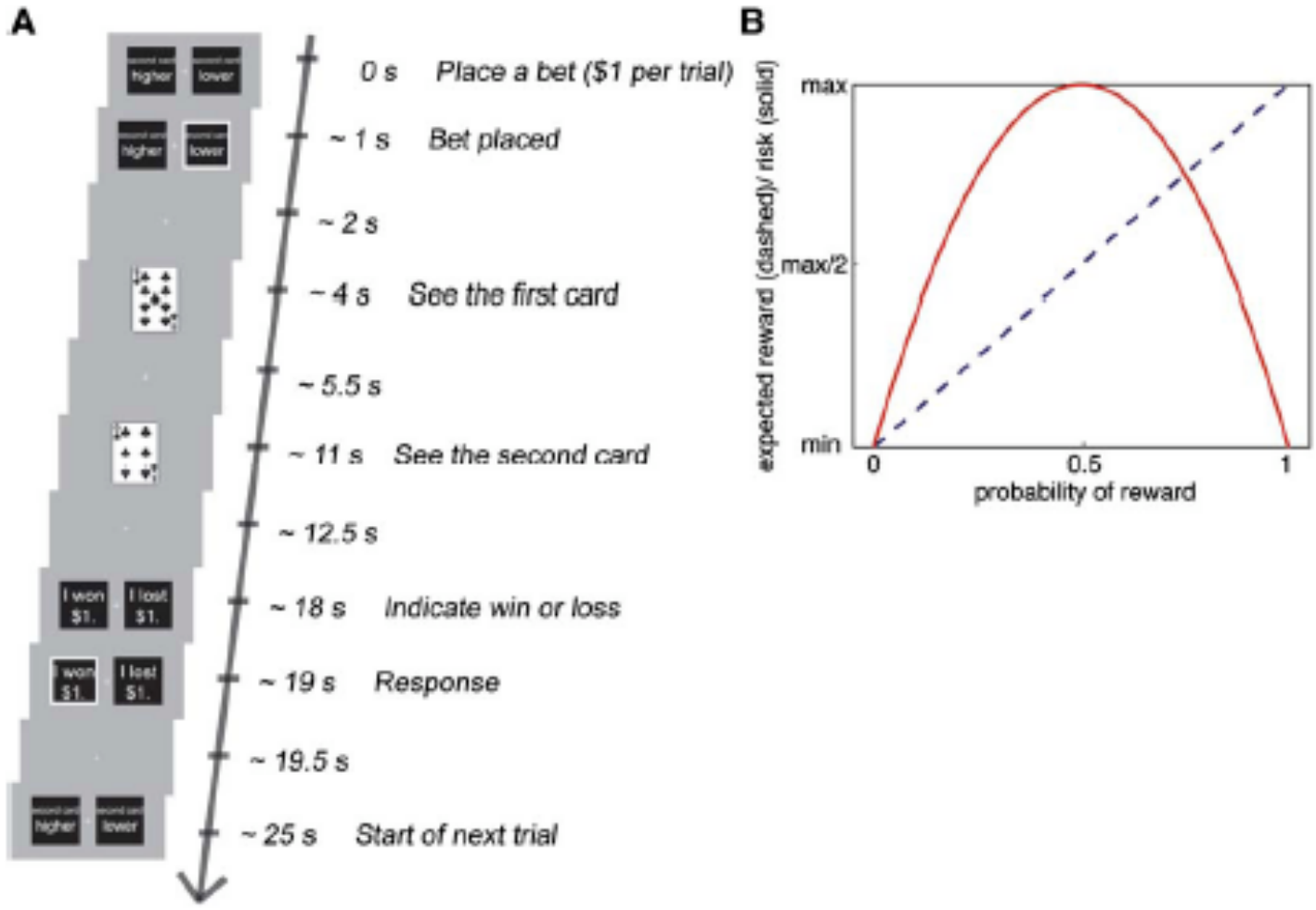
Neural correlates of risk, ambiguity and information

Five studies:

- Reward vs risk (Preuschoff + 06)
- Ambiguity (Huettel+ Neuron 06)
- Ambiguity (Hsu+ Sci 05)
- Curiosity (Kang+ 06)
- Cognitive reappraisal (Sokol-Hessner+ 06)

1. Risk vs reward: Betting on cards (1-10) without learning, salience, motivation (Preuschoff et al Neuron 06)



Exp reward (L) and risk (R)

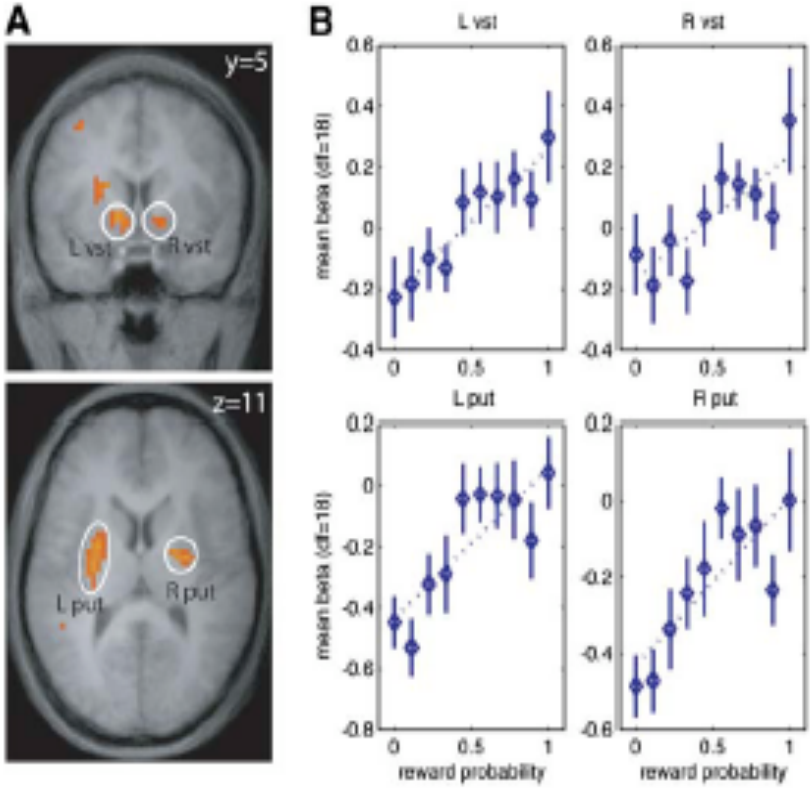


Figure 2. Immediate Neural Correlates of Expected Reward

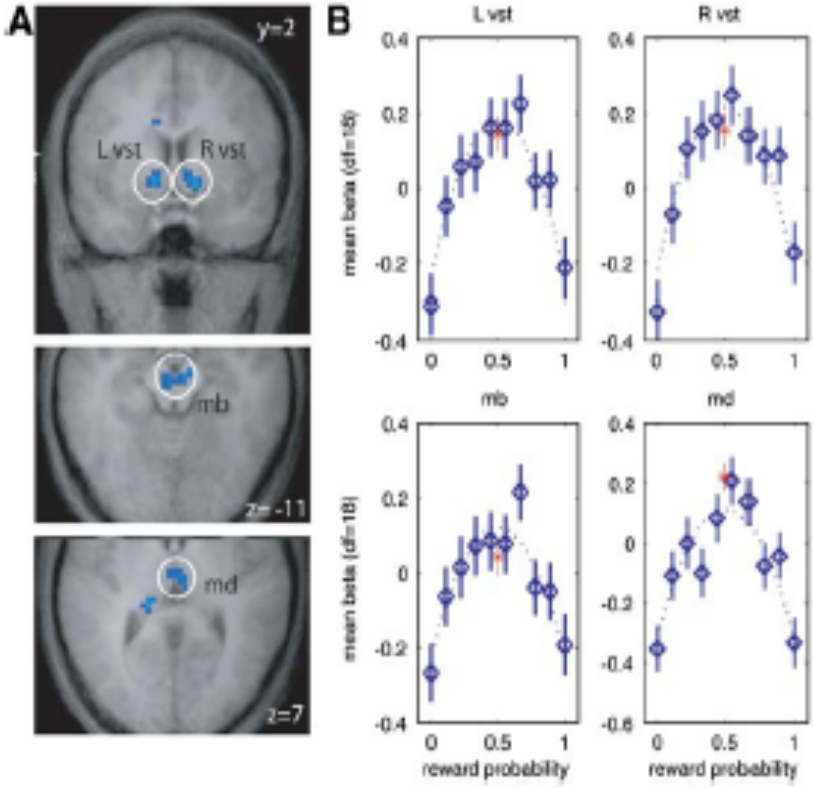
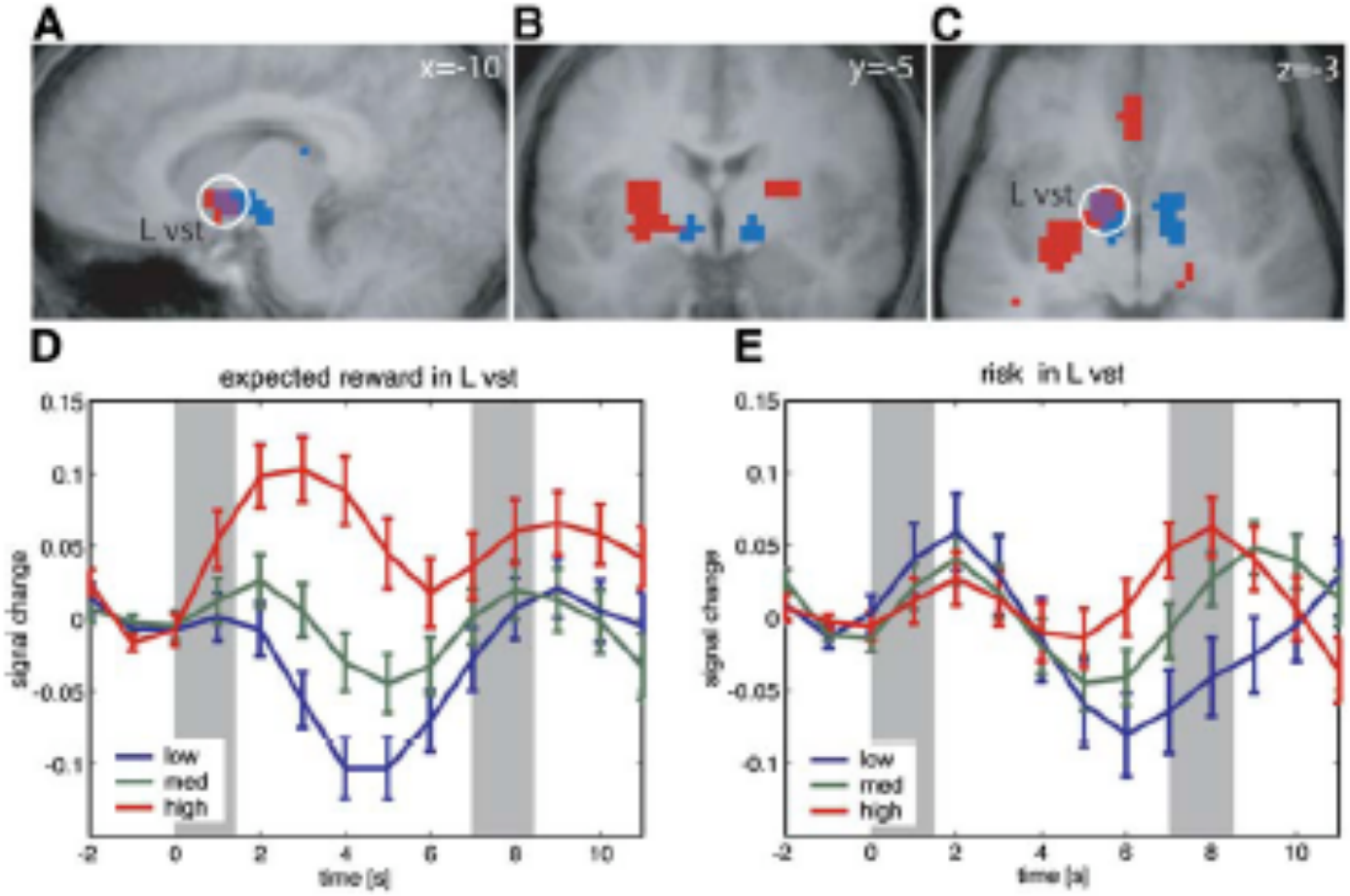


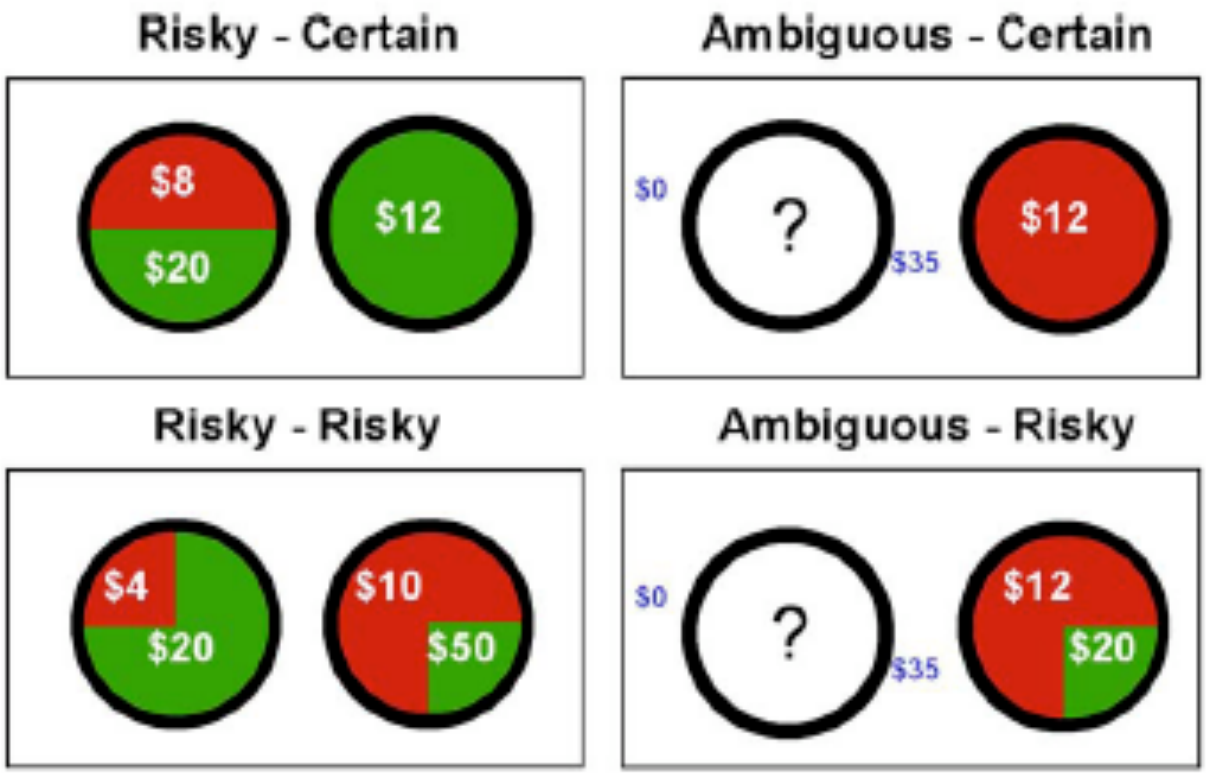
Figure 3. Delayed Neural Correlates of Risk

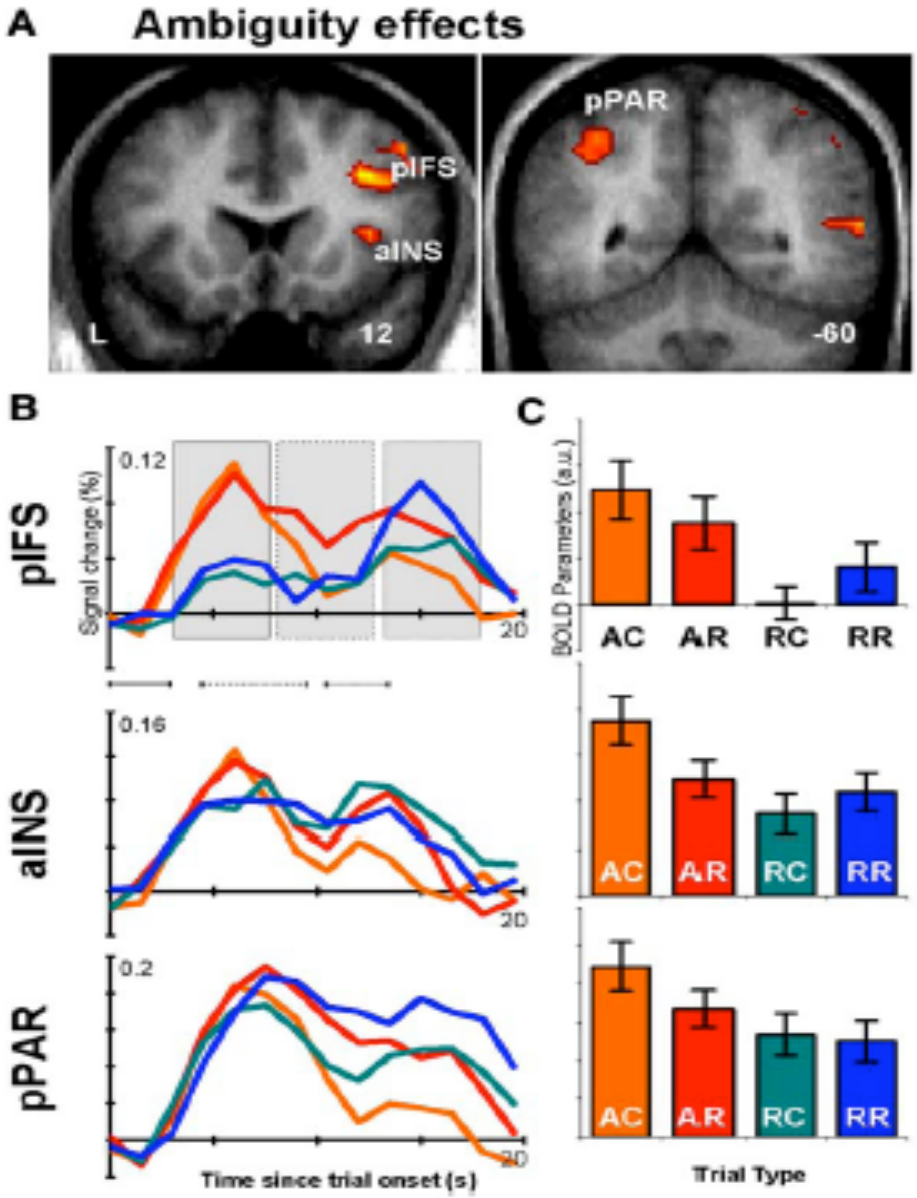
E(reward) fast (red), risk (blue) slow



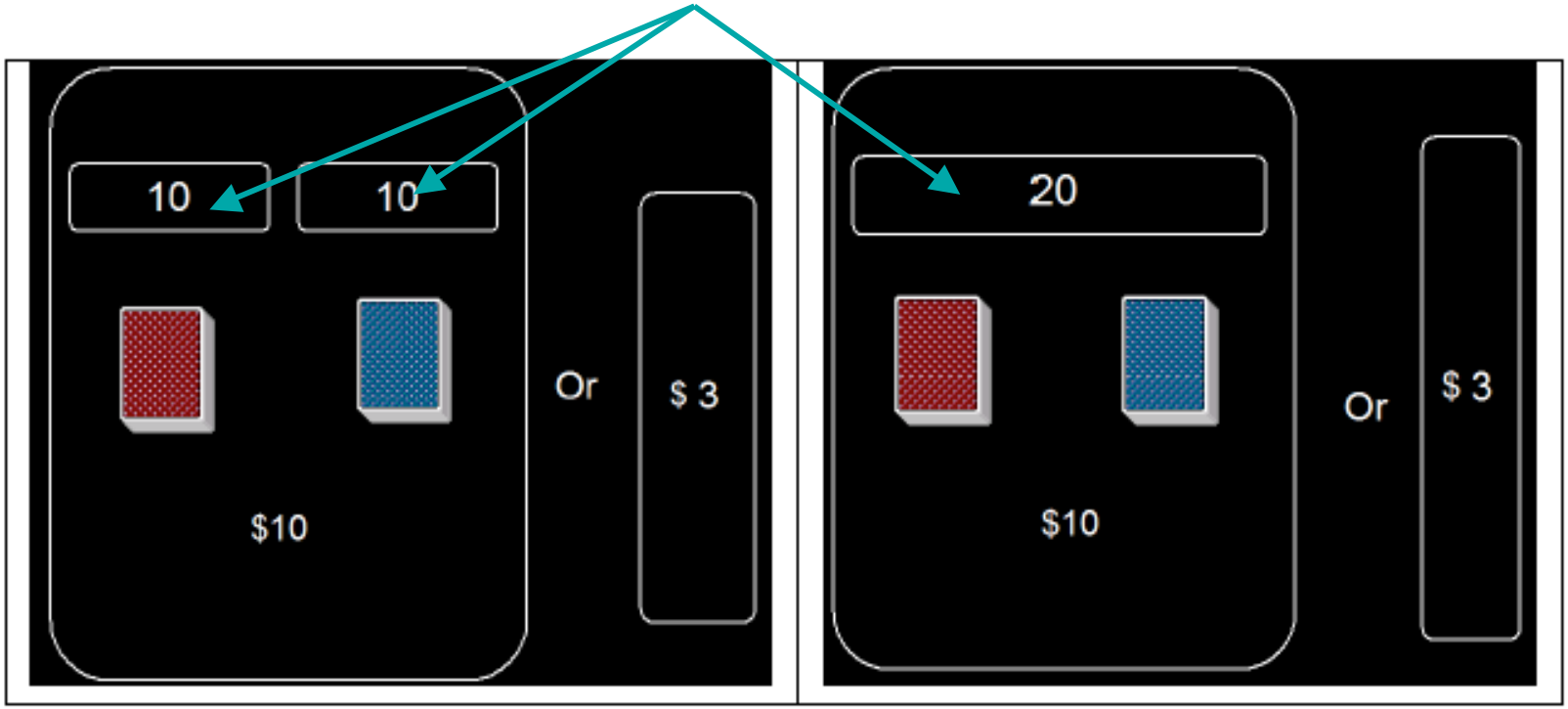
2. Ambiguity = unknown probability

(Huettel et al Neuron 06)

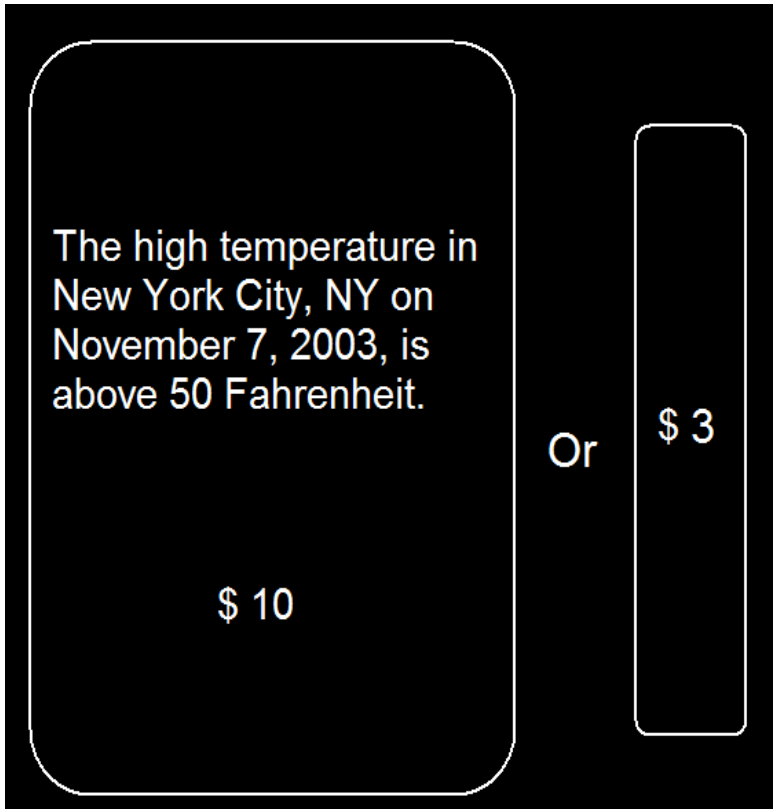



A
Ambiguity effects
pIFS
aINS
L
12
pPAR
-60
B
pIFS
aINS
pPAR
Signal change (%)
0.12
0.16
0.2
20
Time since trial onset (s)
C
BOLD Parameters (a.u.)
AC
AR
RC
RR
Trial Type

3. Ambiguity-aversion: Ellsberg Questions (Hsu, Camerer et al Sci 05)



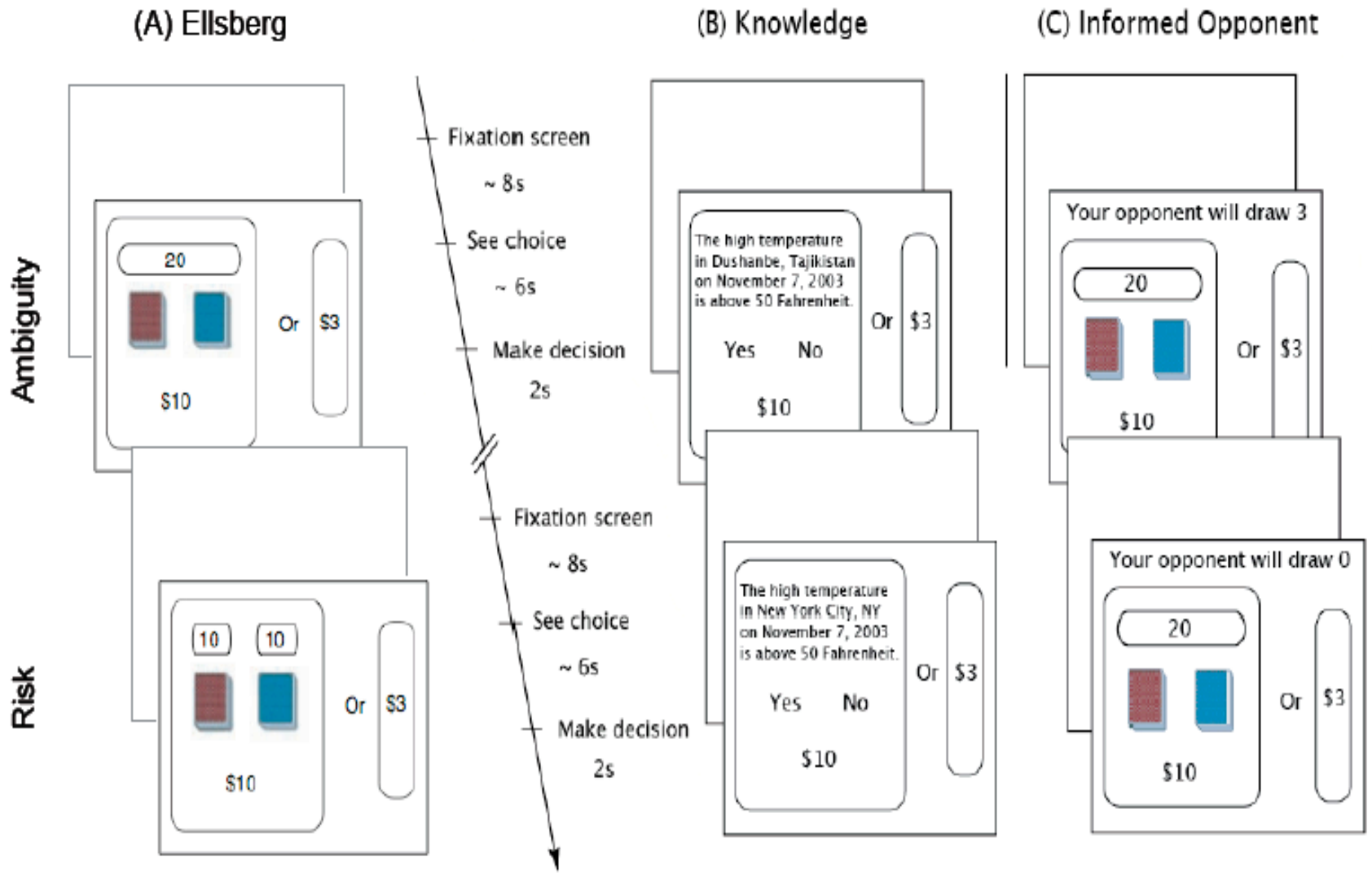
Real World Questions



Ambiguity vs risk

- Is behavior different?
  - Ellsberg: Yes SEU: No
  - Models: Pessimism (nonadditive, set-valued beliefs)
  - Ambiguity is risk plus fear
- Why should economists care?
  - Preference for familiarity
    - Home bias in assets, politics (Arroyo, Kyi, Bush, Schwarzenegger)
  - Robust control in macroeconomics (Sargent)
  - Incomplete contracts (Muhkerji)

Experimental Design

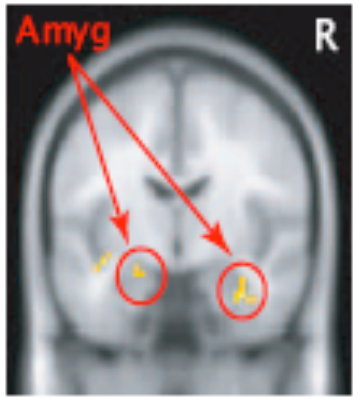


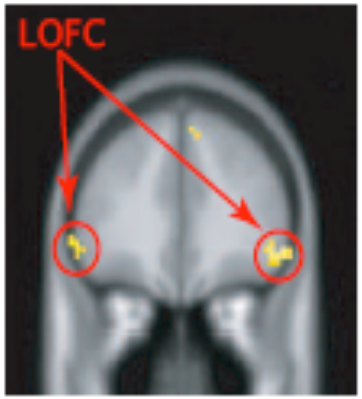
Adverse selection: Don’t bet when someone knows more than you do

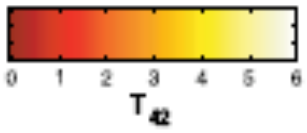
- Expected value of betting against an informed opponent is low
- Coin auction:
  - Guesses highly variable
  - High bidder guessed to high
  - Should bid much less than your guess (*how much* depends on N)

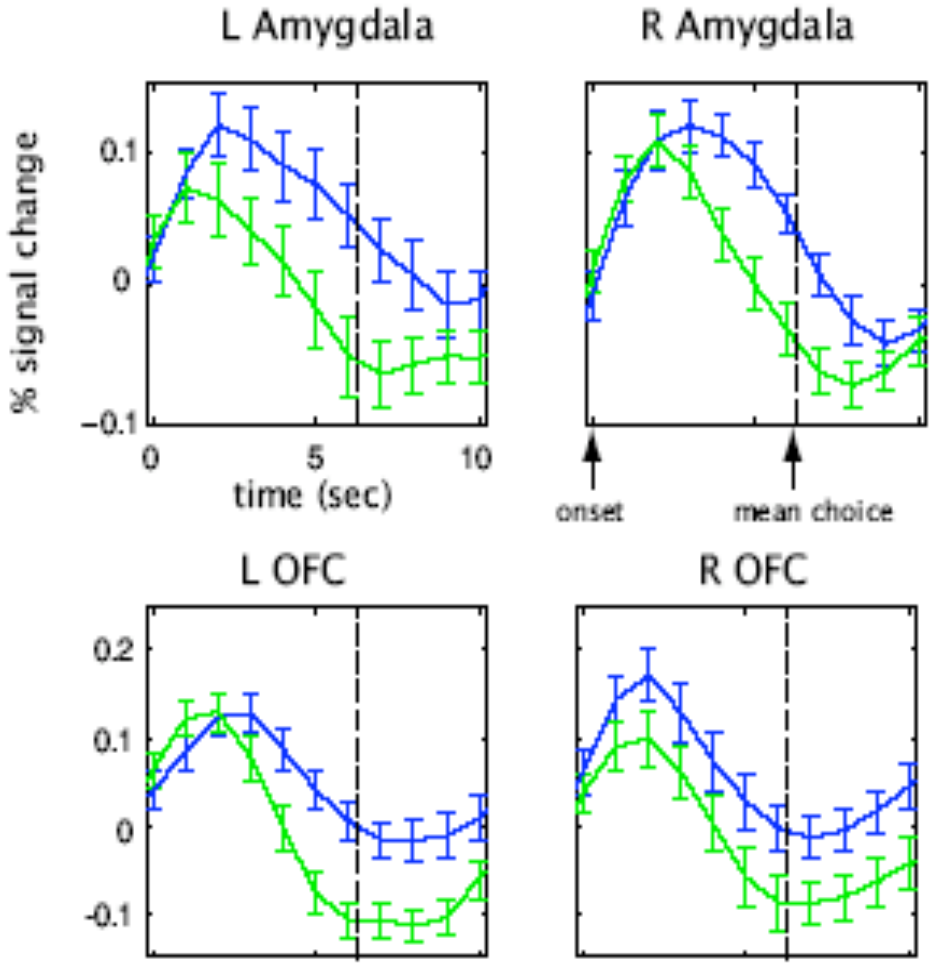
Differential activation ambiguity>risk

- amygdala→
- OFC →

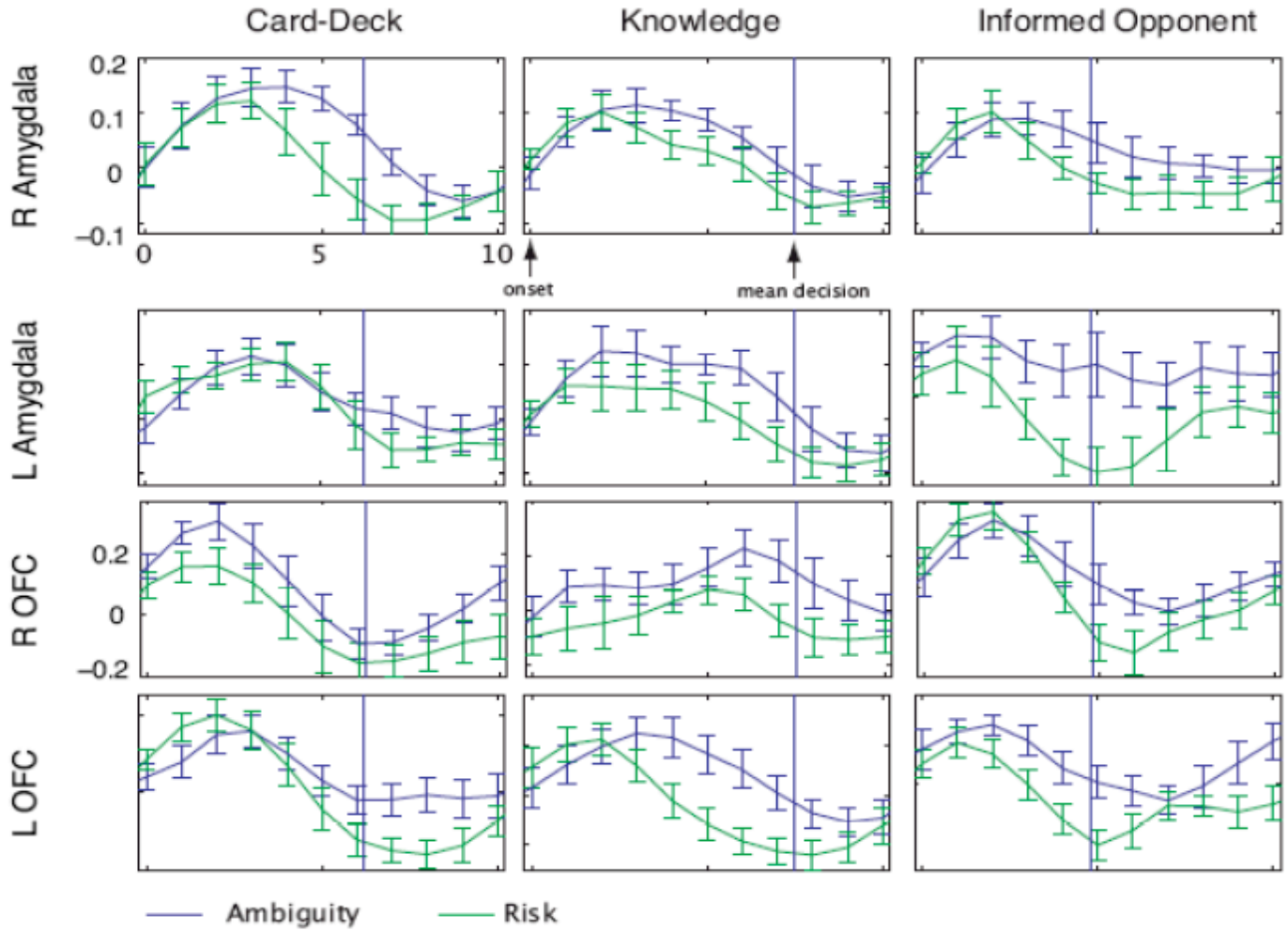








Blood flow (HRF) in ROI's
(blue=ambiguity, green=risk)



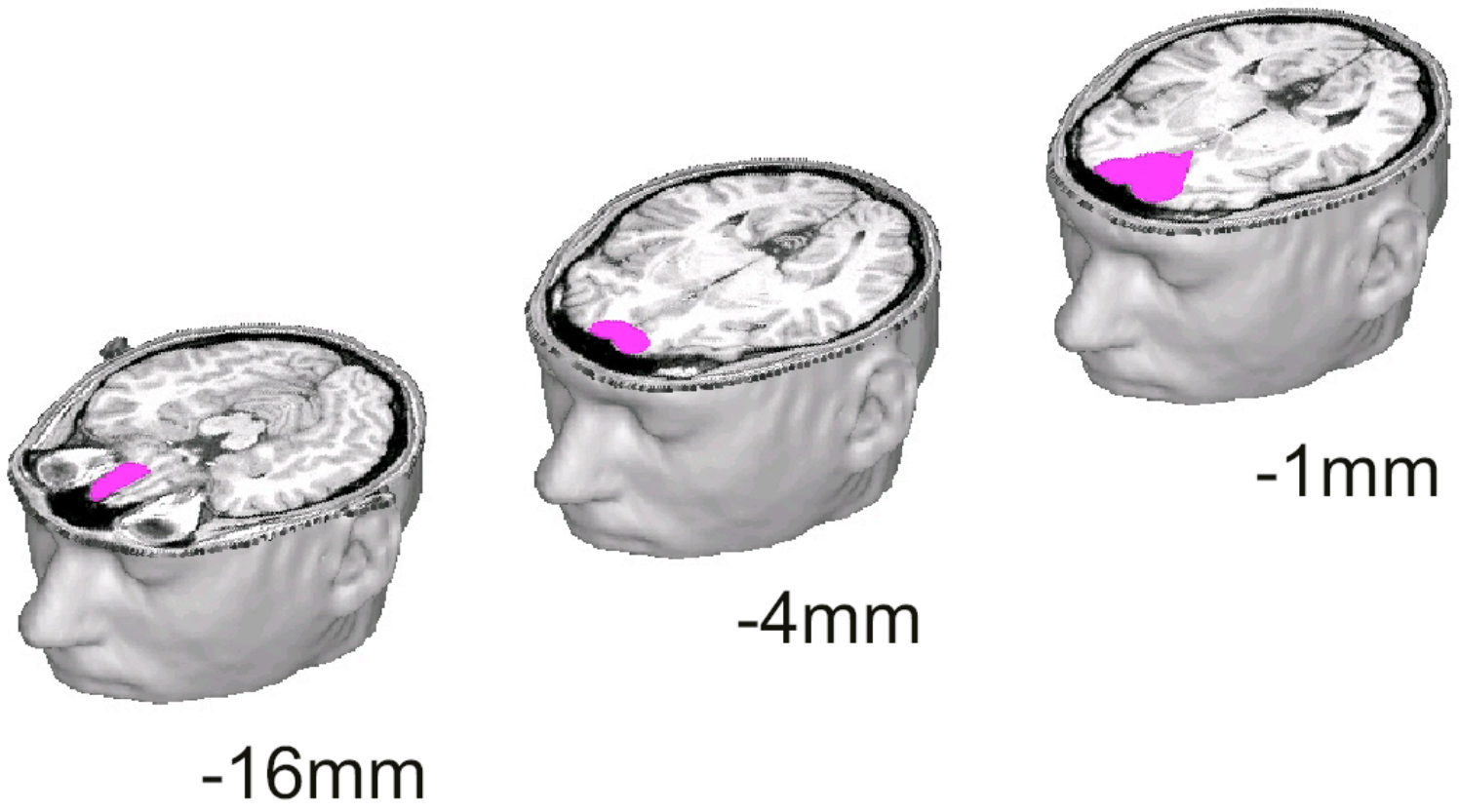
Parametric measurement of risk- and ambiguity-aversion

- Measure ambiguity aversion by $w(red)=[E(P(red)]^{\gamma}$
  - $\gamma>1$ ambiguity-aversion, $\gamma=1$ neutrality
- Measure risk-aversion by $u(x)=x^{\rho}$
  - $\rho<1$ risk-aversion, $\rho=1$ neutrality
- Estimate with logit "softmax" model
  - $P(\text{bet \$10 red}>x)=1/(1+\exp[\lambda*[x^{\rho}-\$10^{\rho}P(red)^{\gamma}]])$

OFC lesions (picture from Coricelli, Sirigu et al, Science 04)

Patients are ambiguity-neutral (n=4 only)

Guess: They are not receiving emotional discomfort from insula



Lesion behavioral data

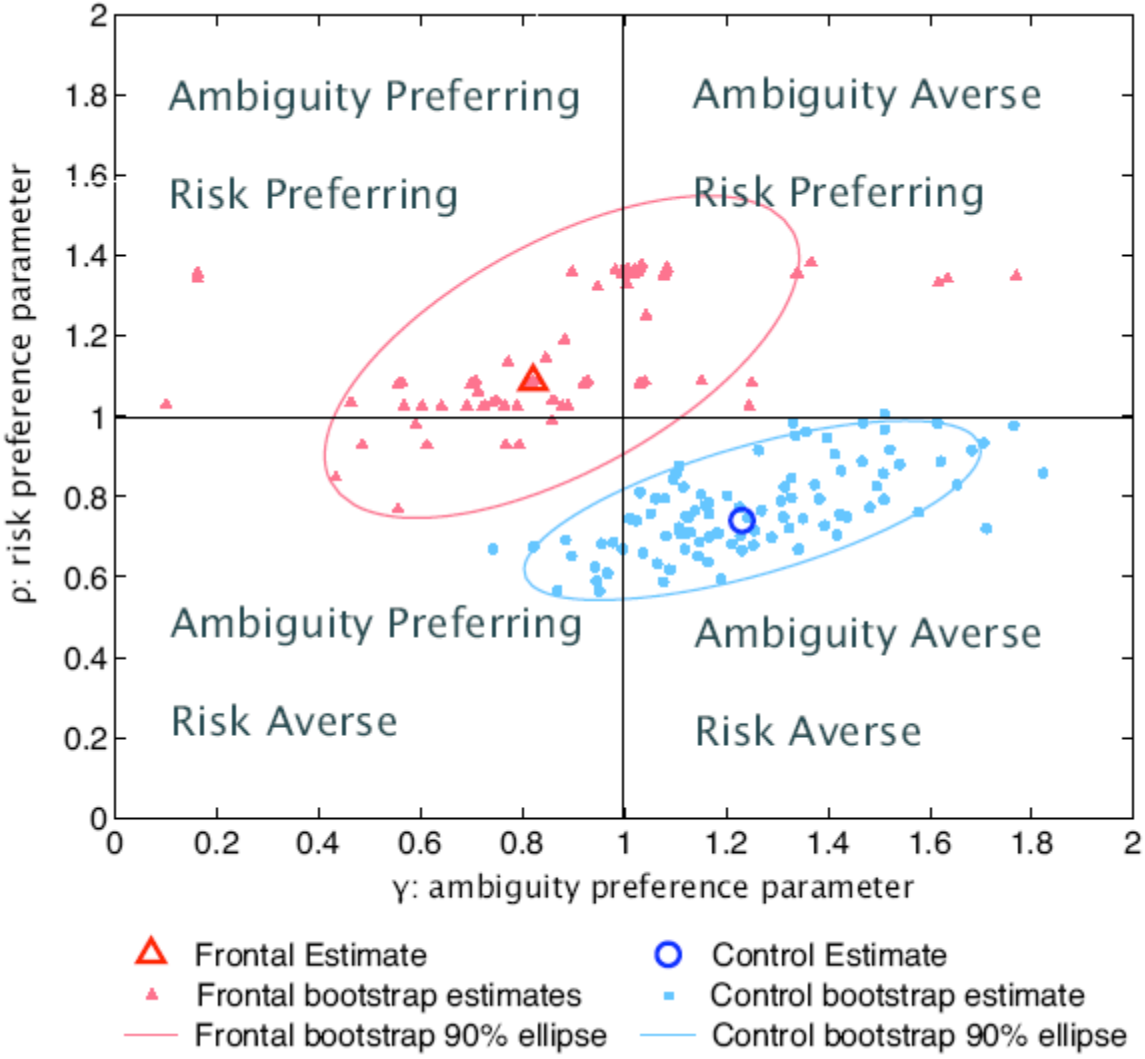
Two-color decks for 0 or 100 points

% Choosing Certain

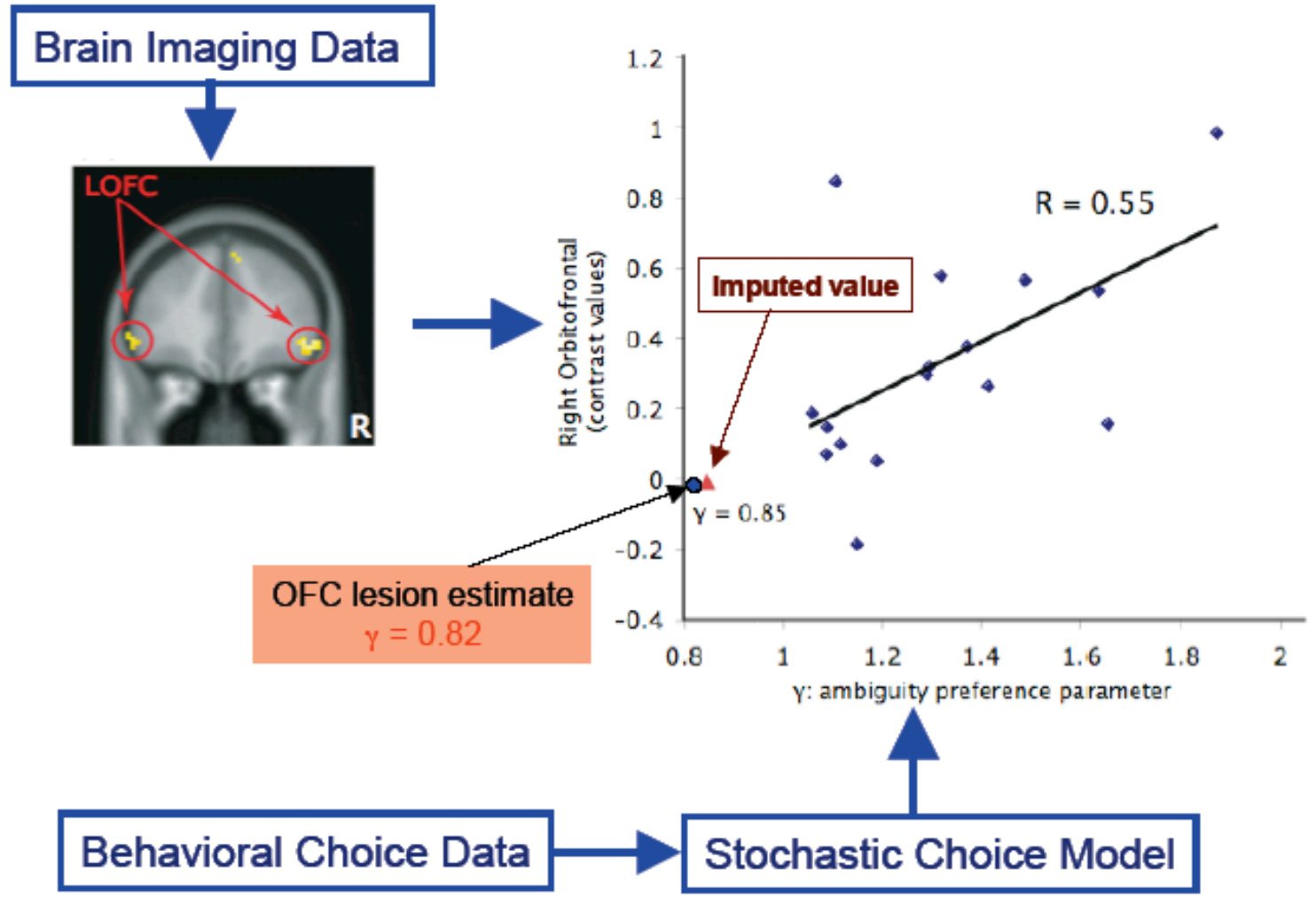
Lesion	Certain Amt	Ambiguity	Risk
Control	15	.29	0
	25	.29	.14
	30	.57	.29
	40	.71	.57
	60	.71	.86
OFC	15	0	0
	25	0	0
	30	0	0
	40	.20	.20
	60	.40	.60

Risk- and ambiguity-aversion in Iowa lesion patients: Frontal damage lined to risk- and ambiguity-neutrality

ρ



Linking Neural, Behavioral, and Lesion Data



R anterior insula correlated with other-race face reactions: Are other-race faces “ambiguous”?

(Phelps et al J Cog Neuro 2000)

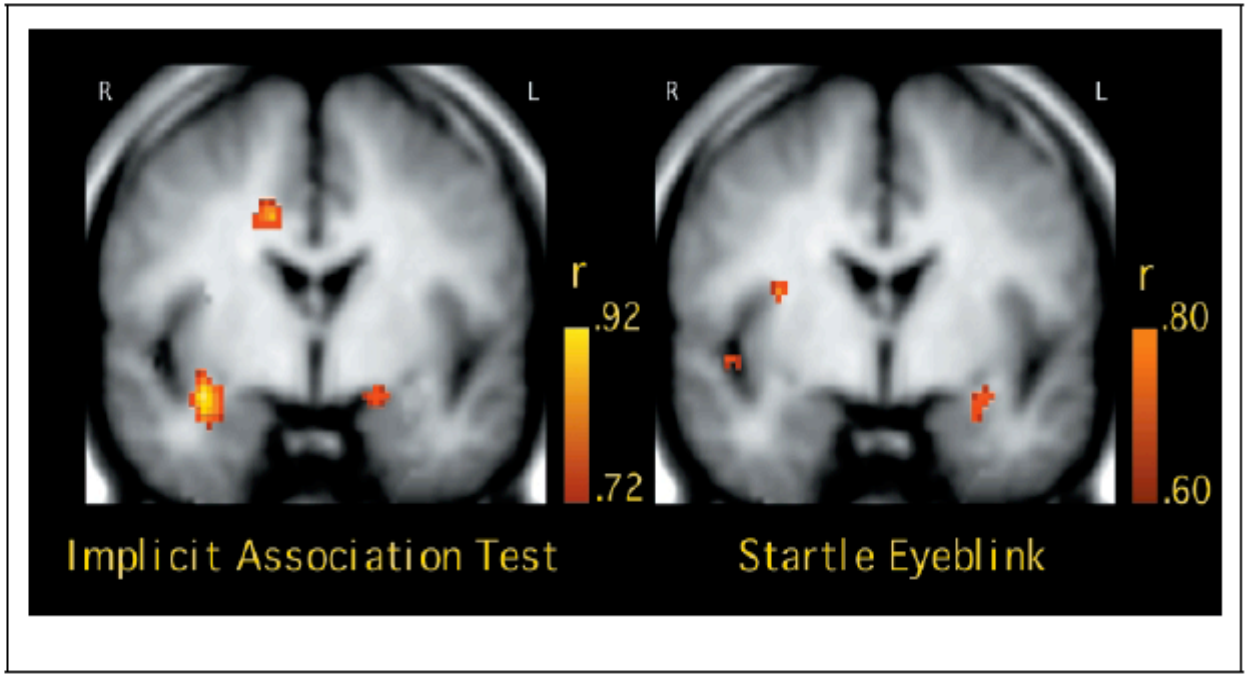


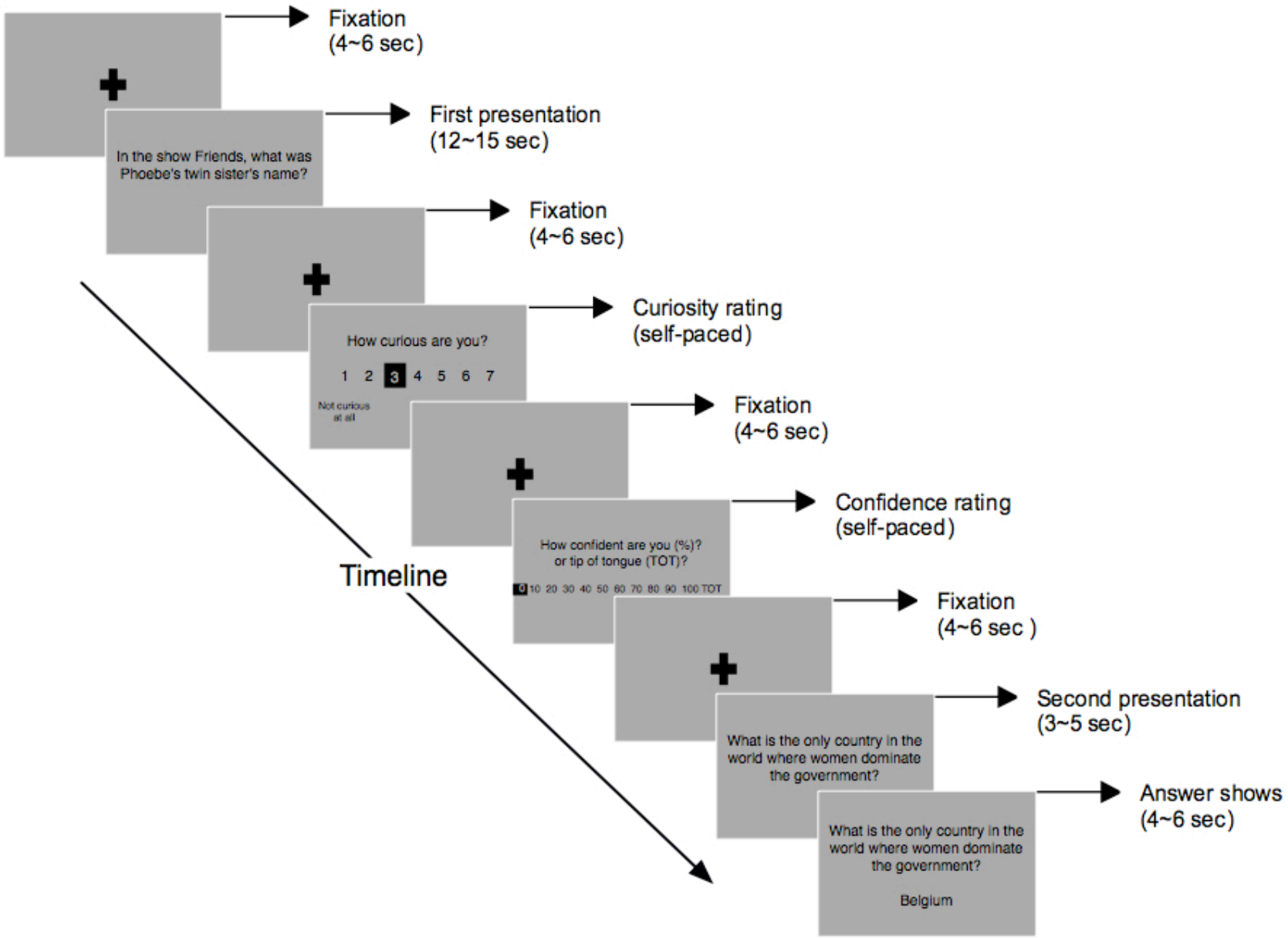
Figure 3. Composite correlation maps displaying regions where magnitude of activation to Black-versus-White faces is correlated with indirect behavioral measures. (a) IAT response latency Black–White, regions of significant correlation include: left-superior amygdala (Talairach & Tournoux coordinates: −17.6, −5, −10.8), right amygdala extending to the inferior insula (31.7, −5, 12.2), and right anterior cingulate (14.1, −5, 36.1). (b) Eyeblink startle difference Black–White, regions of significant correlation include: left-superior amygdala (−22.1, −5, −11.7) and two small regions in the right insular cortex (31.8, −5, 17.1; 41.4, −5, −2.4).

4. Pure demand for information: Curiosity as “information hunger”

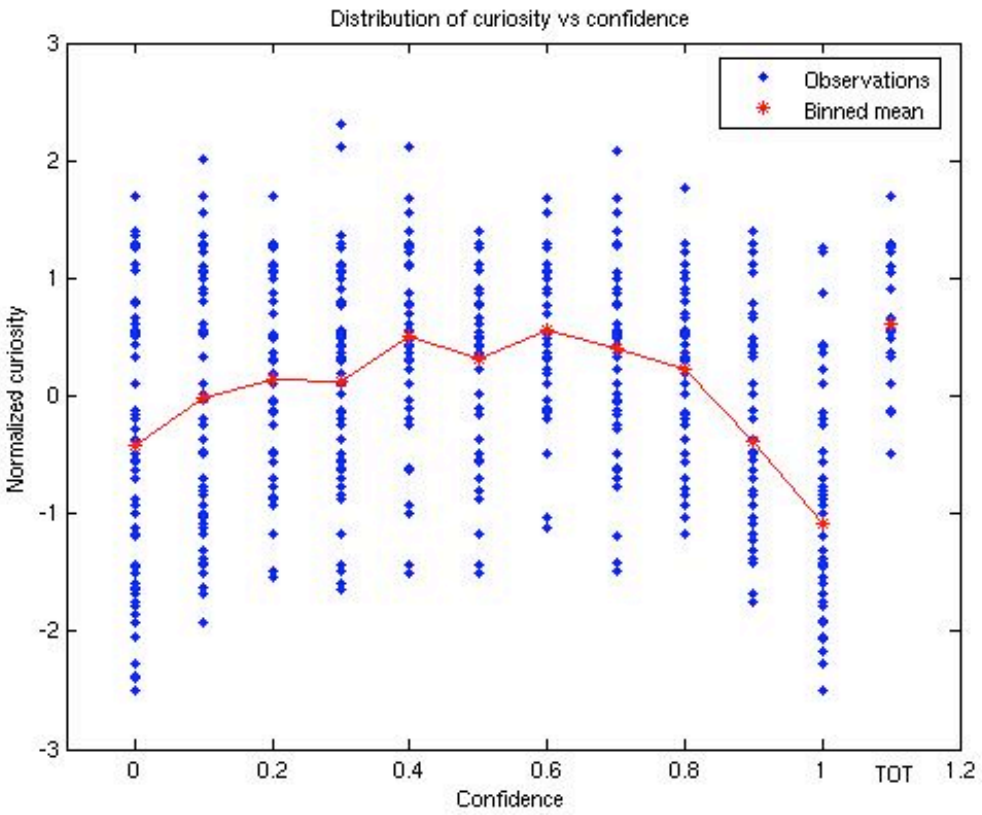
- Curiosity inspires exploratory behavior, great discovery
- Linked to artistic creativity
- Intrinsic motivation of creative professionals
- Can cause misfortunes
  - Pandora, Orpheus, Lot’s wife etc.
- Dark side: thrill seeking
  - Adolescent exploration (sex, drugs)

Curiosity as information foraging

- Information = food?
- VTA, ventral striatum, nucleus accumbens (Schultz et al., 1992, 1997)
- The predictability of rewards modulates activity in the reward-related neural structure (Berns et al., 2001).
- Different brain response before and after satisfying curiosity


Fixation
(4~6 sec)
In the show Friends, what was Phoebe's twin sister's name?
First presentation
(12~15 sec)
Fixation
(4~6 sec)
How curious are you?
1 2 3 4 5 6 7
Not curious at all
Curiosity rating
(self-paced)
Fixation
(4~6 sec)
How confident are you (%)? or tip of tongue (TOT)?
0 10 20 30 40 50 60 70 80 90 100 TOT
Confidence rating
(self-paced)
Timeline
Fixation
(4~6 sec)
What is the only country in the world where women dominate the government?
Second presentation
(3~5 sec)
What is the only country in the world where women dominate the government?
Belgium
Answer shows
(4~6 sec)

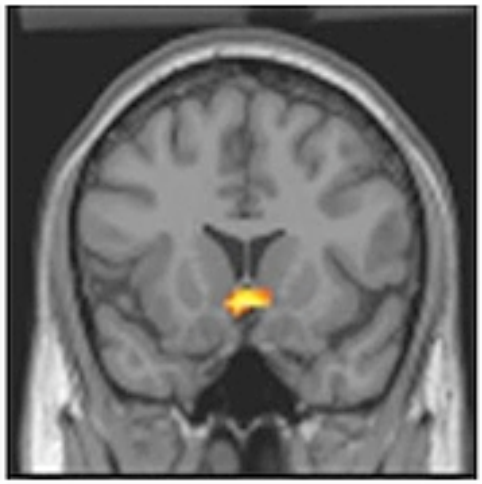
Results: Curiosity ratings



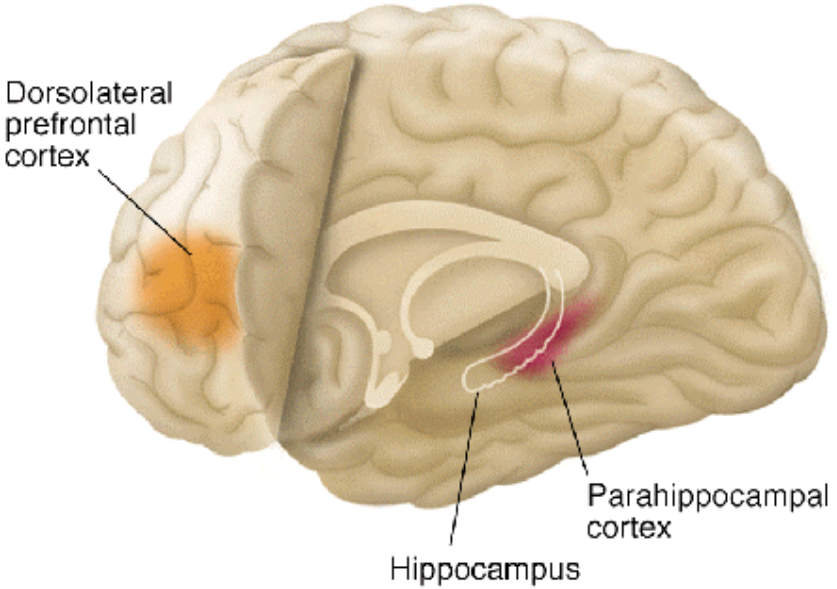
Behavioral data

- Curiosity level normalized for each subject
- Inverted U curve with p(right)

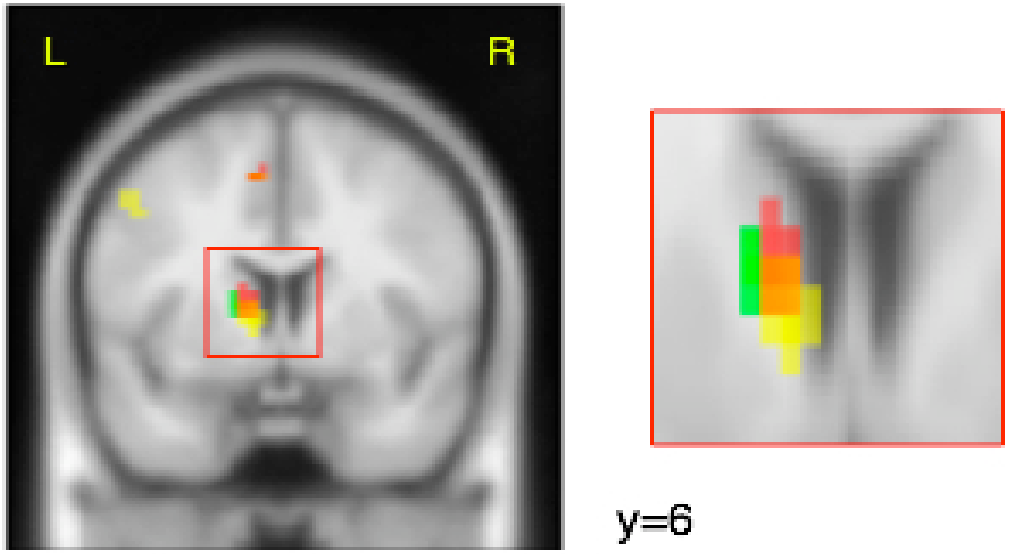
Where do we expect to see activity?



- This is your brain when you are pleased from unpredicted squirts of juice. (the ventral striatum) (Berns et al)

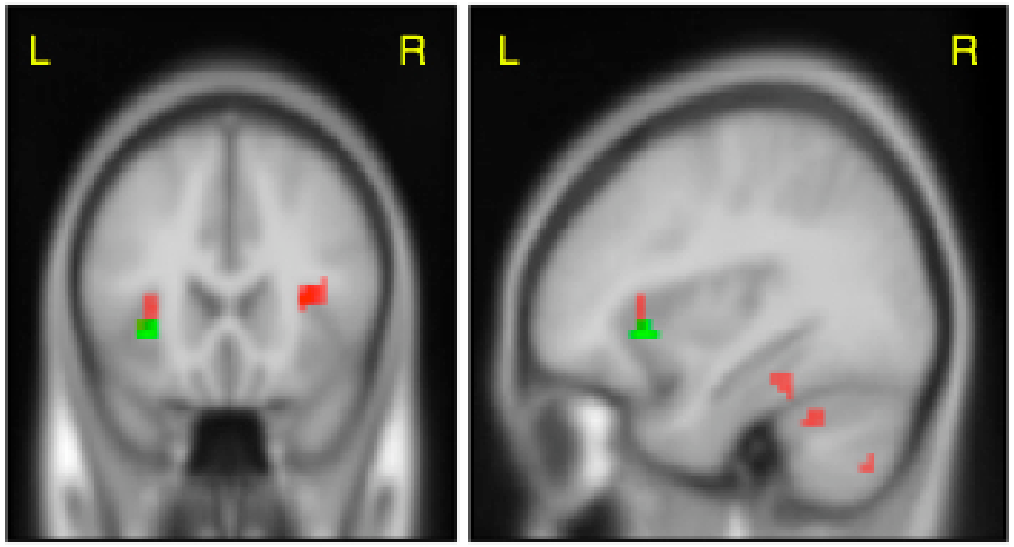


Curiosity effect during question presentation



- P<0.001 (uncorrected), 5-voxel threshold
- Left caudate activation (-12, 6, 9 in high>low curiosity contrast)
- Curiosity linked to anticipated reward
- Robust result: seen in all three contrasts
  - High > low curiosity (red)
  - Beta coefficient for normalized linear curiosity (yellow)
  - Beta coefficient for residual curiosity (green)

Second question presentation: Insula “itch”



y=21 x=-33

- Bilateral Insula activation in p(1-p) contrast (“itch”)
- Overlapped regions in p(1-p) and residual contrasts ($p<0.005$)
- Red: p(1-p) (strong), green: residual curiosity (weak)

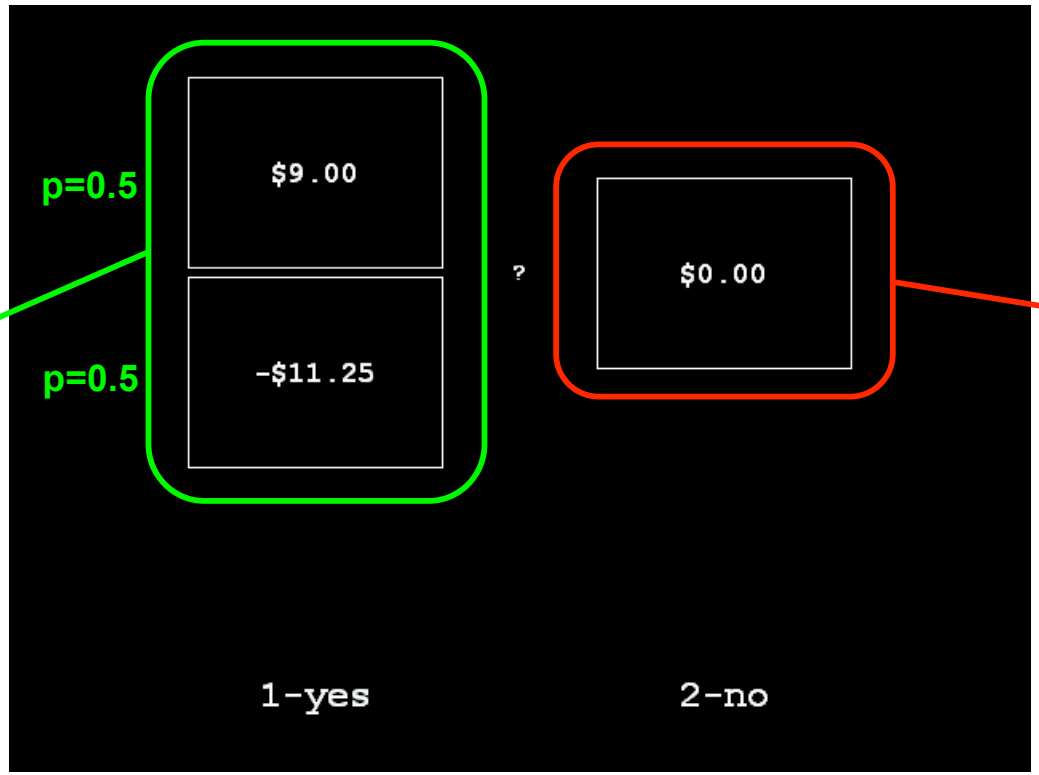
5. Risk modified by cognitive re-appraisal*

One way to think of this instruction is to imagine yourself a trader. You take risks with money every day, for a living. Imagine that this is your job, and that the money at stake is not yours – it's someone else's. Of course, you still want to do well (your job depends on it). You've done this for a long time, though, and will continue to. All that matters is that you come out on top in the end – a loss here or there won't matter. In other words, you win some and you lose some.

*cf. G. Becker-Rubinstein: "persons can handle their fears…by acquiring the necessary skills"

The Basic Task

140 choices



Risky Gamble

Guaranteed

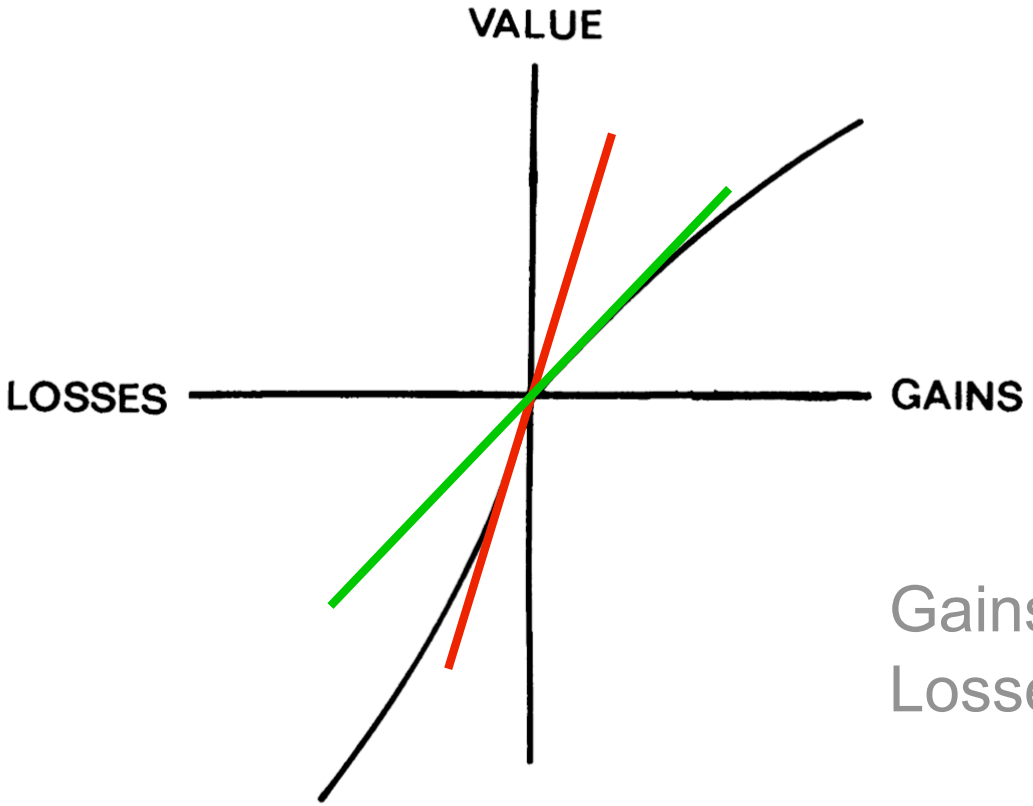
Accept the gamble?

(Collaboration with
C. Camerer & M. Hsu)

A Value Function

A special role for losses

- Prospect Theory (Kahneman & Tversky, 1979)

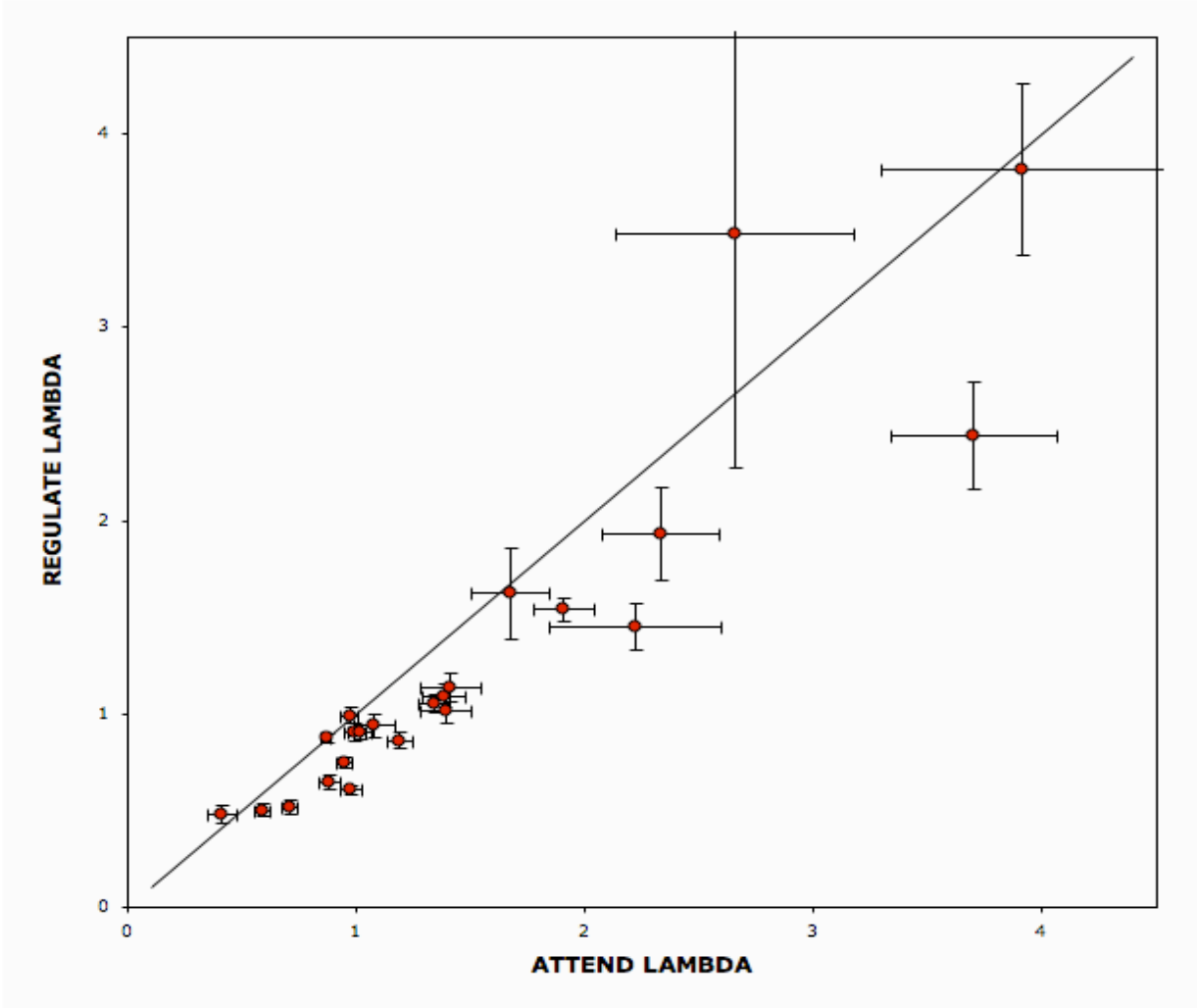


Gains = $x^{(\rho)}$

Losses = $-\lambda^*(-x)^{(\rho)}$

FIGURE 3.—A hypothetical value function.

Re-appraisal often reduces loss-aversion (λ)



Risky choice: Open questions

- Components of risk aversion
  - Loss aversion, π(p), concavity of u(x), emotion
- *Direct* test of attention & emotion effects
- Extremes:
  - pathological gambling, professional traders
- Stability across domains (E. Weber)