

EXECUTIVE FUNCTIONS

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Beth Israel Deaconess Medical Center*

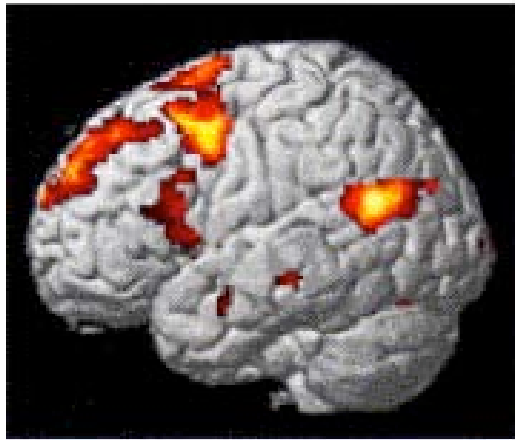
Executive Functions

- Theorized cognitive system that controls and manages other cognitive processes
- Handling novel situations outside the domain of some of our 'automatic' psychological processes
 - Situations that involve planning or decision making
 - Situations that involve error correction or troubleshooting
 - Situations where responses are not well-learned or contain novel sequences of actions
 - Dangerous or technically difficult situations.
 - Situations which require the overcoming of a strong habitual response or resisting temptation

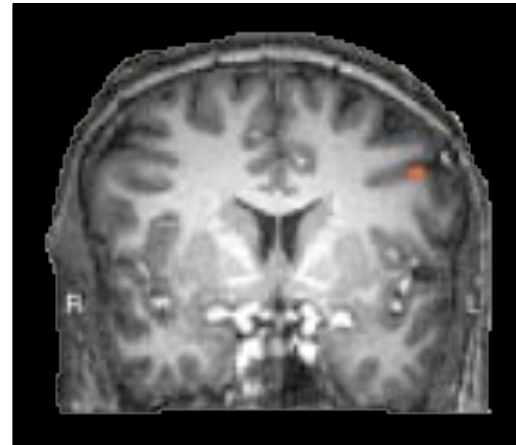
Cognitive Control, Will-Power, Behavioral Regulation

- Fundamental executive capacity
- Goal-driven cognitive control or regulation of impulses, passions, cravings, and habits
- Behavioral changes critical for the prevention, management, and treatment of many important health conditions.

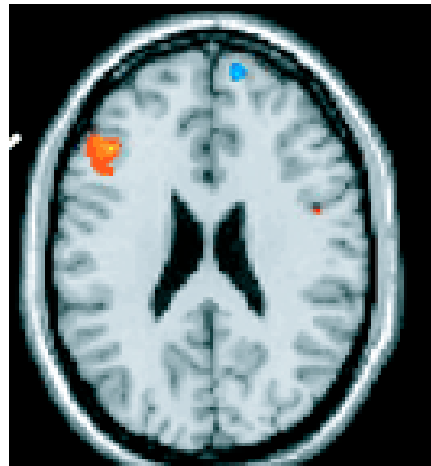
Cognitive Control



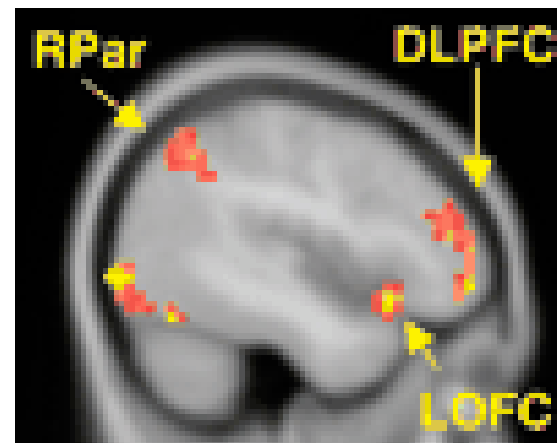
EMOTION



REWARD



MEMORY



DELAYED GRATIFICATION

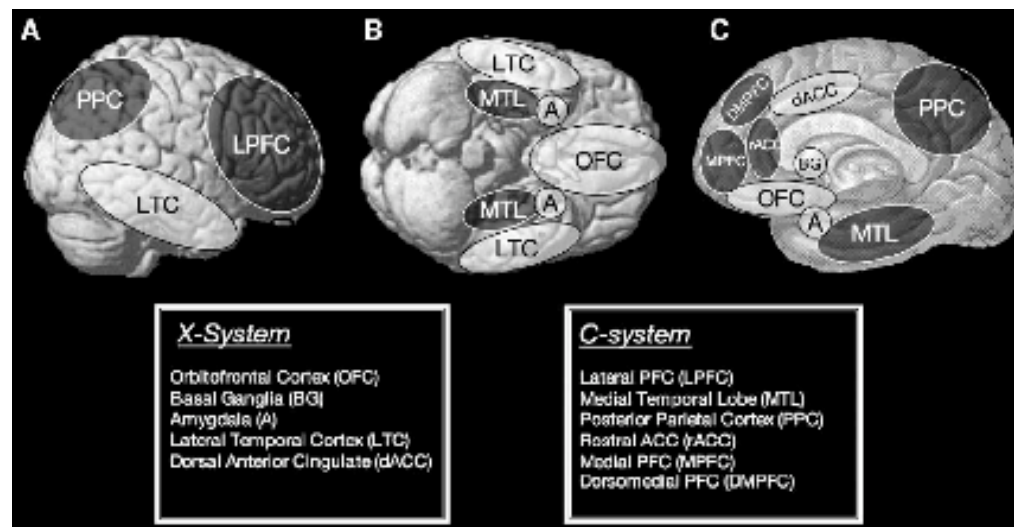
Dual-Process Model

Reflexic (X-System)

- Automatic processes
- Fast operating
- Slow learning
- Phylogenetically older

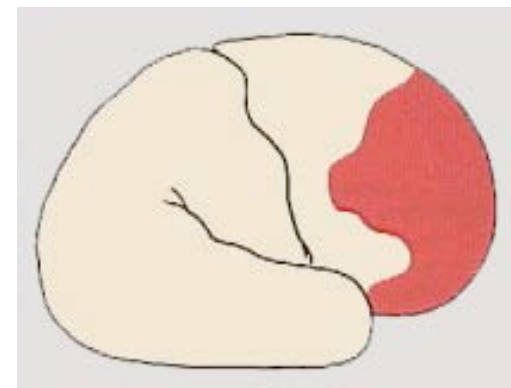
Reflective (C-System)

- Controlled processes
- Slow operating
- Fast learning
- Phylogenetically newer
- Special cases & abstract concepts



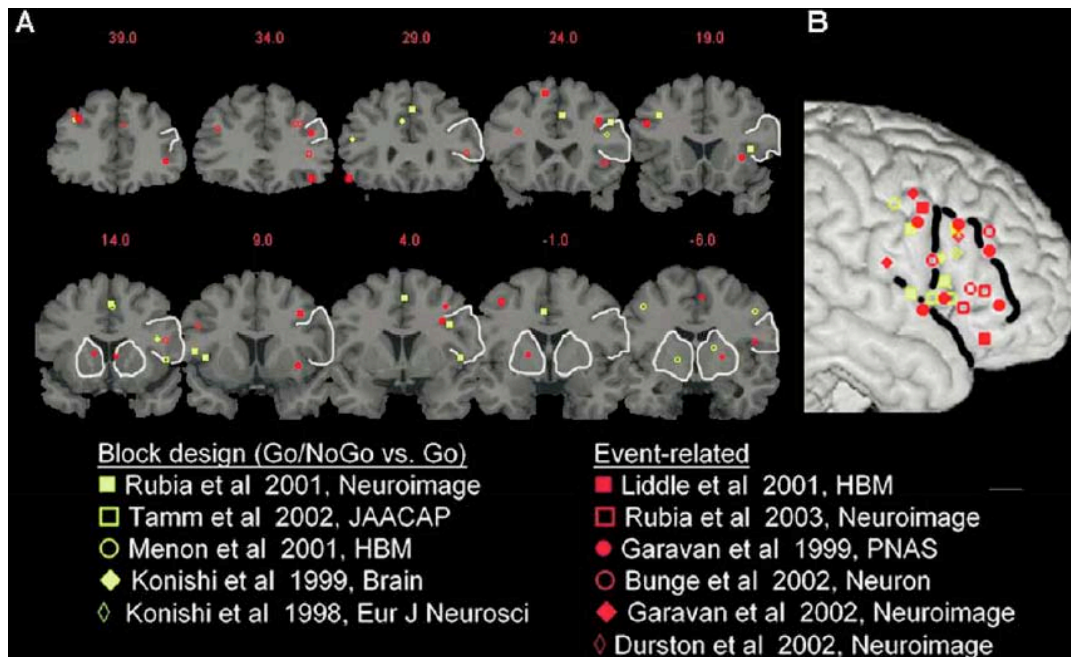
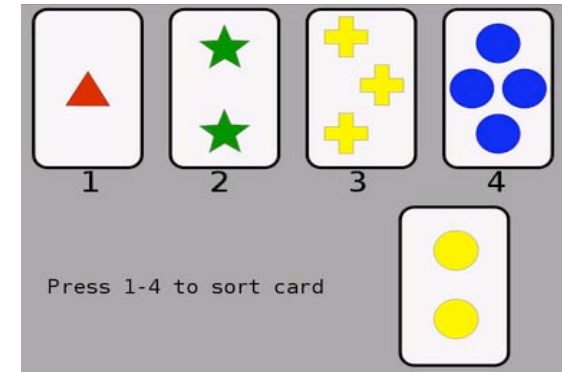
Can human behavior be influenced by modulation of the reflective system?

- Promote understanding of decision making
 - Address uniquely human aspects of behavior
 - Enhance cognitive control
 - Translated to human disease
-
- Ethical debate
 - Steven & Pascual-Leone 2006
 - Canli et al. 2007

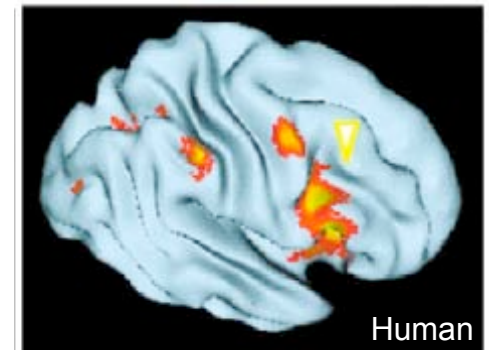
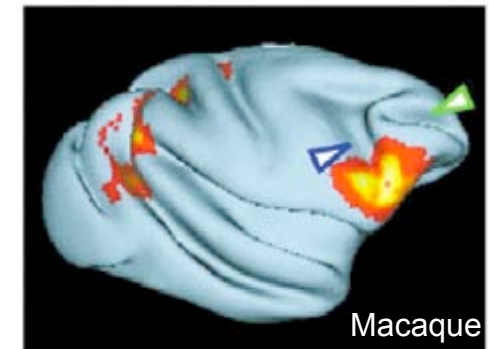


Right Lateral Prefrontal Cortex & Inhibition

- Wisconsin Card Sorting Test
- Go/No-Go & Stop Signal Paradigms
- Task-set switching



Aron & Poldrack, 2005



Nakahara et al, 2002

Ultimatum Game



Proposer



16

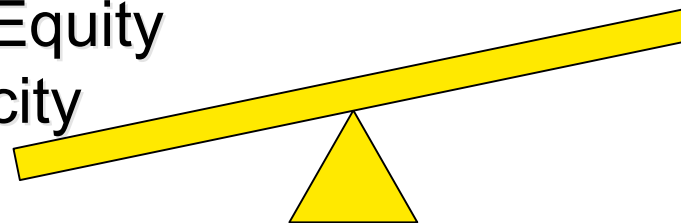
4

Responder



Fairness • Equity
Reciprocity

Self-interest



Knoch et al. *Science* 2006

Altruistic Punishment

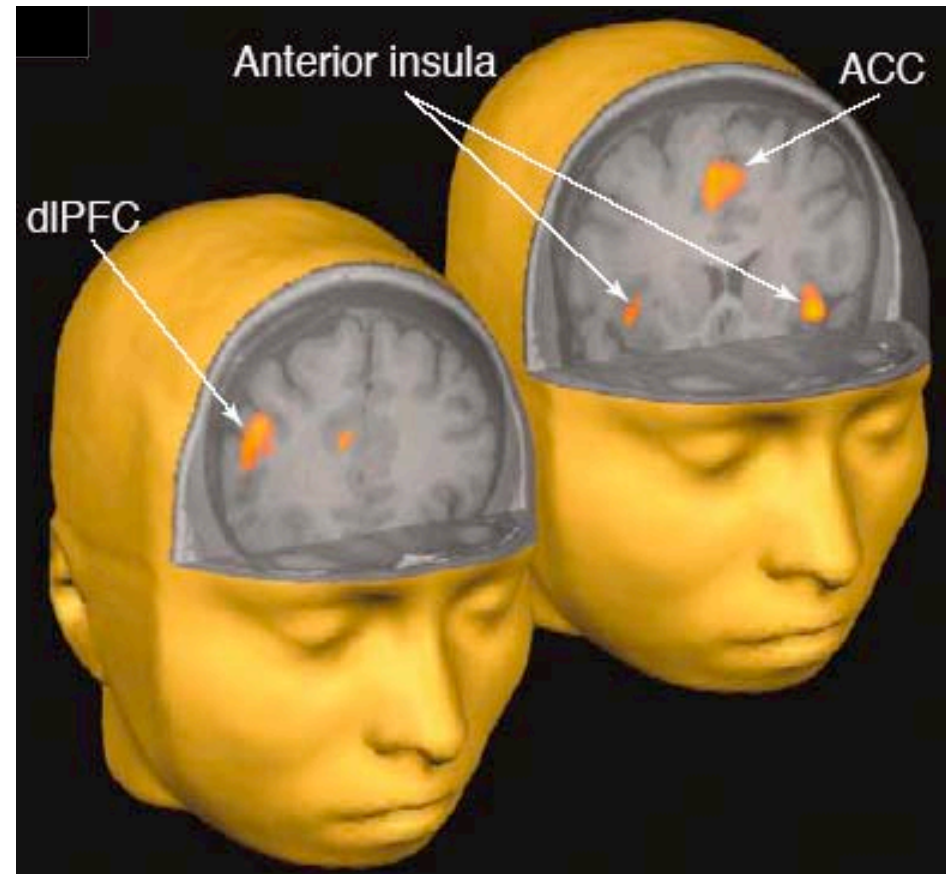
- People reject low offers even if stake levels are as high as three months' income
- Rejection rates up to 80% for offers below 25% of the available money

Responder



fMRI Study

- Anterior insula & DLPFC activated when responders decide whether to accept or reject an unfair offer
- DLPFC more strongly activated when subjects face unfair offers compared to when they face fair offers



Sanfey et al. Science 2003

Role of the Lateral PFC

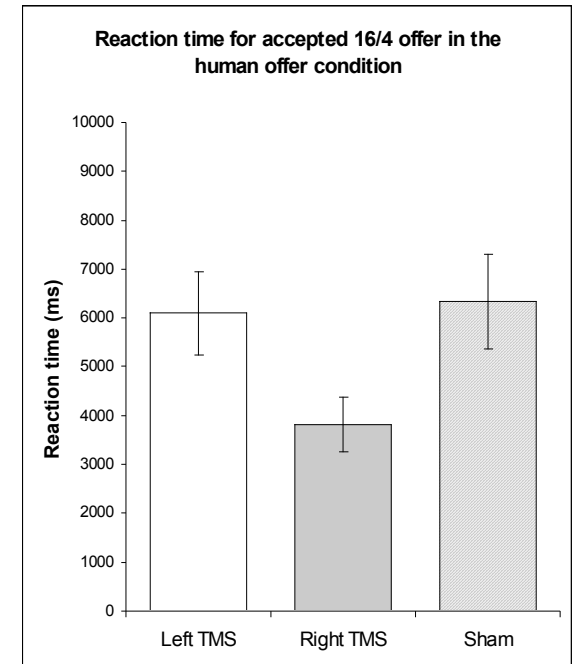
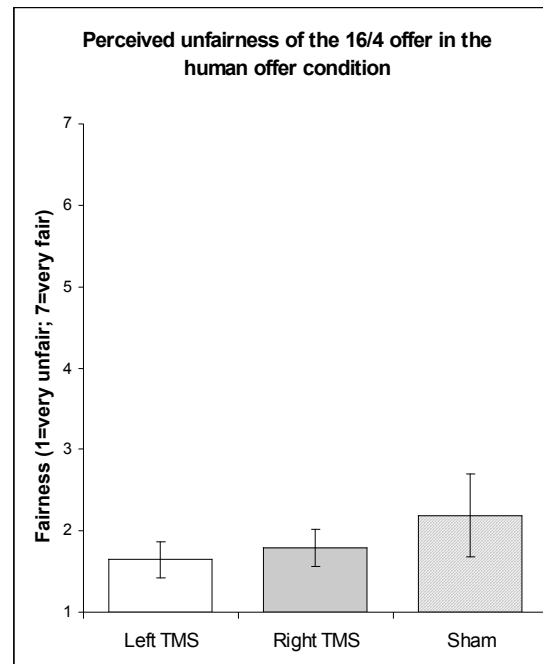
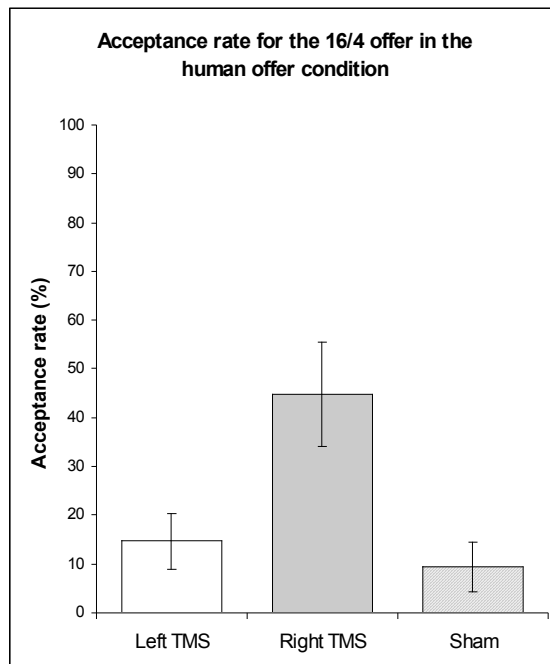
- Involved in the control of the emotional impulse to reject unfair offers; cognitive control of the emotional impulse associated with fairness goals (Sanfey et al.)
- Involved in the inhibition of selfish impulses
 - Note that emotional forces may be associated with selfish impulses as well as with fairness goals - consistent with dual systems approaches
 - Need to inhibit self-centered impulse in order to enable “morally appropriate” behavior

Predictions for Disruption of Lateral PFC

- If Lateral PFC exerts cognitive control for suppression of fairness impulses:
 - *reduce* the acceptance rate of unfair offers
- If Lateral PFC suppresses selfish impulses:
 - *increase* the acceptance rate for unfair offers





Ultimatum Game



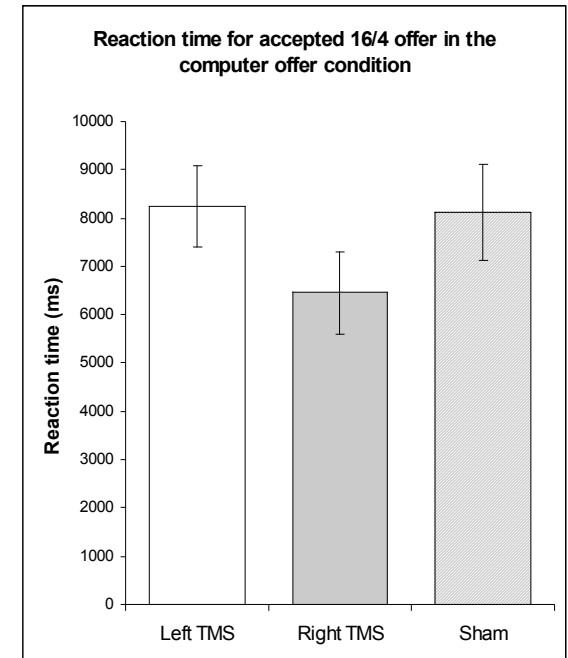
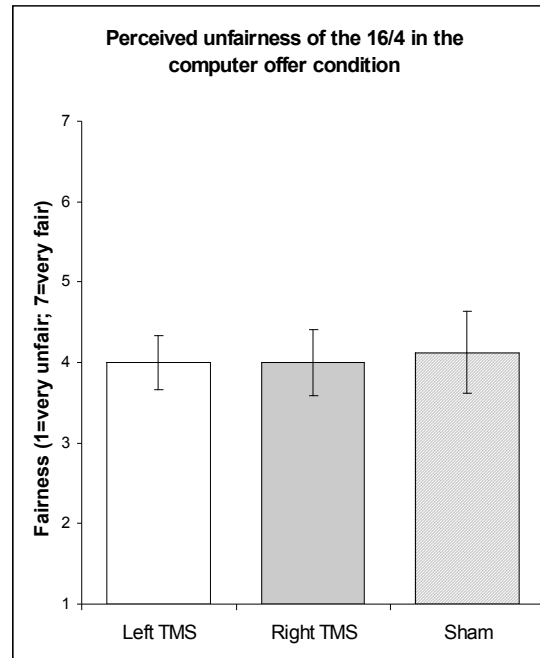
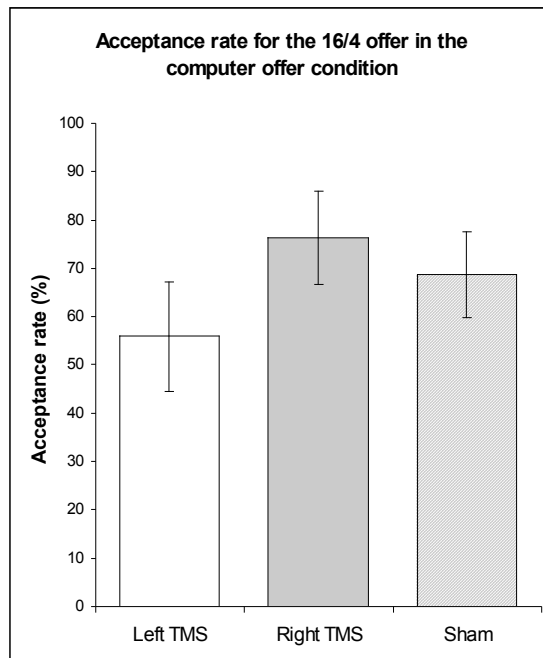
Ultimatum Game



Proposer	Self-interest	Fairness Equity	Reciprocity
	+	+	+
	+	+/-	-



Ultimatum Game



Ultimatum Game



- Social interaction often involves the simultaneous interaction of *many* subjects.
- In experiments examining altruistic behaviors it is important that subjects interact only *once* with many different partners.
- The absence of interaction partners during the experiment may raise suspicion among the subjects and may change their behaviors.
- The best implementation of social interactions is the simultaneous presence of all subjects during the experiment.

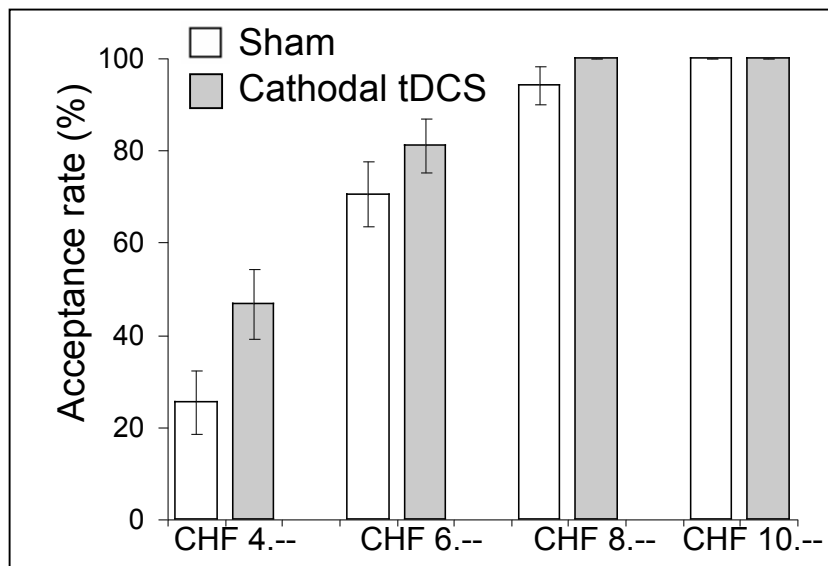


tDCS

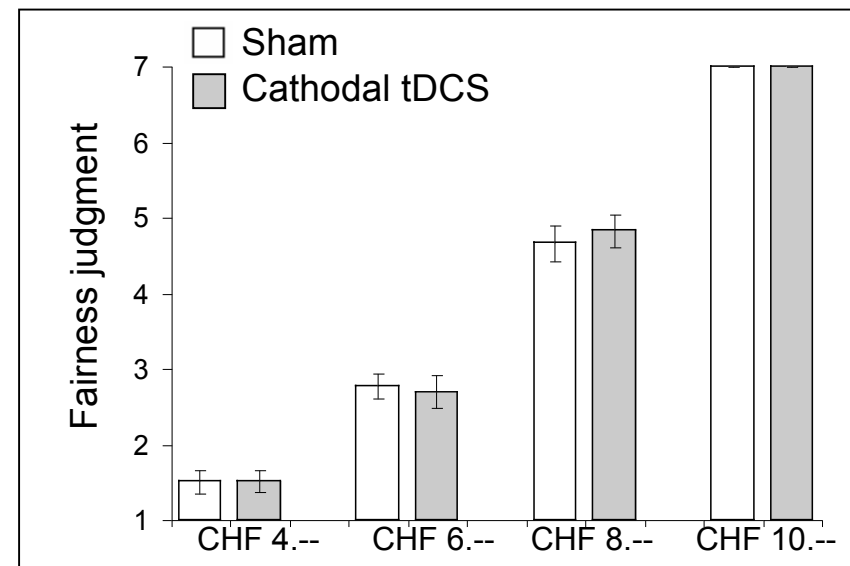
Ultimatum Game



a



b



Ultimatum Game Experiments:

It is possible to modify response without altering the fairness judgment.

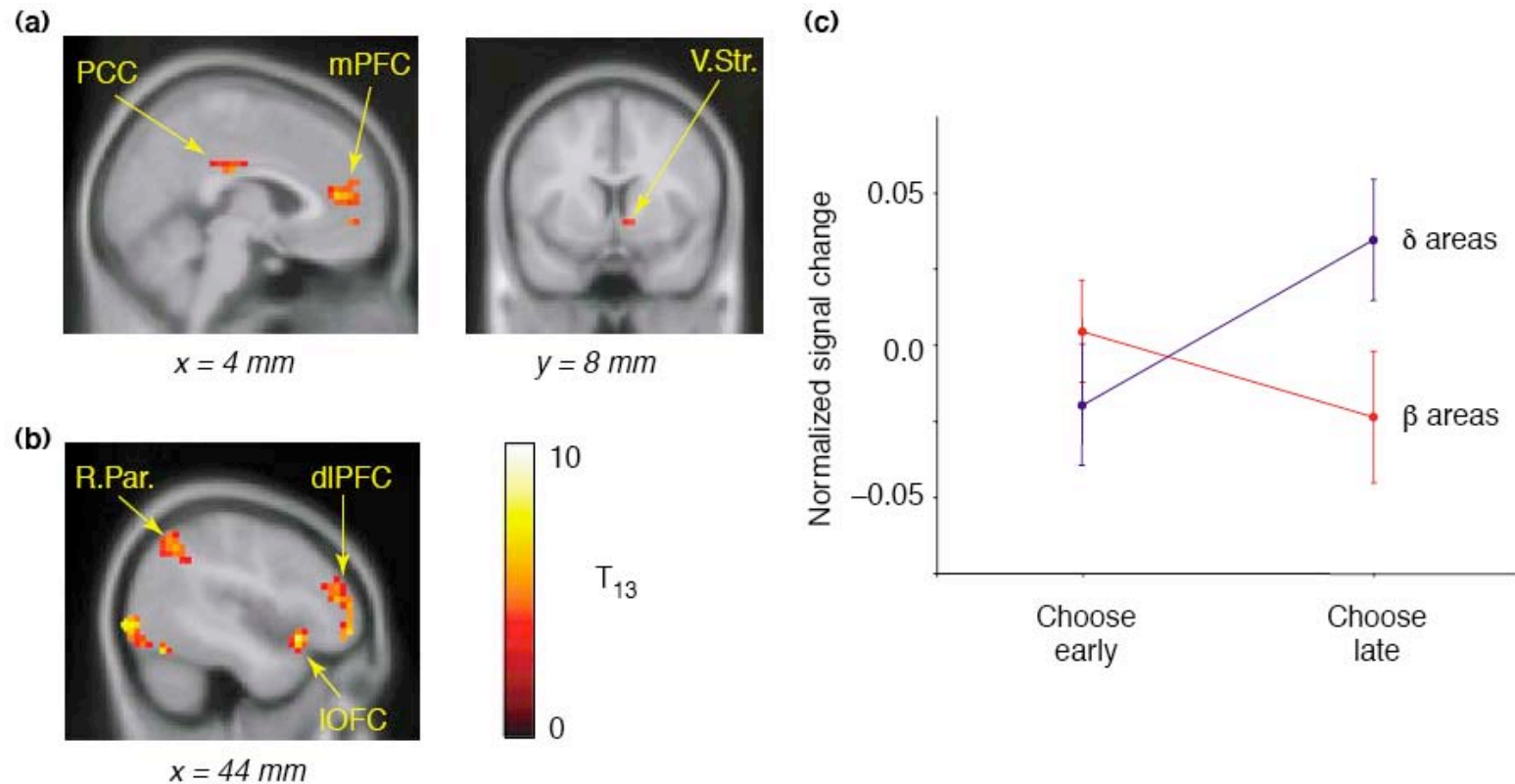
Suppression of the RIGHT Lateral PFC leads to an *increase* in acceptance rate for unfair offers.

The Lateral PFC (right) suppresses self-centered impulses.

Control of self-centered behavior is critical to suitably balance risk taking impulses. Is the role of the lateral PFC demonstrable in a risk task?

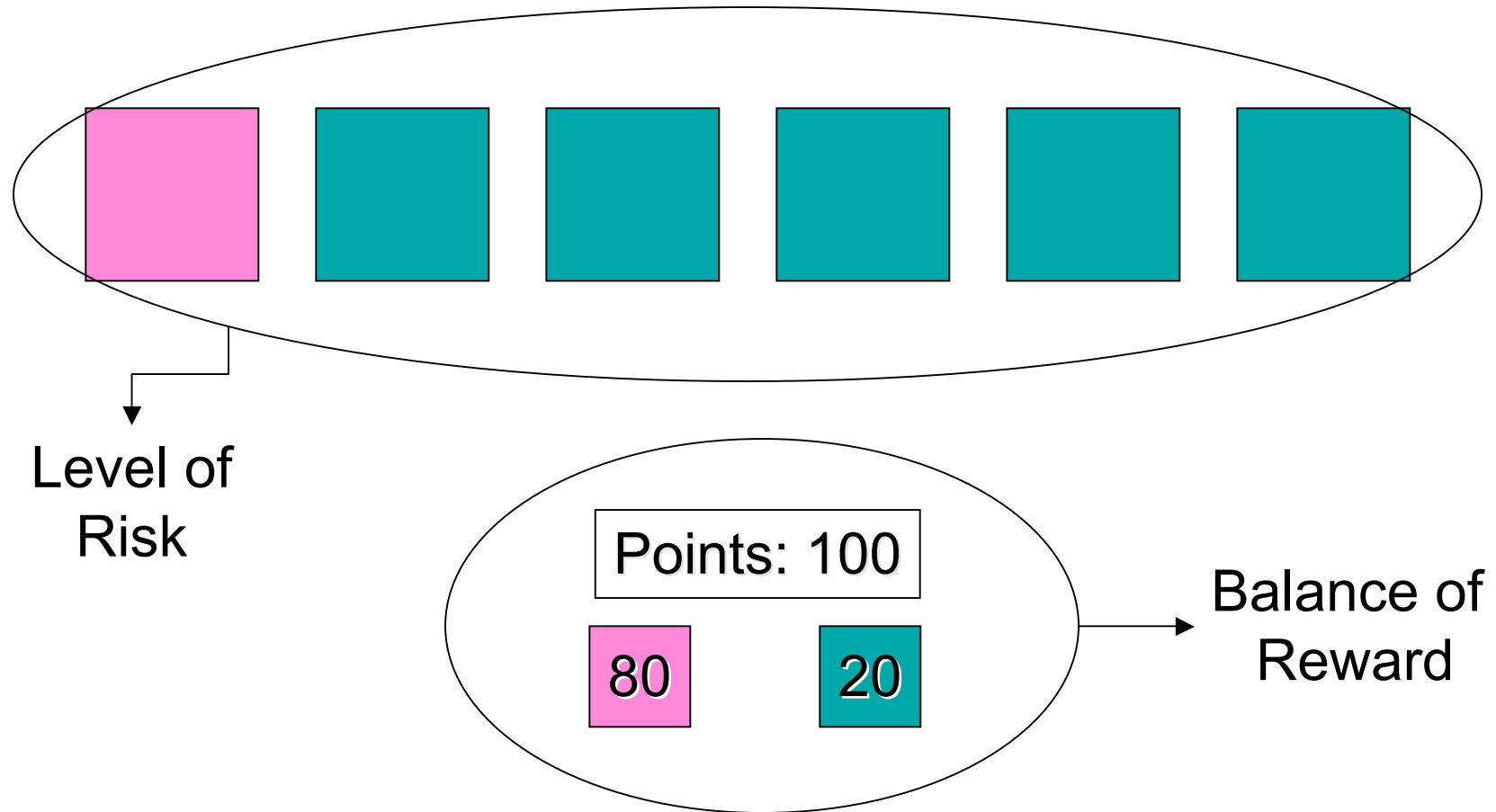
Decisions over time

- Impulsive / Fast Decisions: Affective mechanism (β areas): heavily values the present
- Reflective Decisions: Deliberative mechanism (δ areas): over time considerations

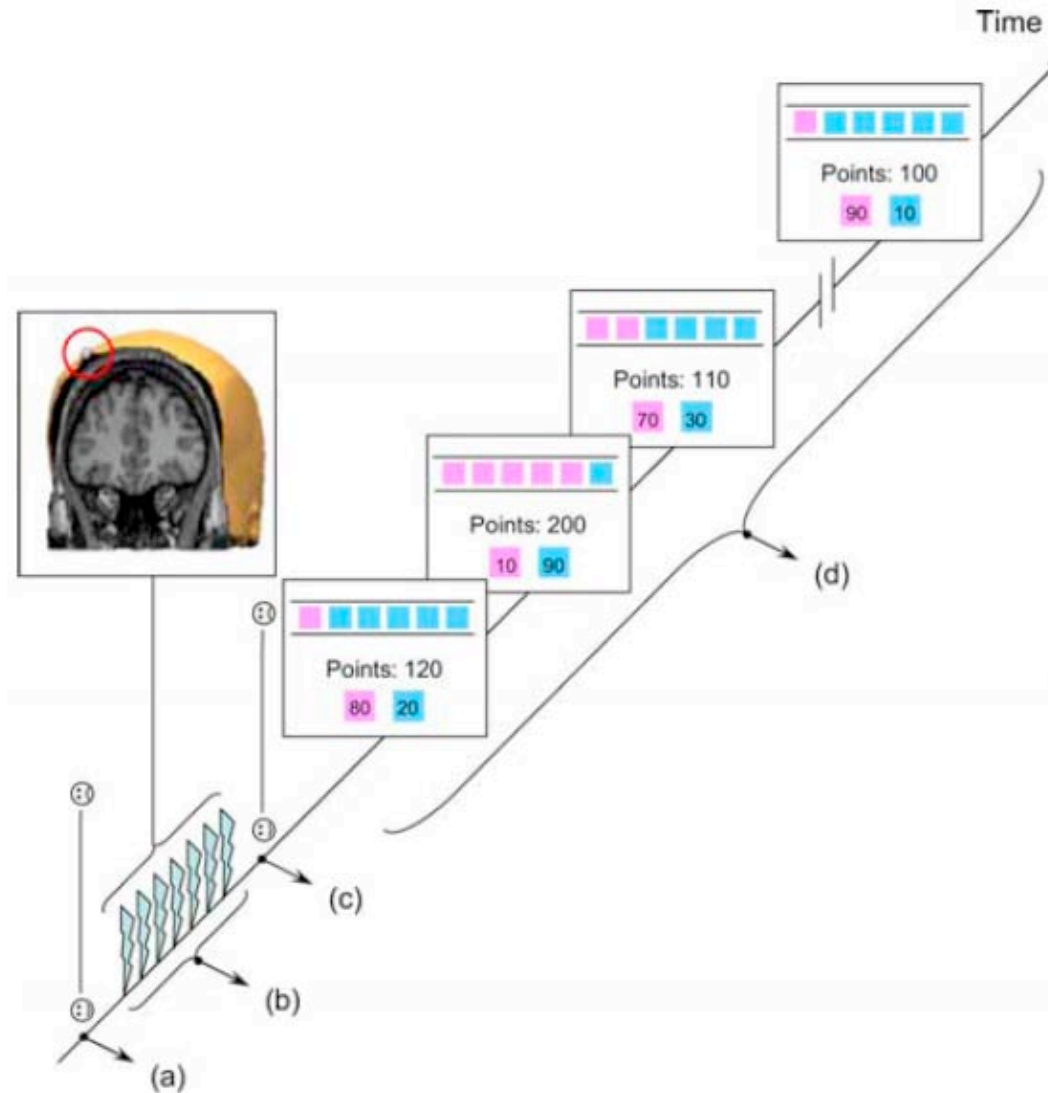


McClure et al., Science 2004

Risk Task



Risk Task

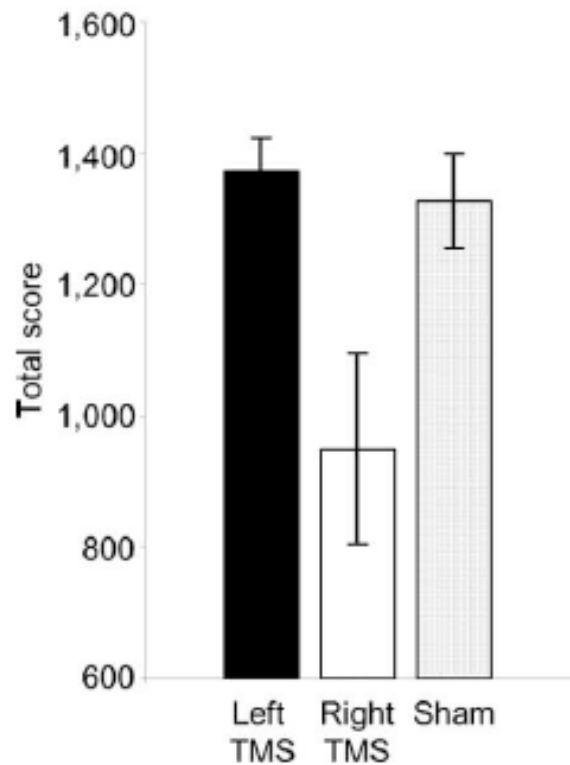


Knoch et al. *J Neurosci* 2006

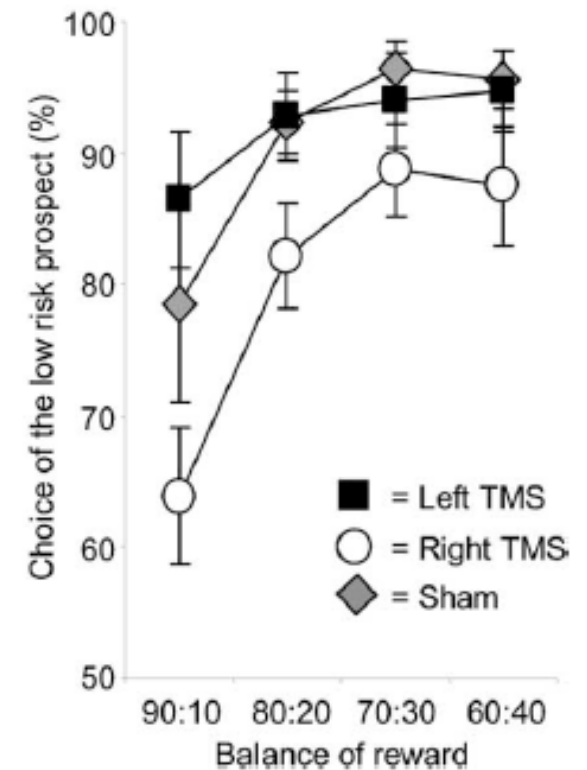
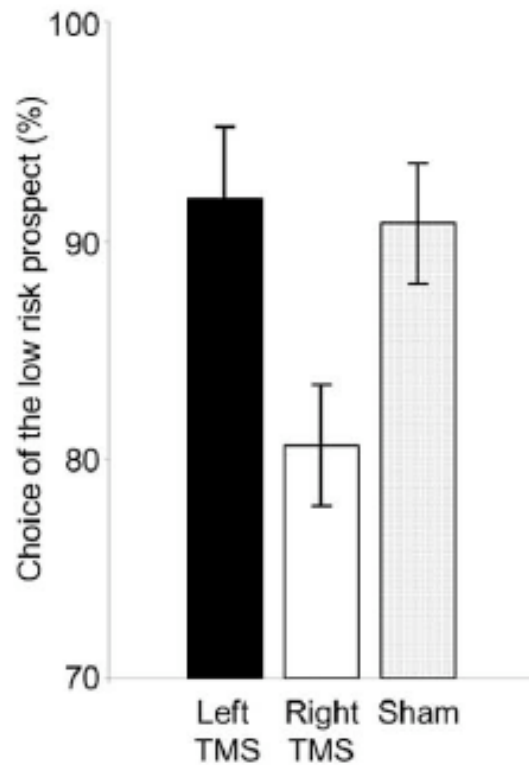
Risk Task



Points Earned



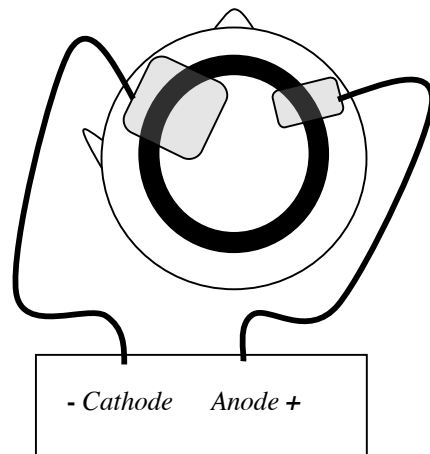
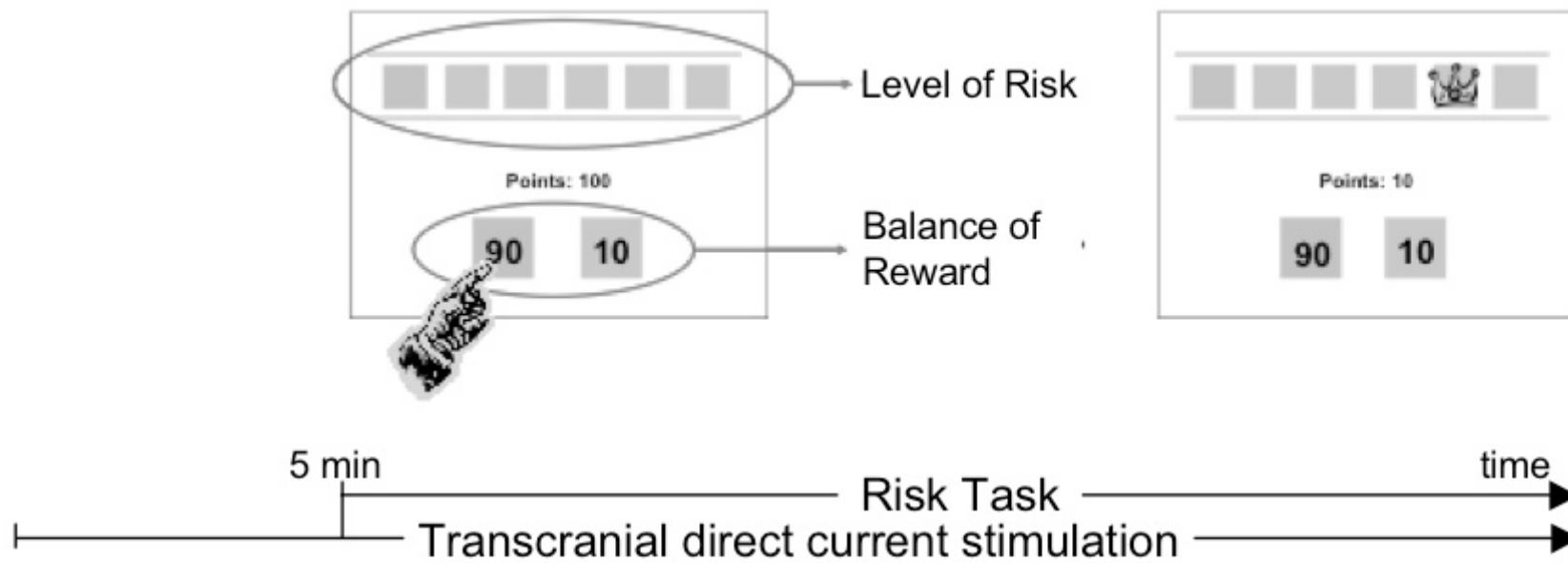
Choice of Low Risk Option



Suppression of the right lateral PFC leads to increased risk taking behavior.

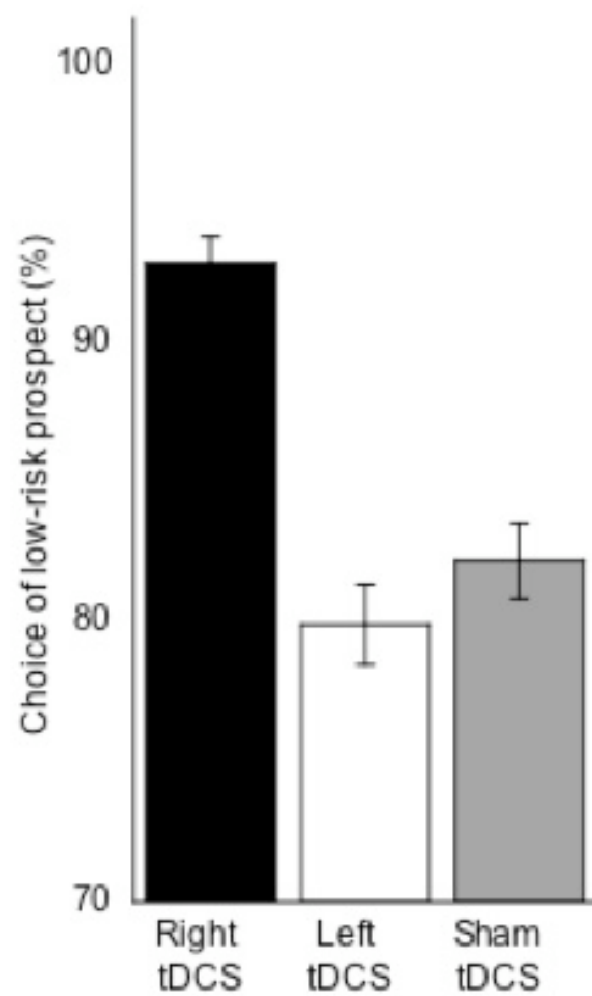
Lateral PFC (right) suppresses impulsive, self-centered behavior.

Is it possible to decrease risk-taking behavior by increasing activity in the lateral PFC?

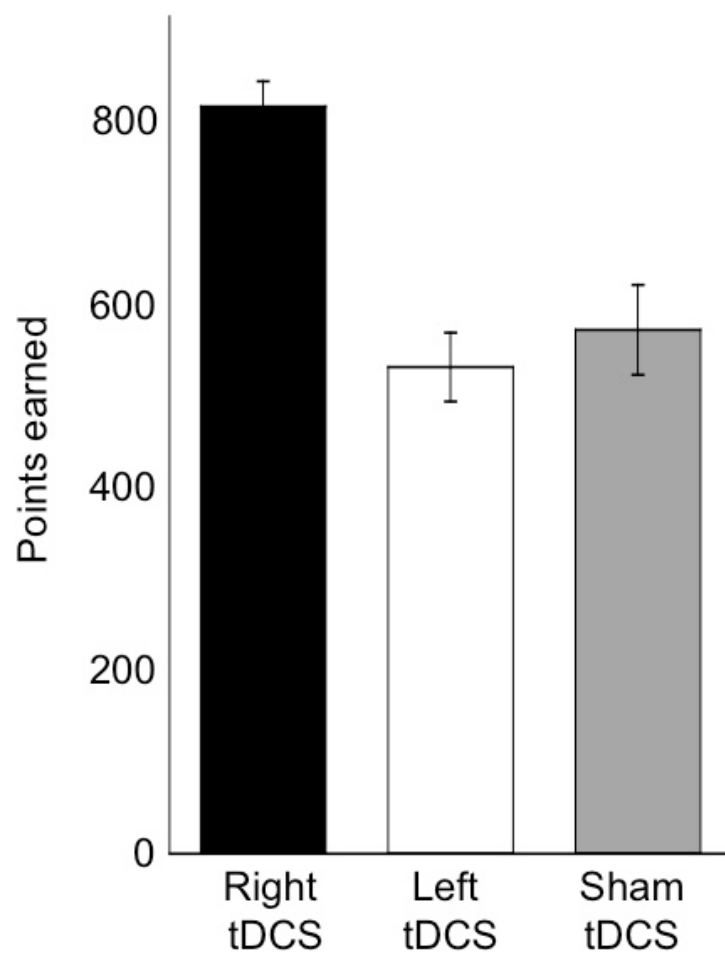


↑ Right Lateral PFC

Fecteau et al. *J Neurosci* (2007)



Fecteau et al. *J Neurosci* (2007)



Fecteau et al. *J Neurosci* (2007)

Increasing activity in the RIGHT lateral PFC decreases risk taking behavior.

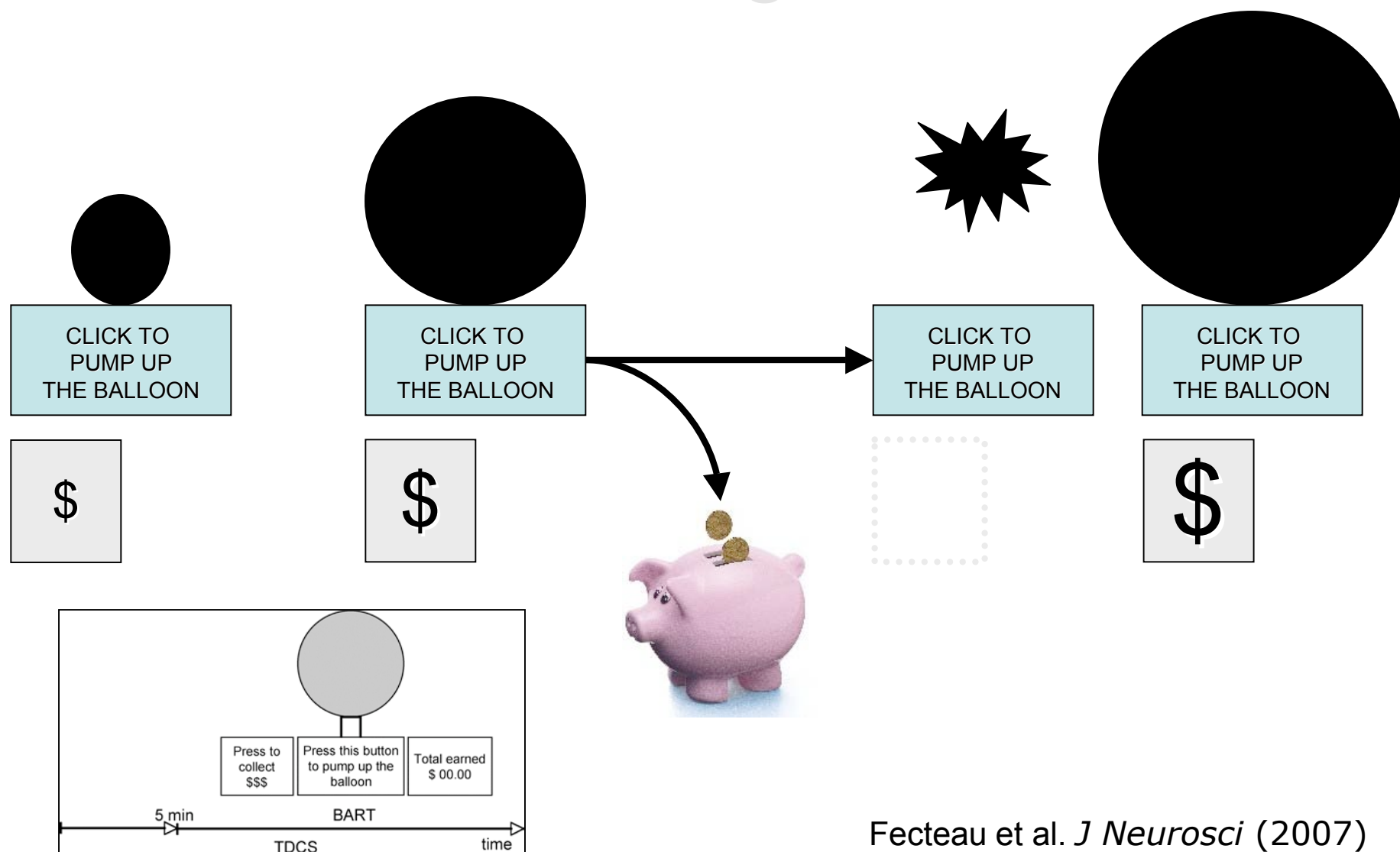
Lateral PFC (right) suppressive impulsive, self-centered behavior.

What happens in circumstances when the balance of risk is unknown?

Is the level of activity in the right lateral PFC the critical variable, or the relative balance between left and right?

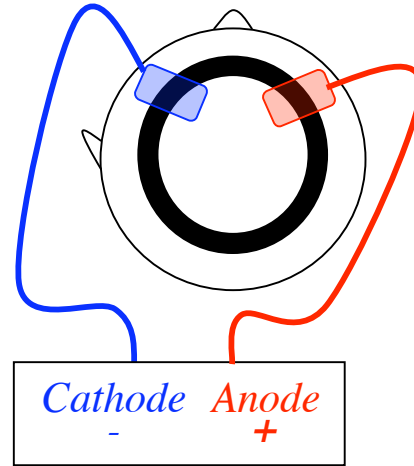
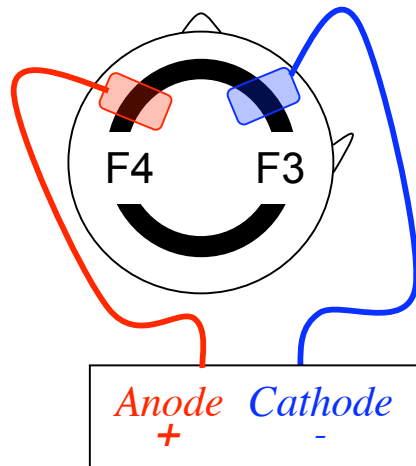


Balloon Analog Risk Task

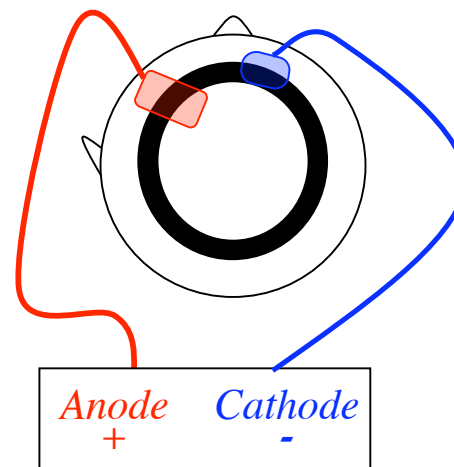
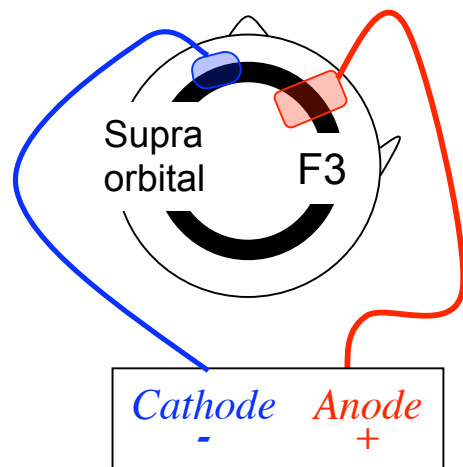




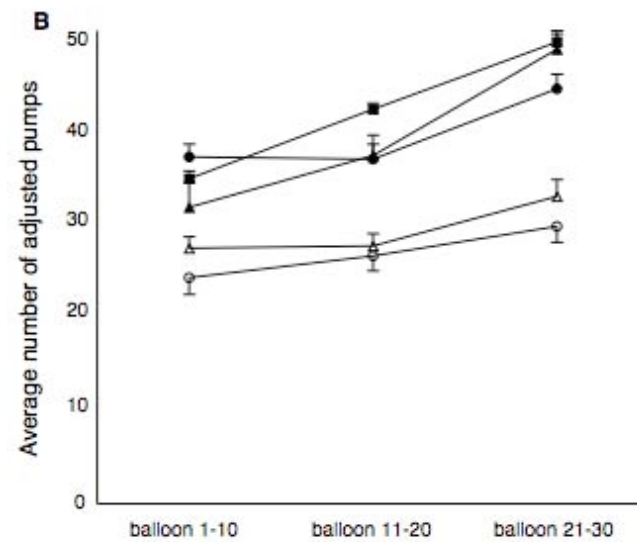
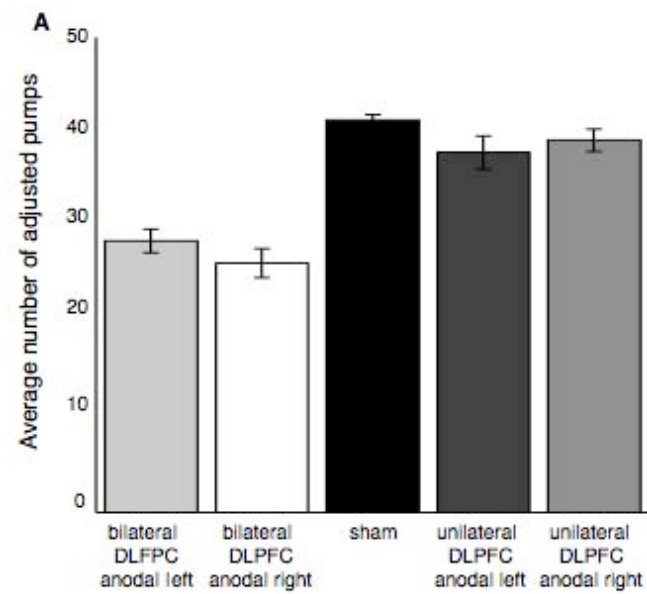
35 cm²



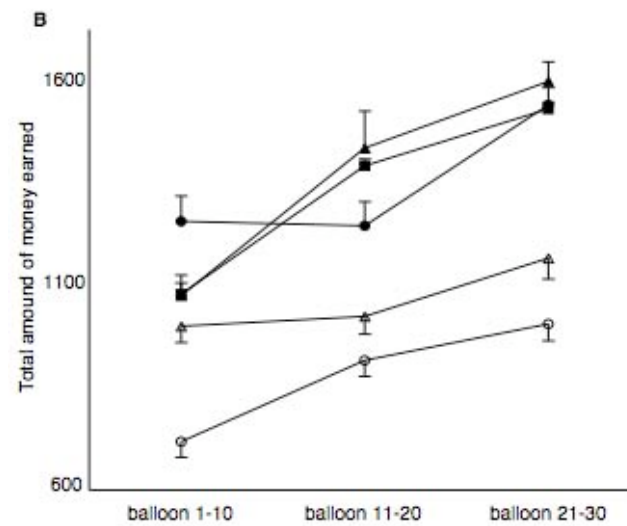
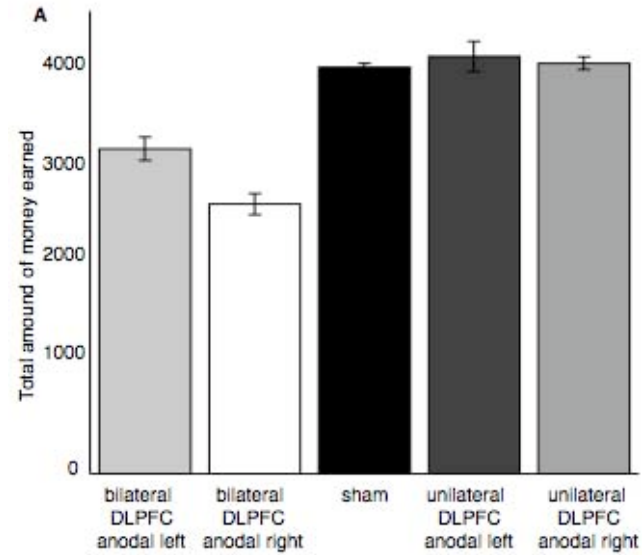
Bilateral
tDCS



Unilateral
tDCS



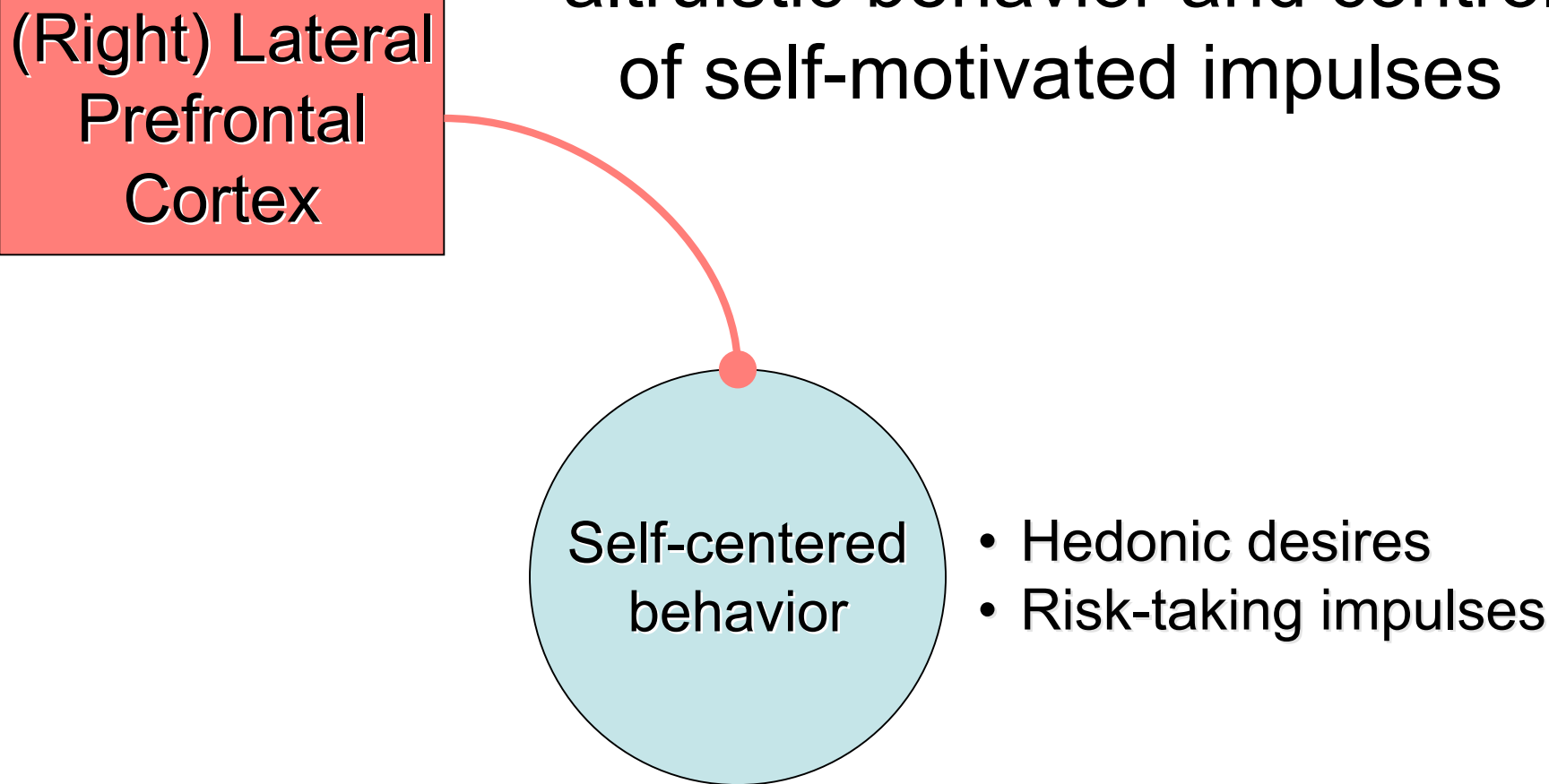
Fecteau et al. *J Neurosci* (2007)



Fecteau et al. *J Neurosci* (2007)

Noninvasive modulation of
Right Prefrontal activity can
modify unique human traits of
altruistic behavior and control
of self-motivated impulses

(Right) Lateral
Prefrontal
Cortex



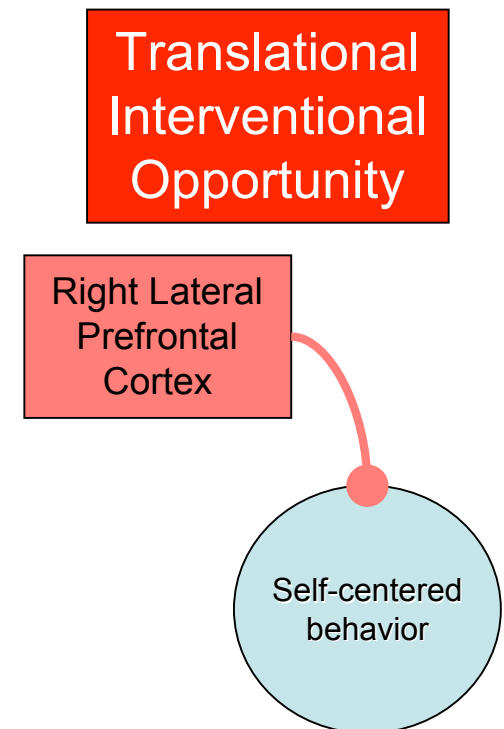
The diagram consists of a red rectangular box on the left containing the text '(Right) Lateral Prefrontal Cortex'. A red curved line originates from the right side of this box and terminates at a small red dot on the top edge of a light blue circle. Inside the circle is the text 'Self-centered behavior'. To the right of the circle is a bulleted list containing 'Hedonic desires' and 'Risk-taking impulses'.

Self-centered
behavior

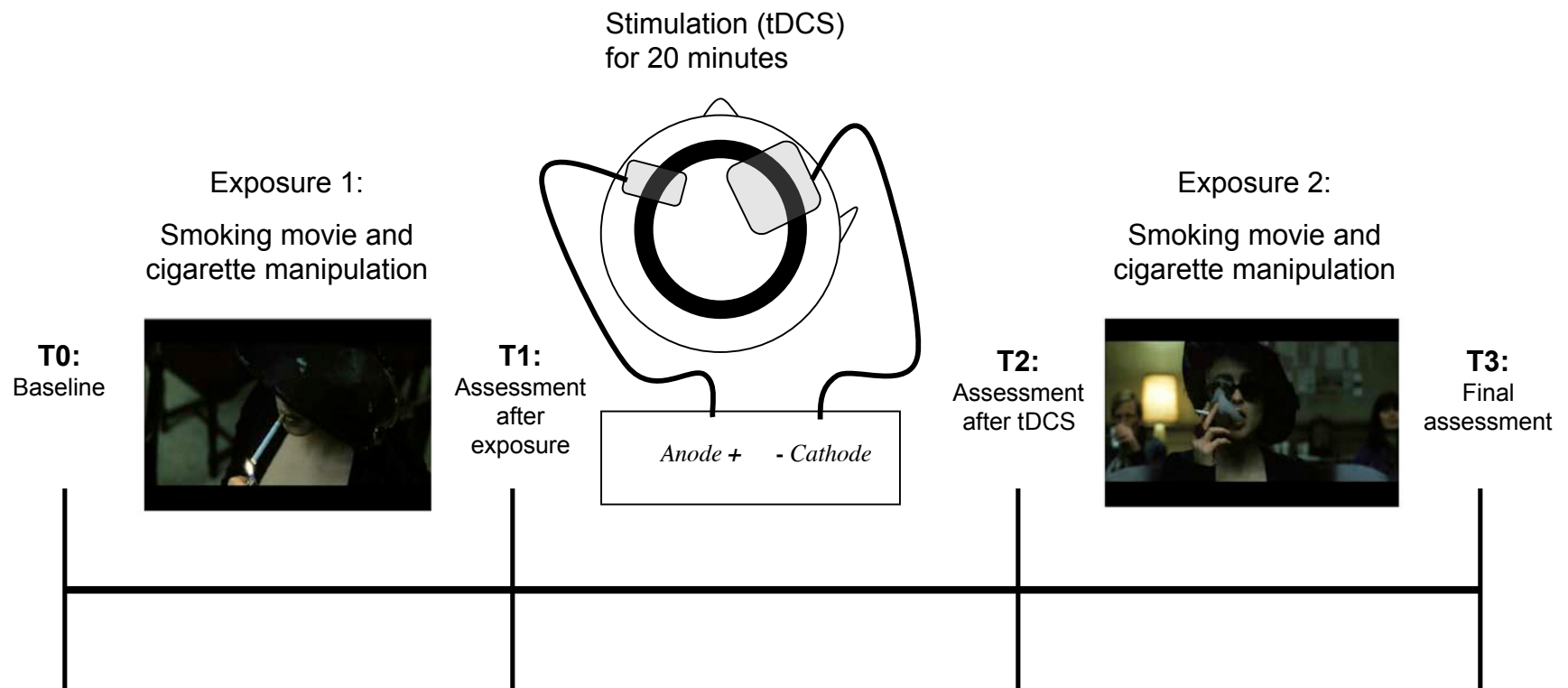
- Hedonic desires
- Risk-taking impulses

Right Lat PFC Failure

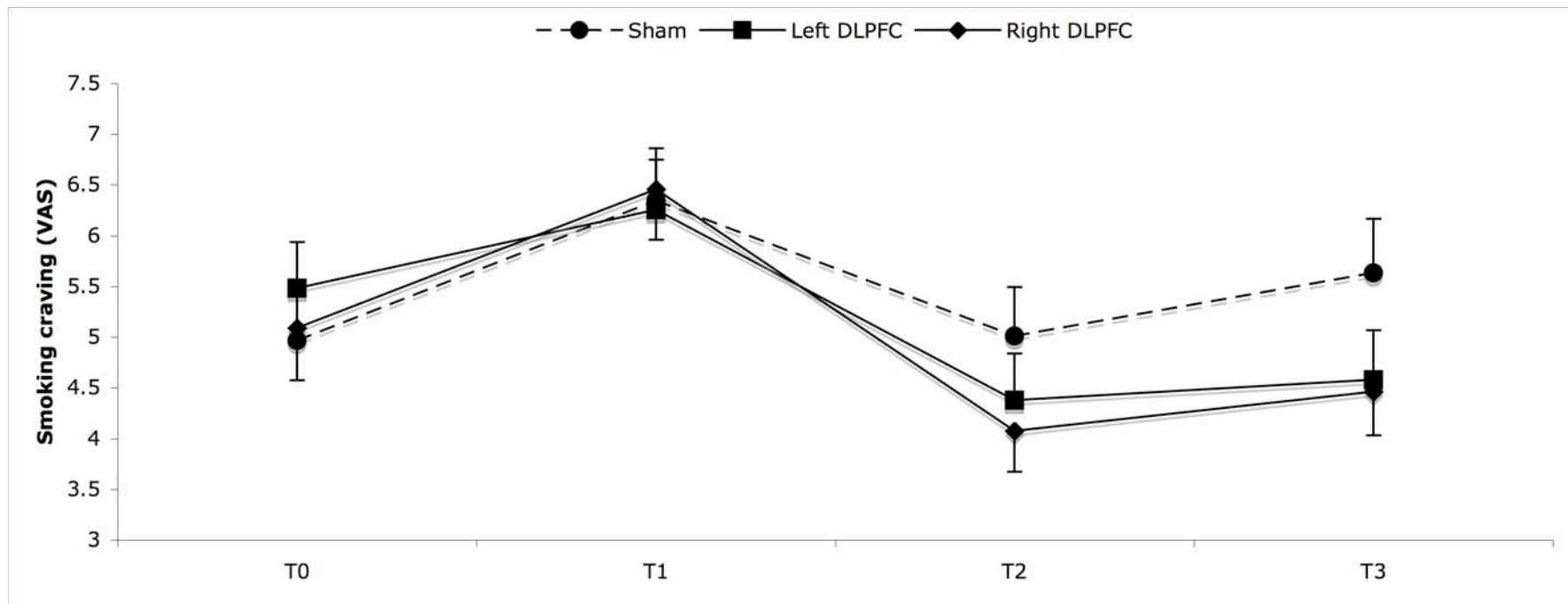
- Impulsive, self-centered behavior with disregard to cultural & social convention
 - Traumatic brain injury
 - Frontal dementia
 - Mood Disorders
 - Sociopathic personality behavior
 - Borderline personality disorder
 - Addictive behavior
 - Cocaine
 - Nicotine
 - Pathological gambling
 - Eating disorders - Obesity



Cue-Provoked Nicotine Craving

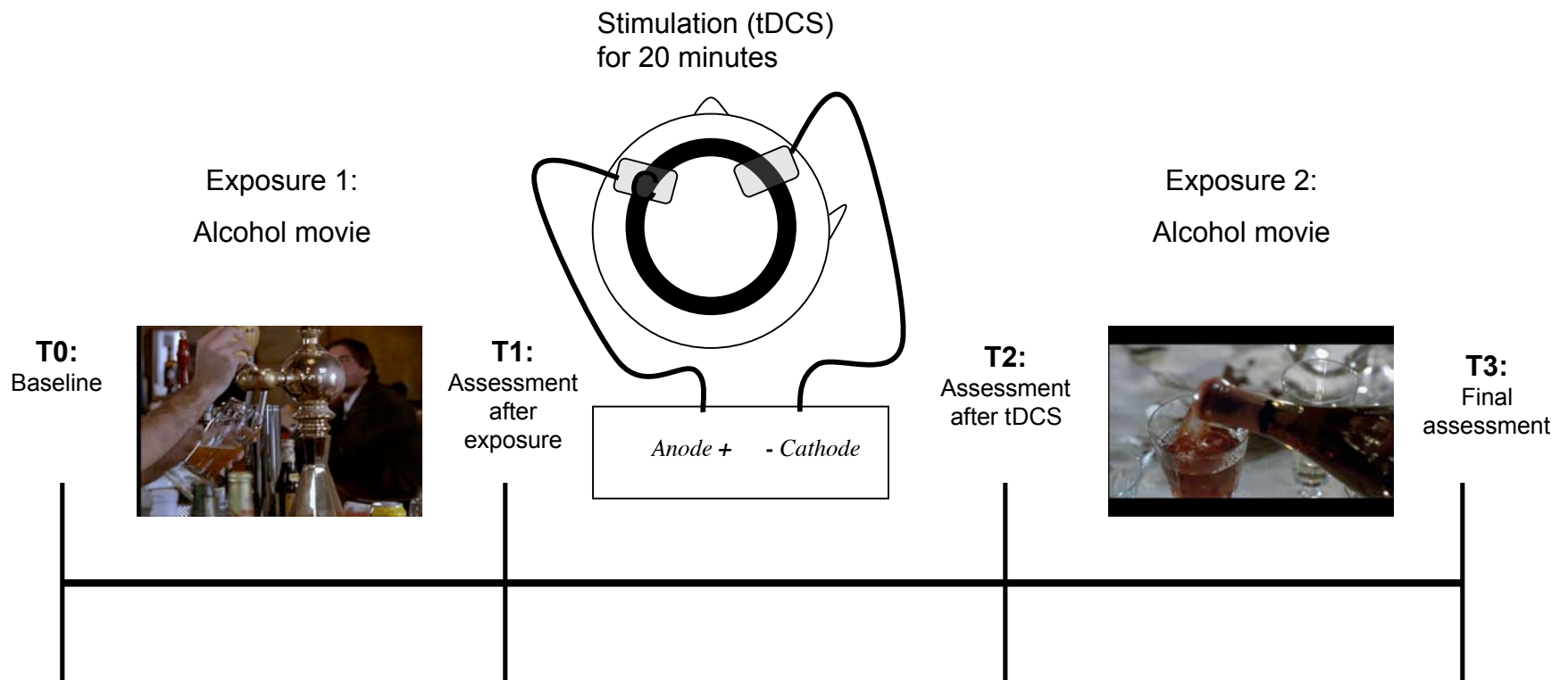
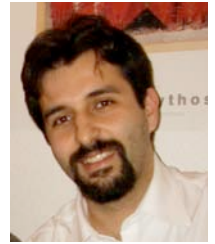


Cue-Provoked Nicotine Craving



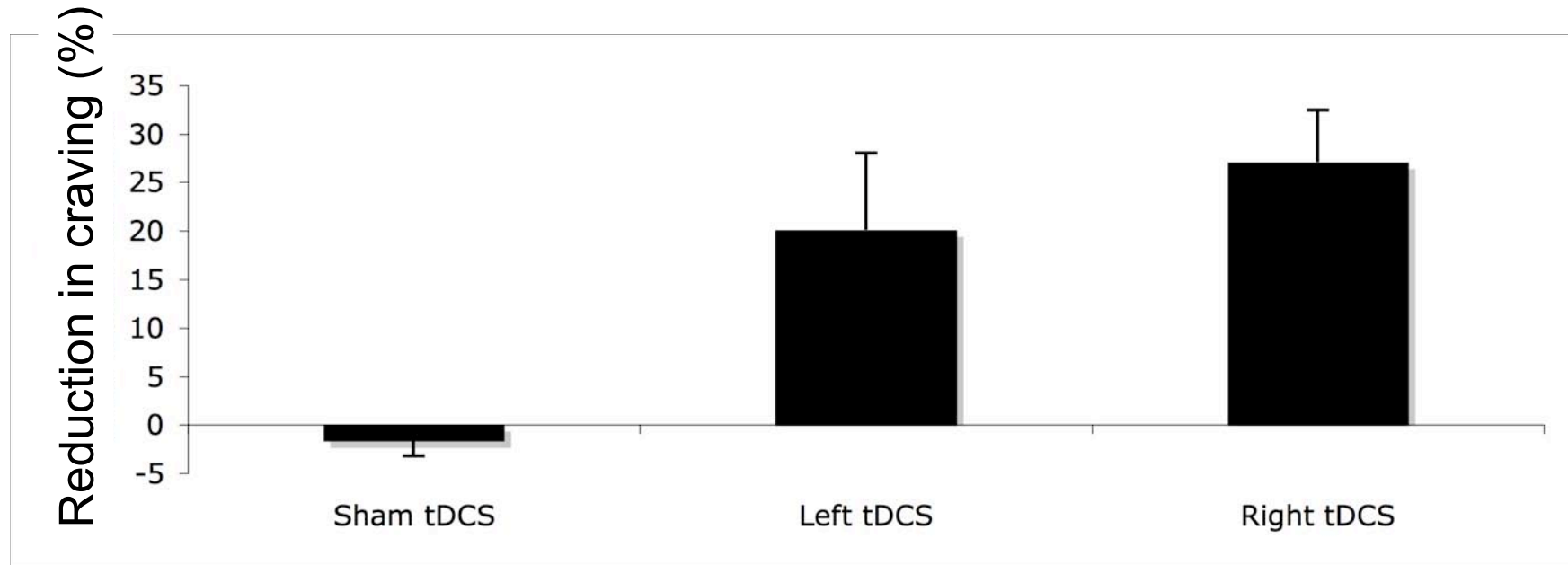
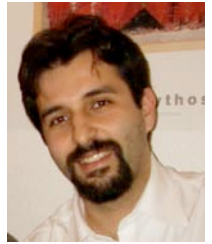
Fregni et al. *J Clin Psych* (2008)

Cue-Provoked Alcohol Craving



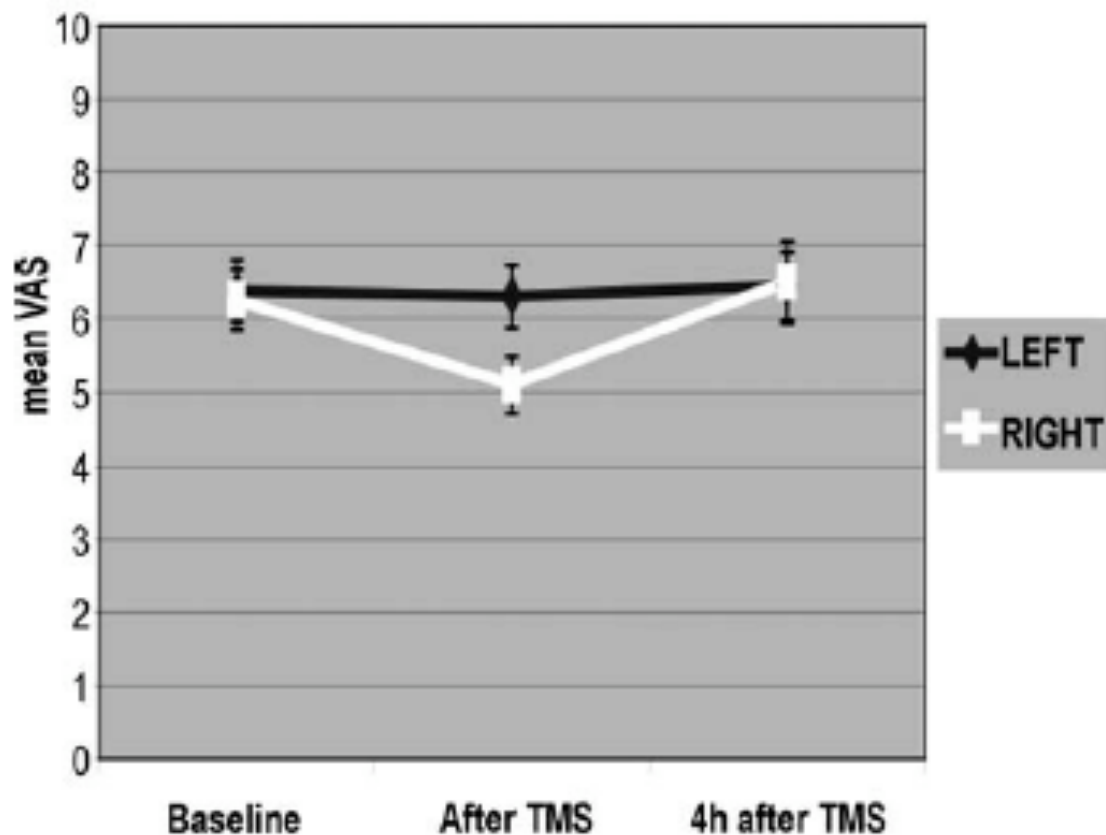
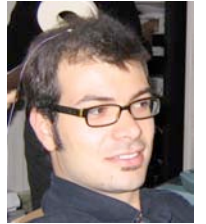
Boggio et al. *Drugs and Alcohol Dependence* (2008)

Cue-Provoked Alcohol Craving



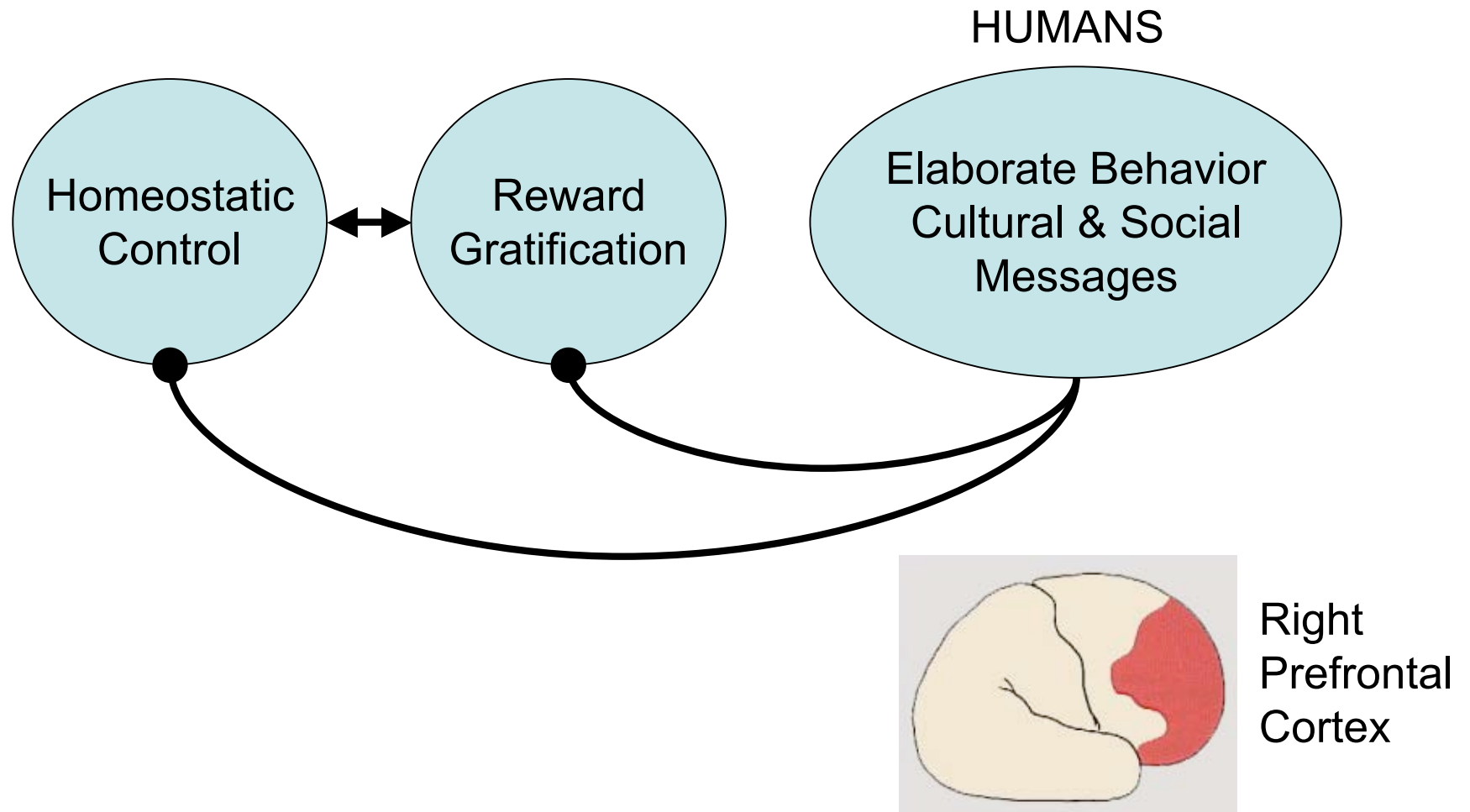
Boggio et al. *Drugs and Alcohol Dependence* (2008)

Right PF rTMS in Cocaine Craving



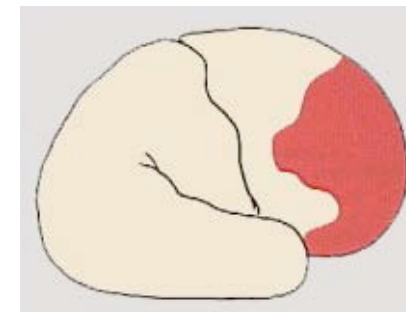
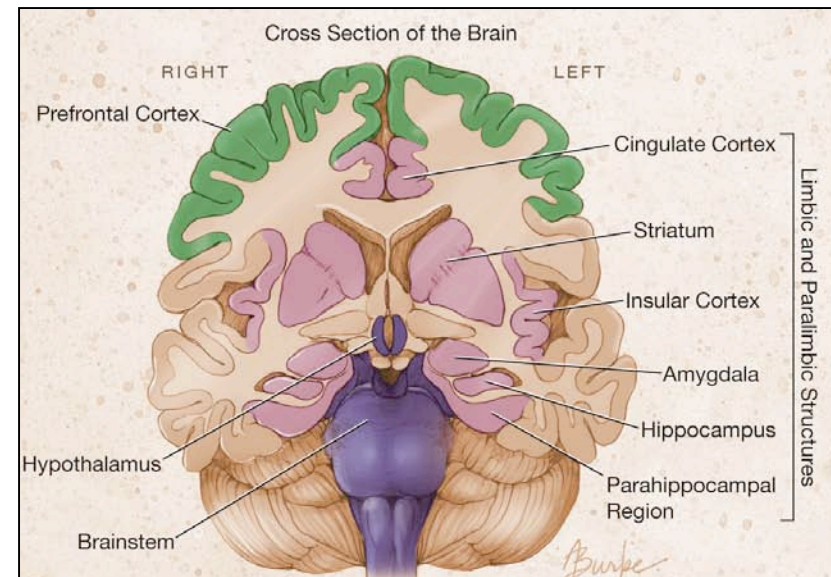
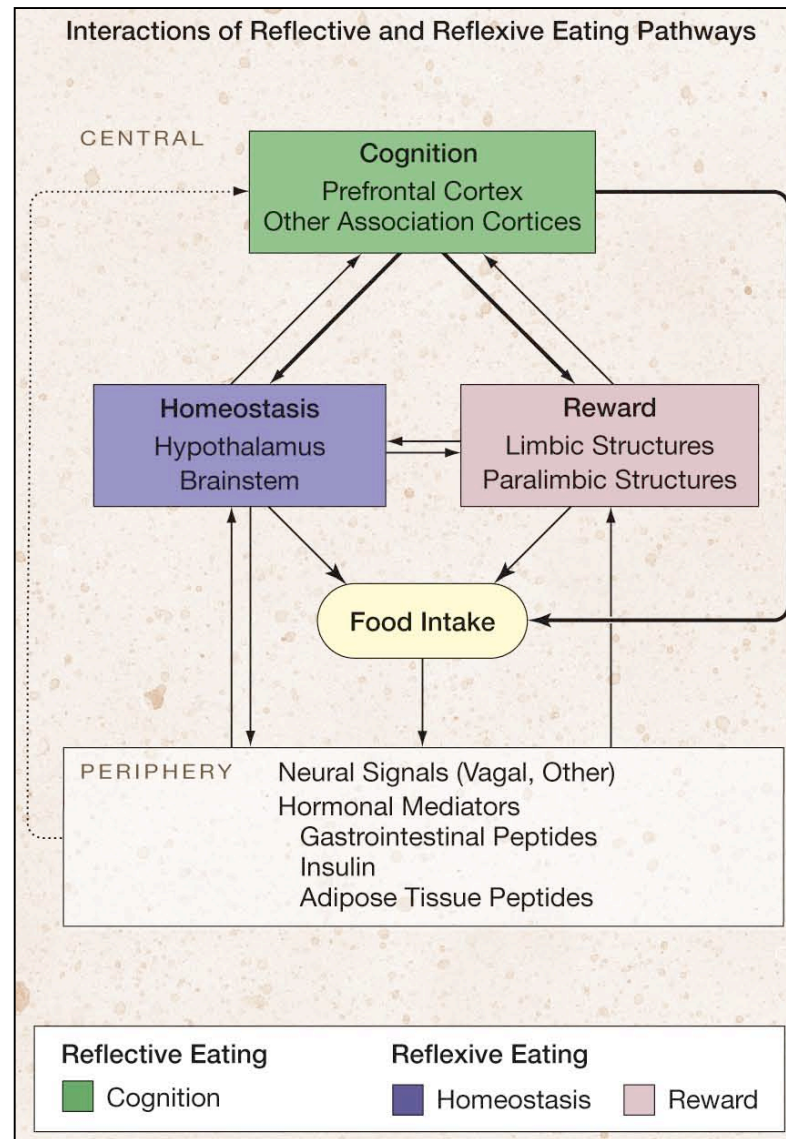
Camprodon et al. *Drug Alcohol Dependence* (2006)

Obesity



Alonso & Pascual-Leone *JAMA* 2007

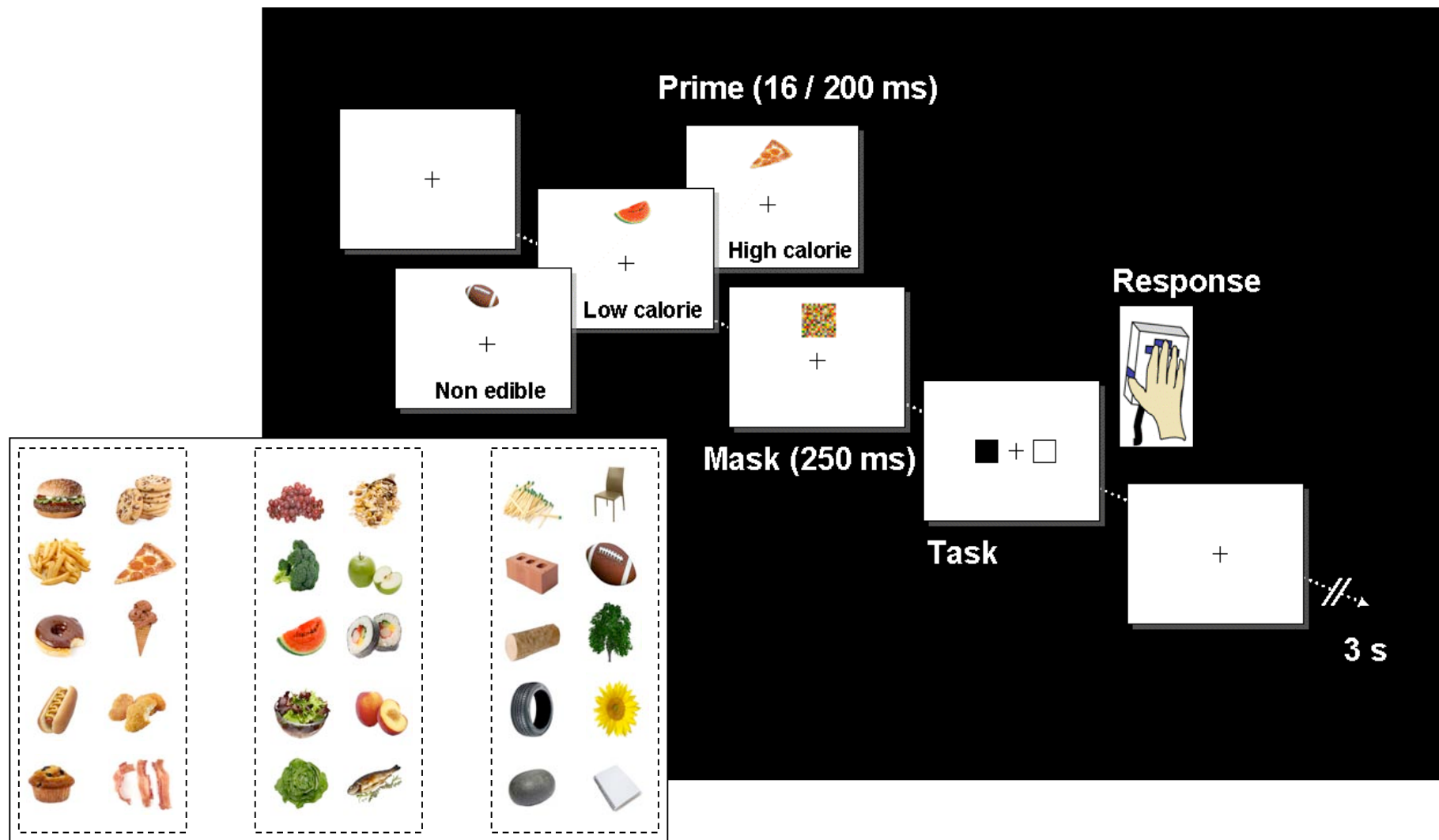
Right Brain Hypothesis of Obesity



Right Prefrontal Cortex

Alonso & Pascual-Leone *JAMA* 2007

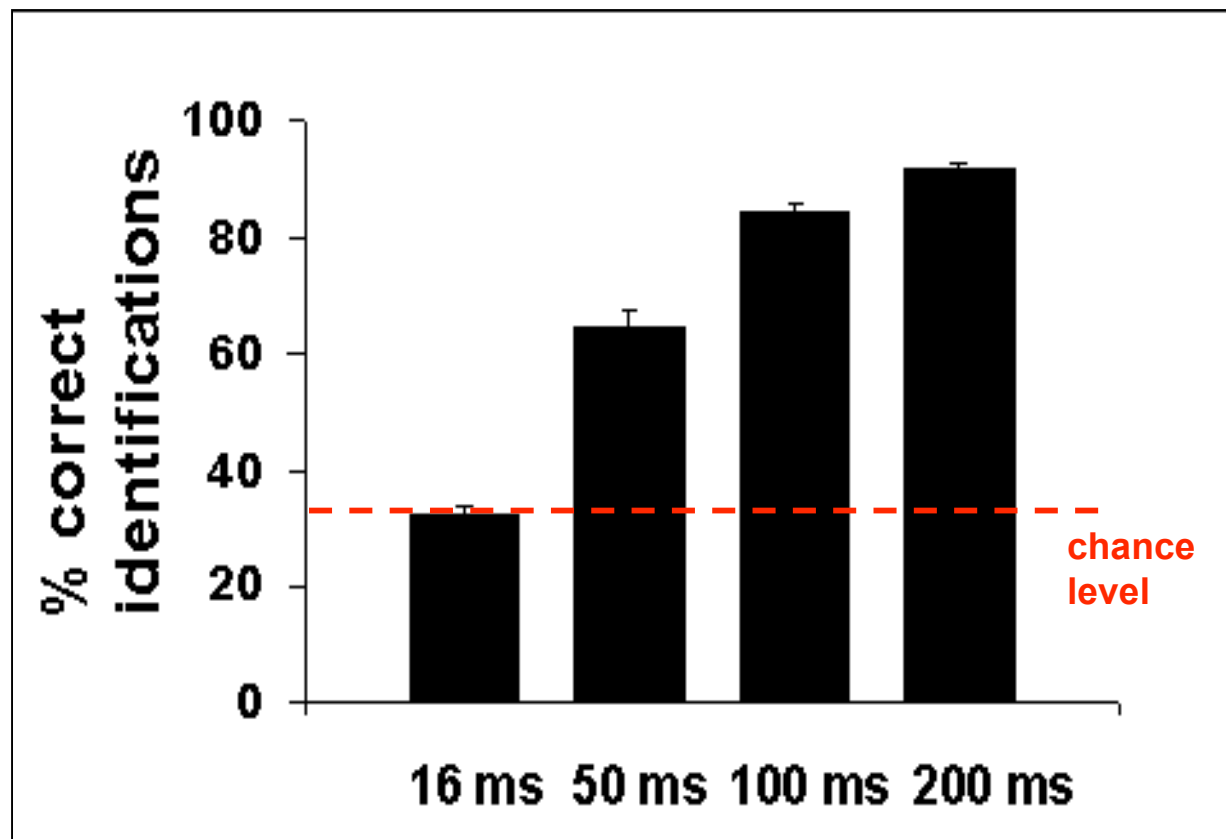
Brain responses to subliminal presentation of food predict obesity risk



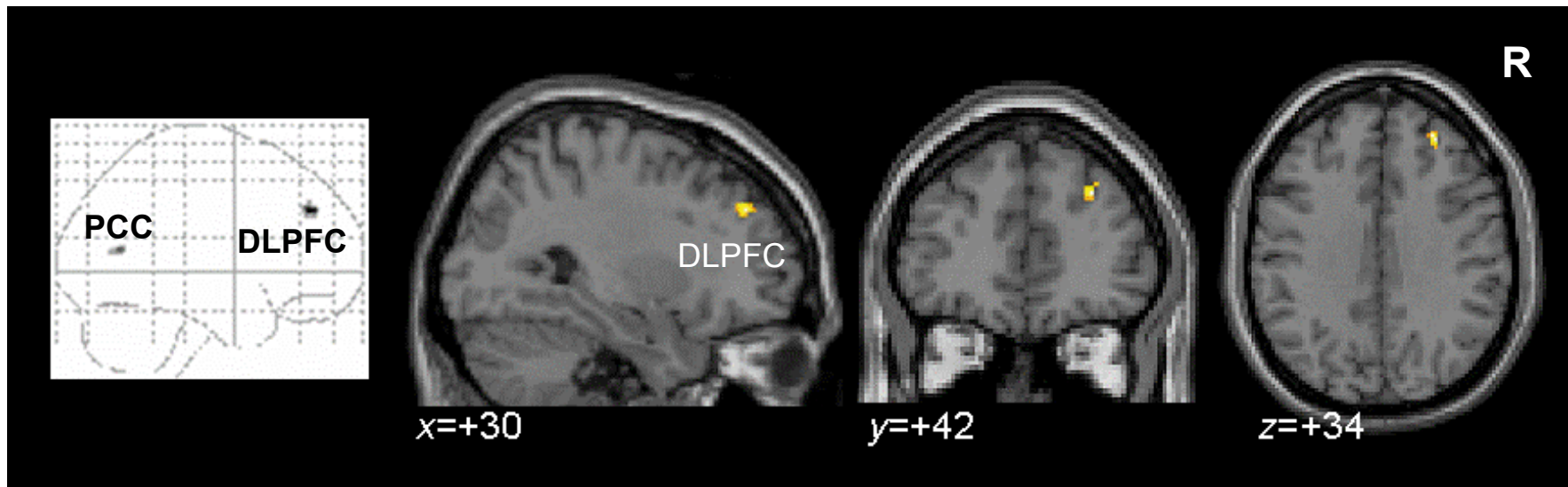
Brain responses to subliminal presentation of food predict obesity risk



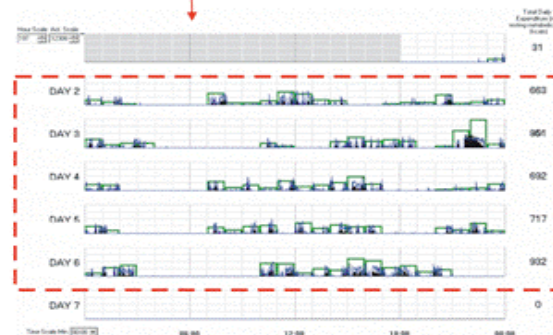
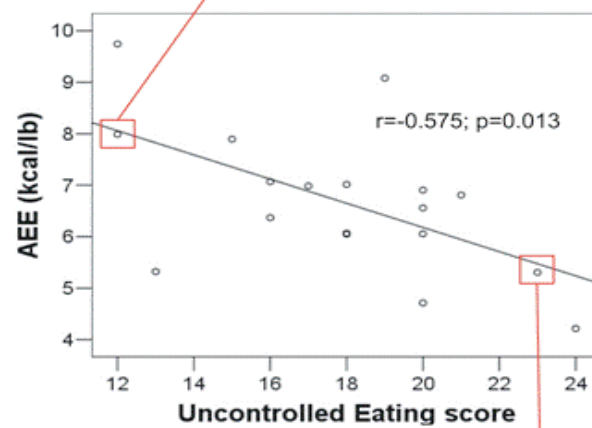
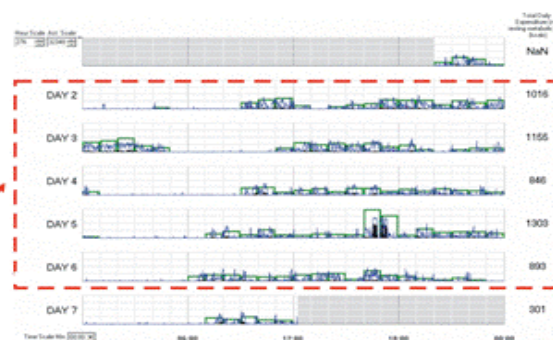
Forced Choice Recognition Task



Brain responses to subliminal presentation of food predict obesity risk

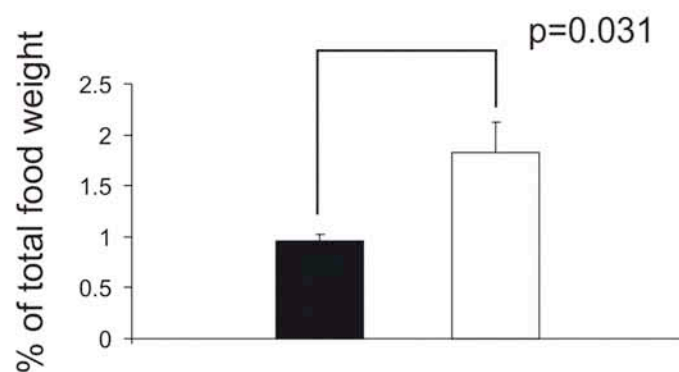


Subliminal HI>LO

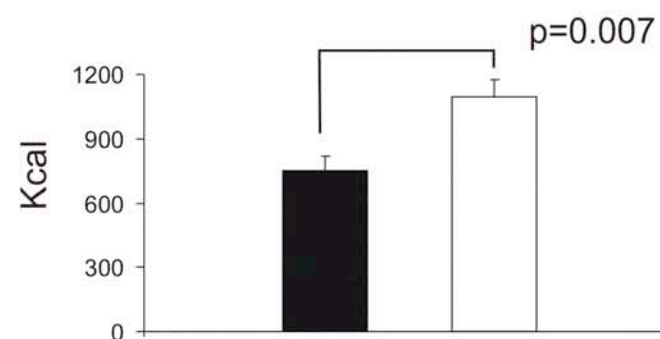




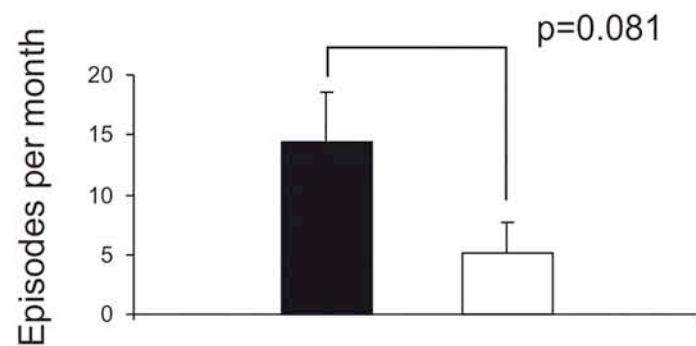
Daily Fiber Intake



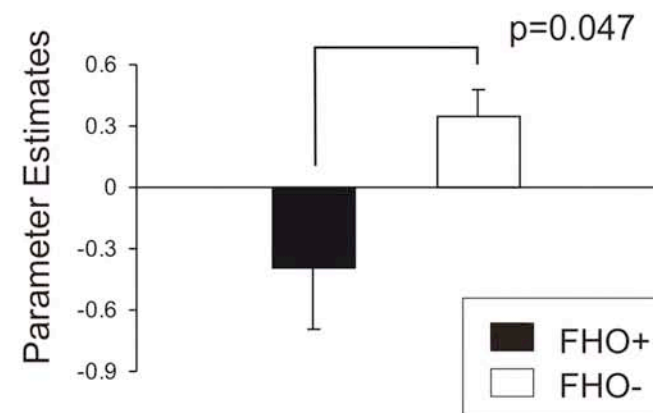
Daily Energy Expenditure



Frequency of breakfast away

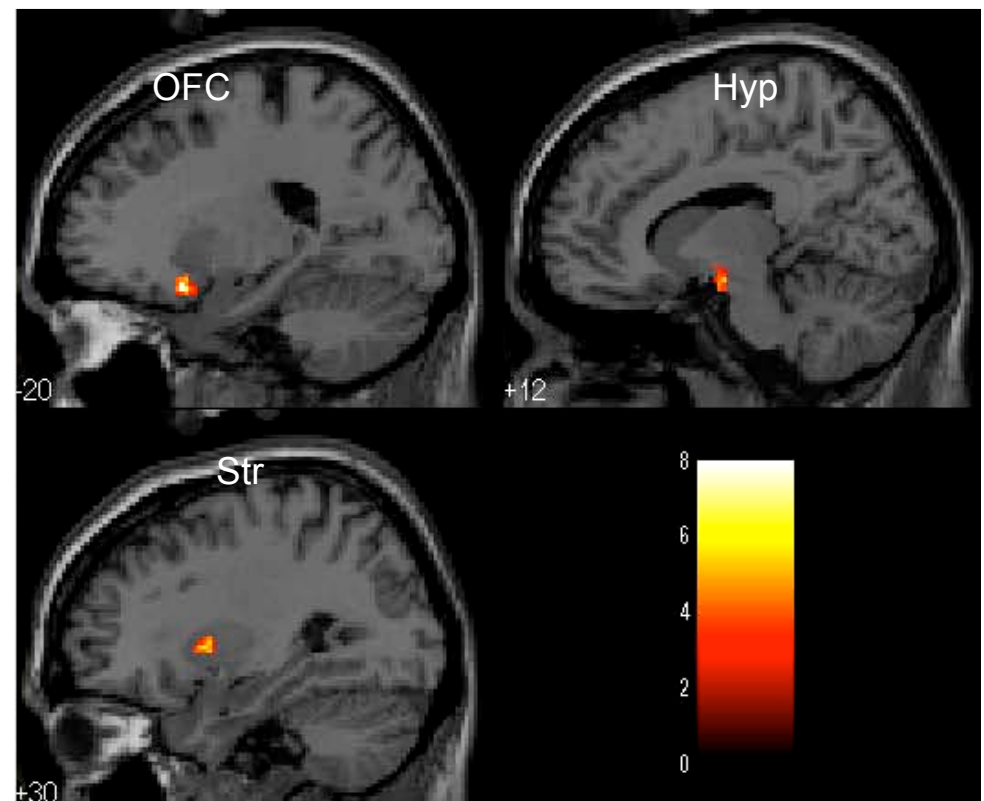
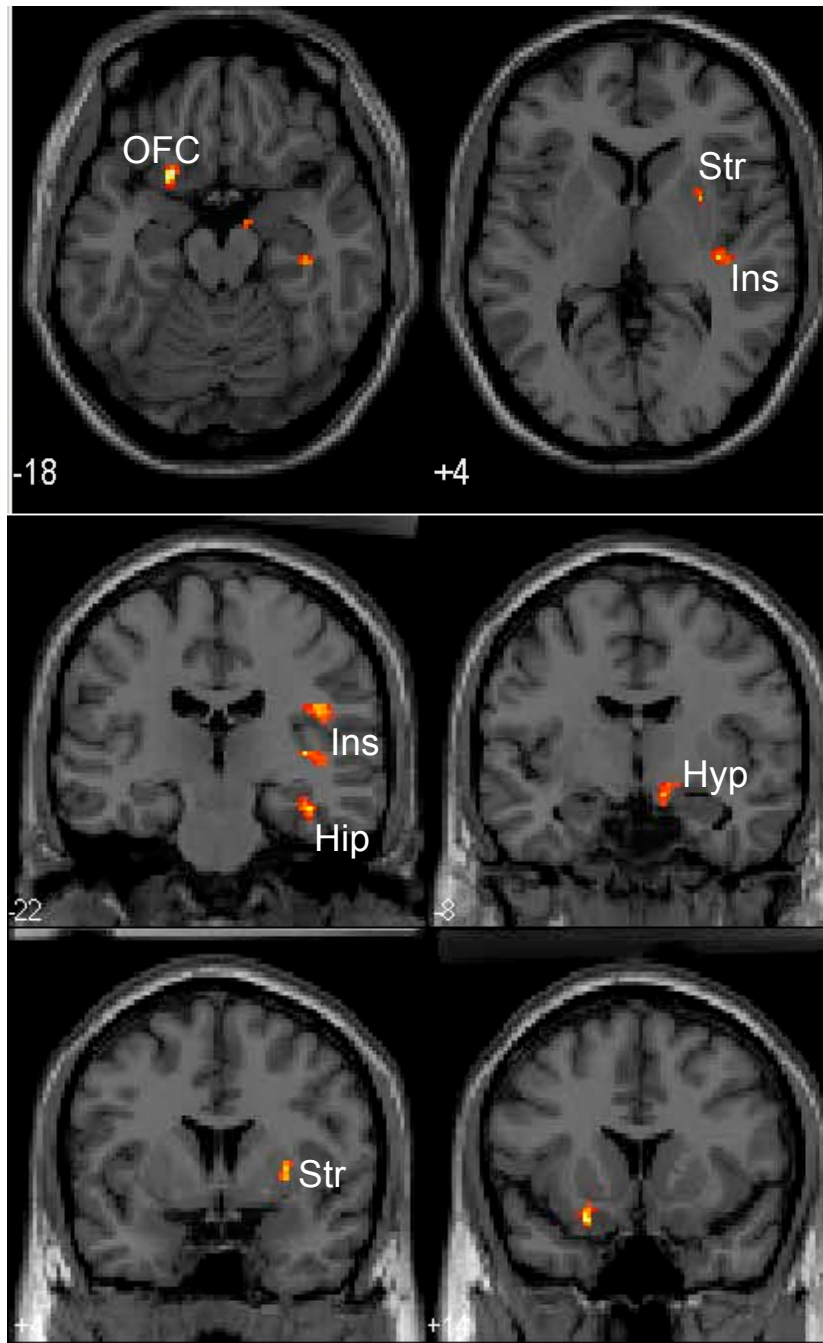


Right DLPFC activation

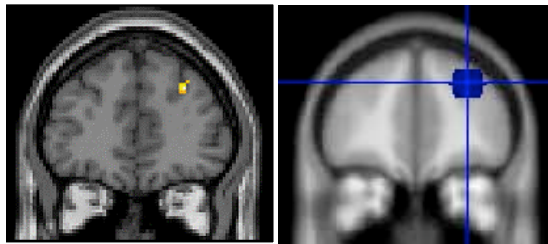




Obese show
different pattern of
brain activity

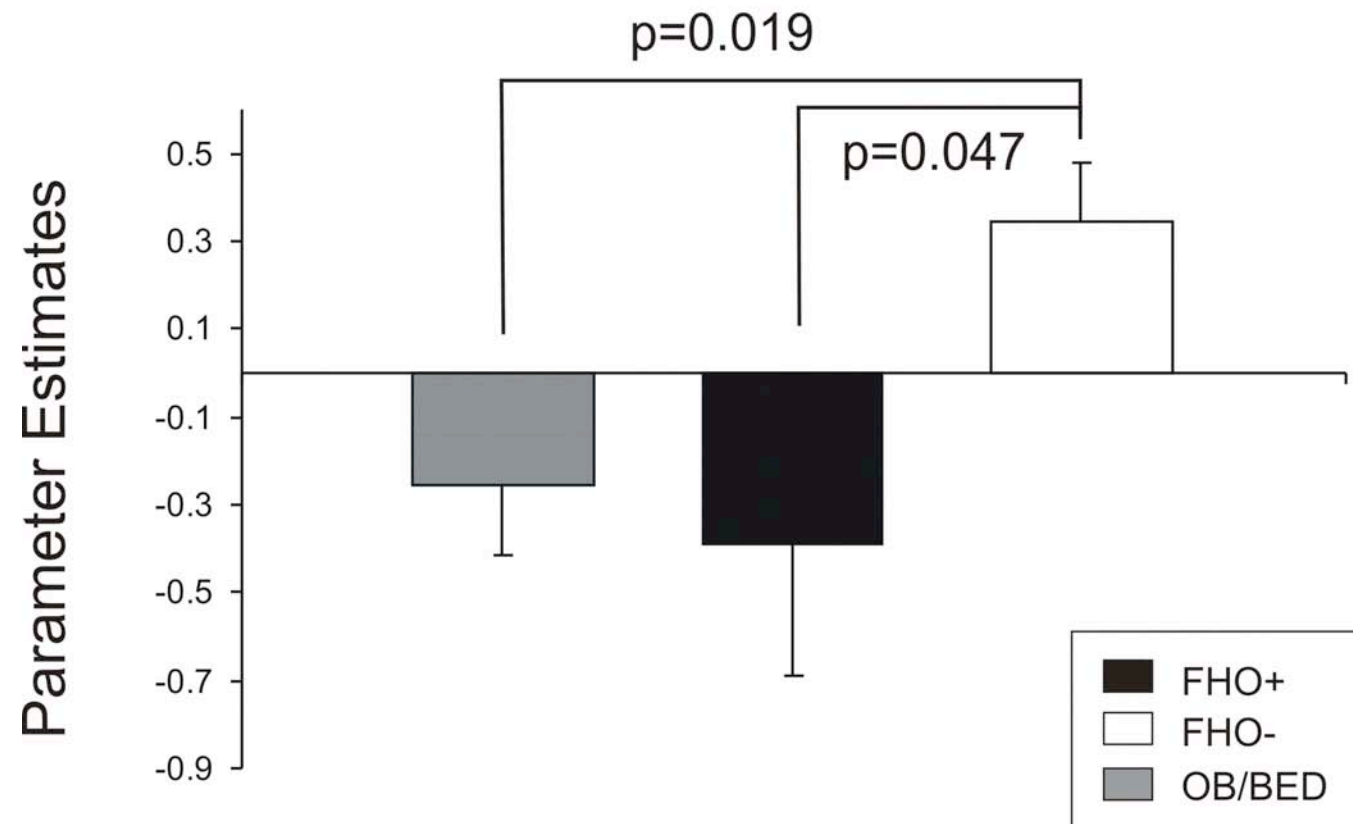


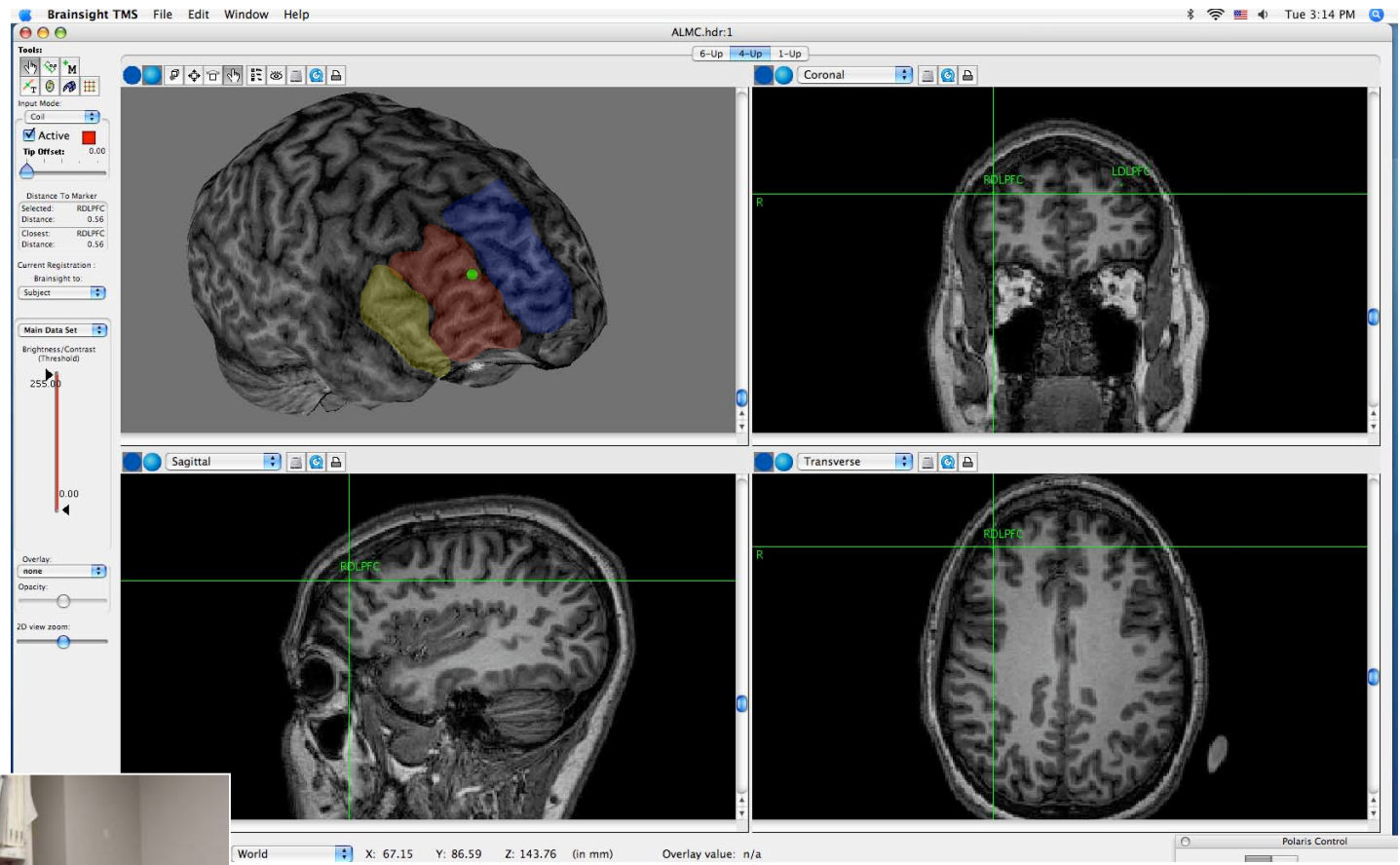
Subliminal HI>LO

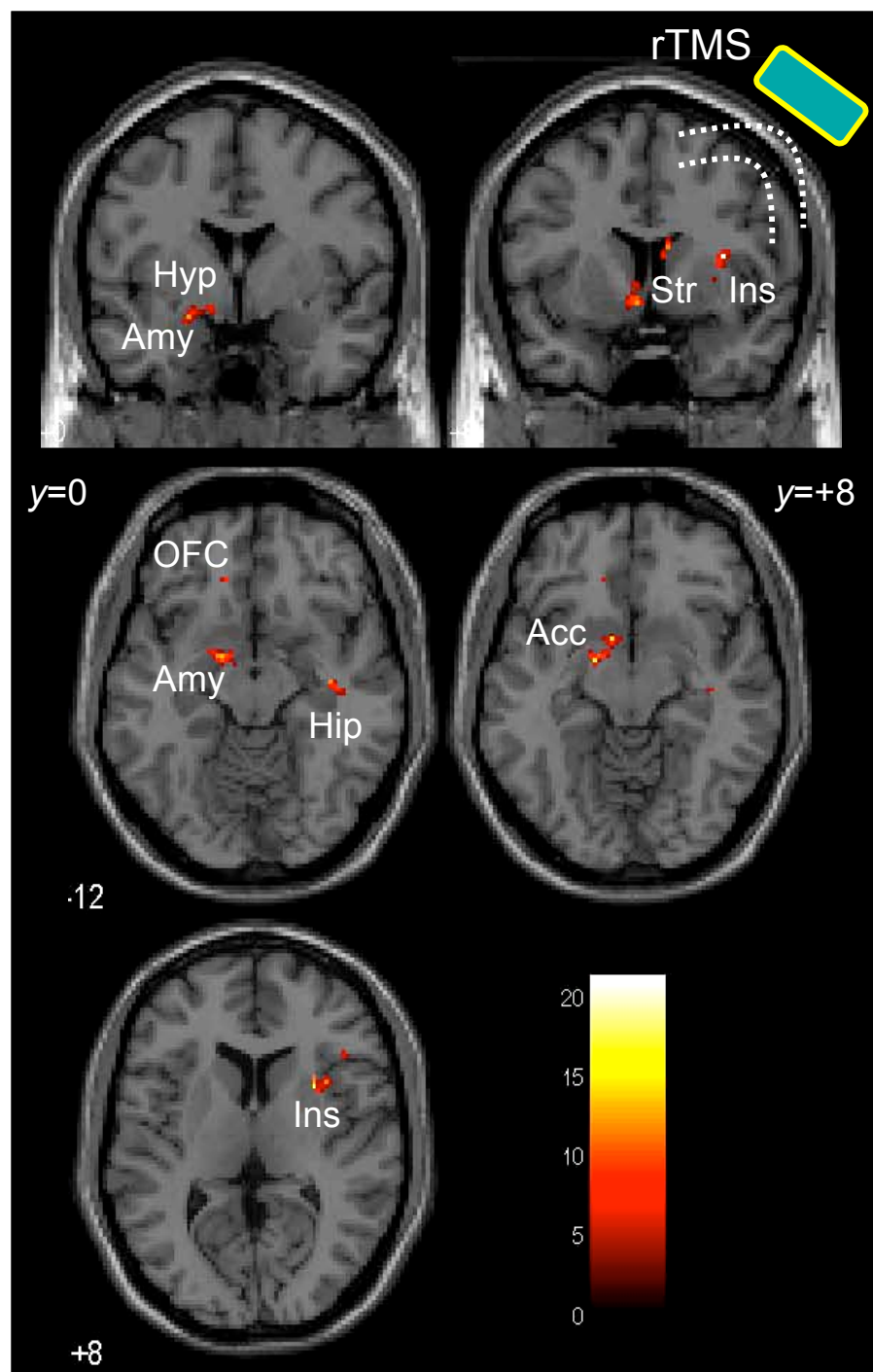


Region of interest
(ROI) analysis

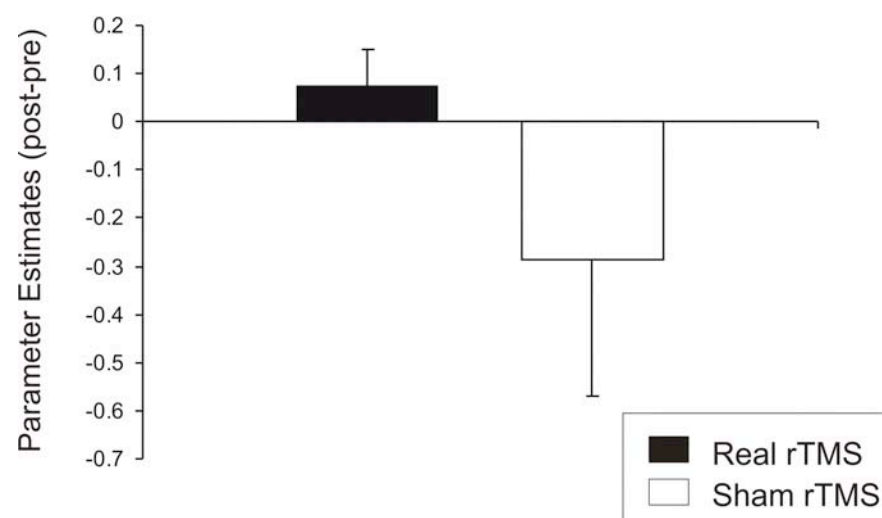
Right DLPFC activation







Changes in Right DLPFC activation



IOWA GAMBLING TASK

Iowa Gambling Test

Previous Total: 2800
Current Total: 2600

total gains: ■
total losses: ■


Choose Deck 1


Choose Deck 2


Choose Deck 3








Choose Deck 4

Gain: +50
Loss: -250



[Click here to continue](#)

Cards obtained thus far: 14 of 100

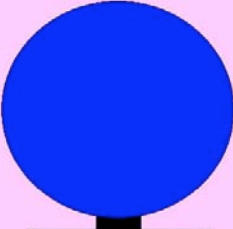
RISK TASK



Points: 540

6040

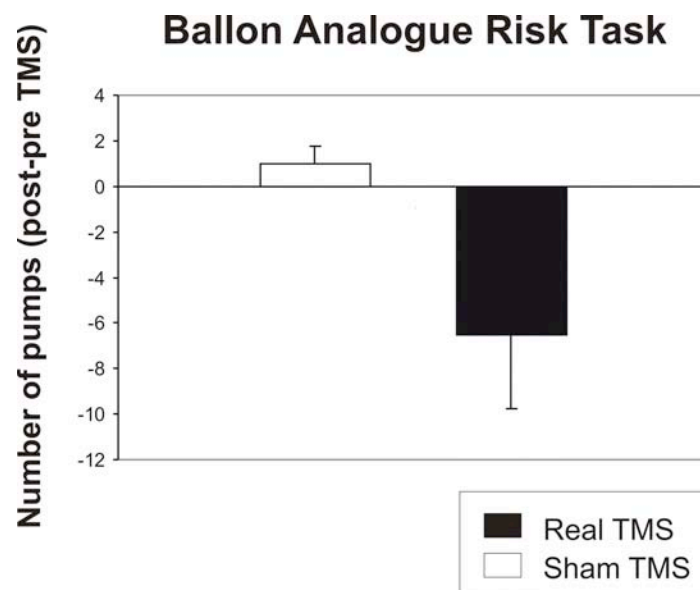
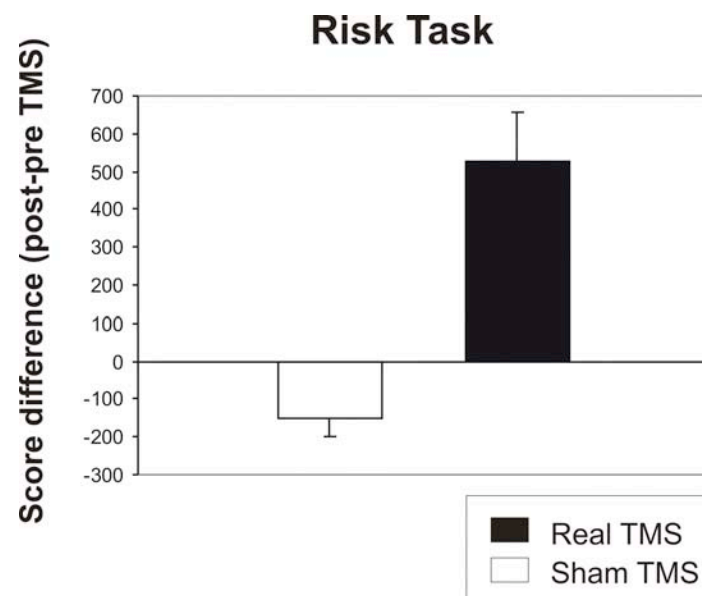
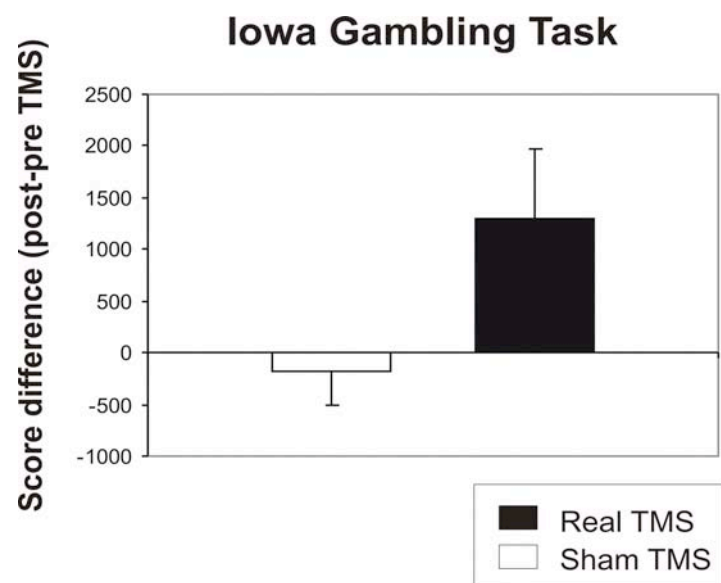
BALLOON ANALOGUE RISK TASK (BART)



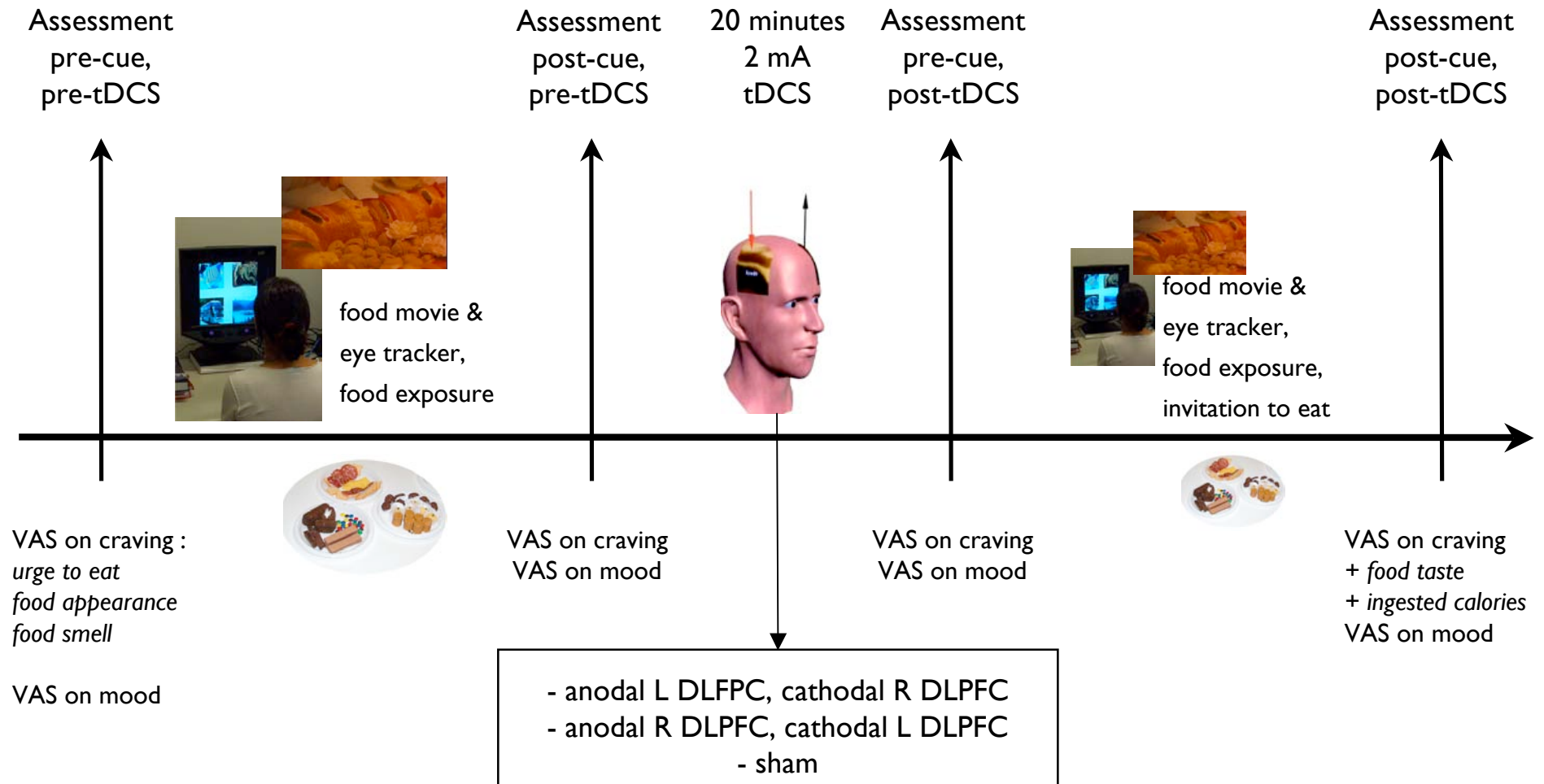
[Collect \\$\\$\\$](#)

[Click Here to Pump up the Balloon](#)

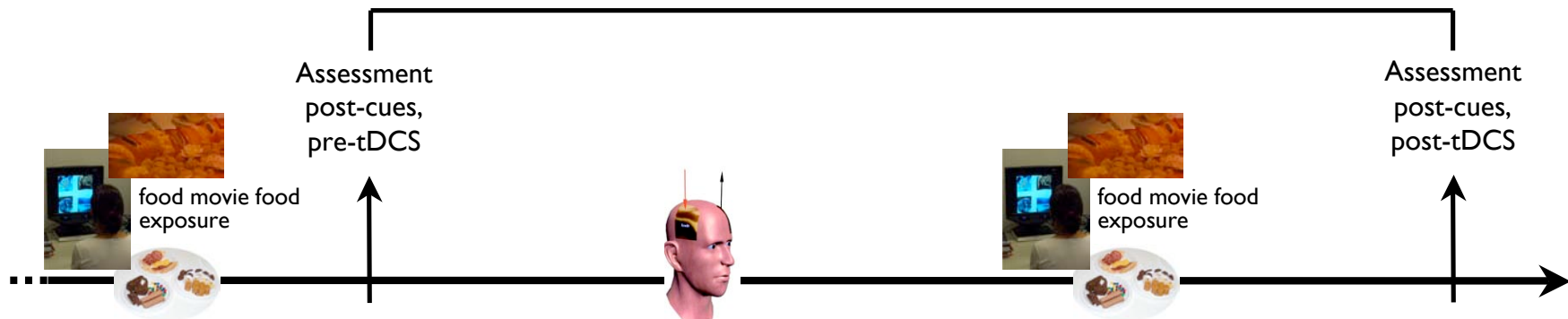
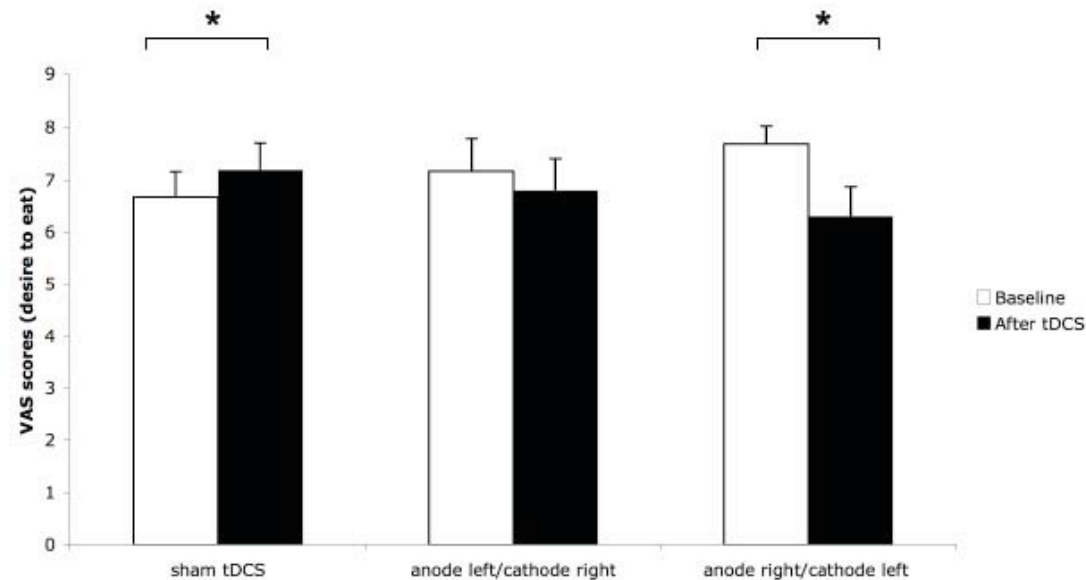
Total \$\$\$ **\$6.50**



Food craving



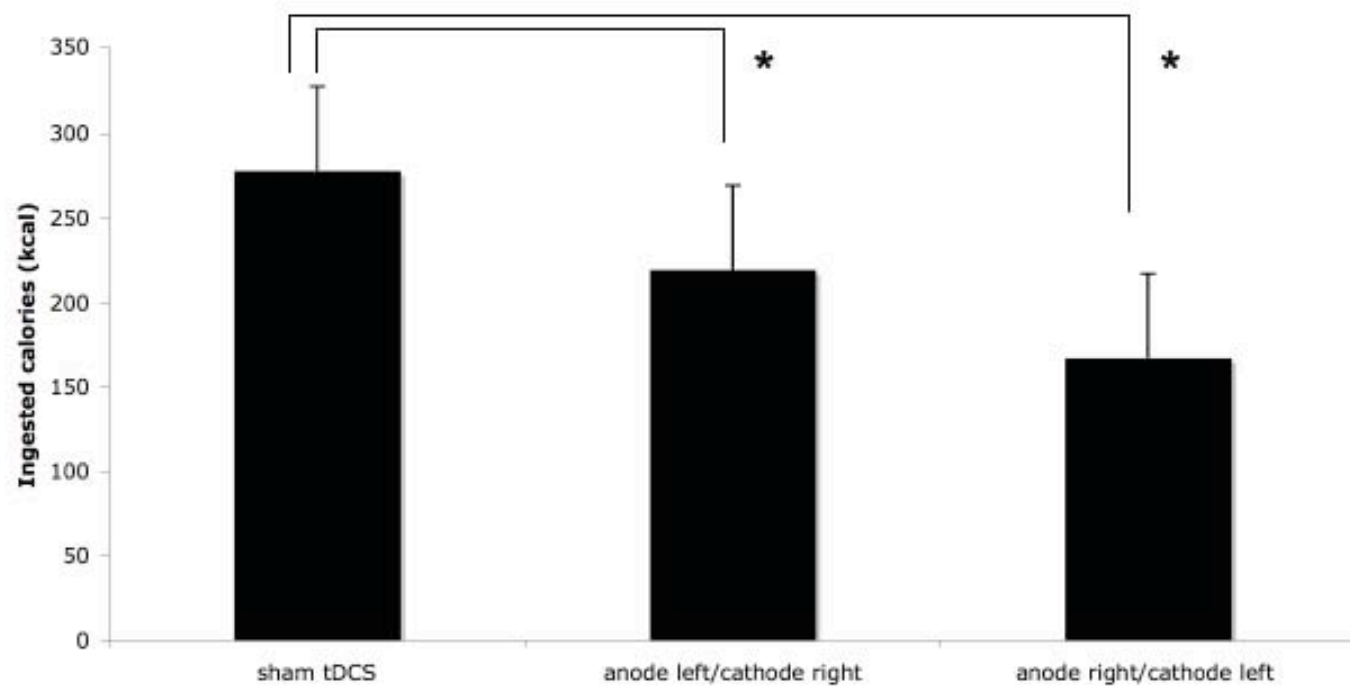
Anodal stimulation over the R DLPFC reduces food craving



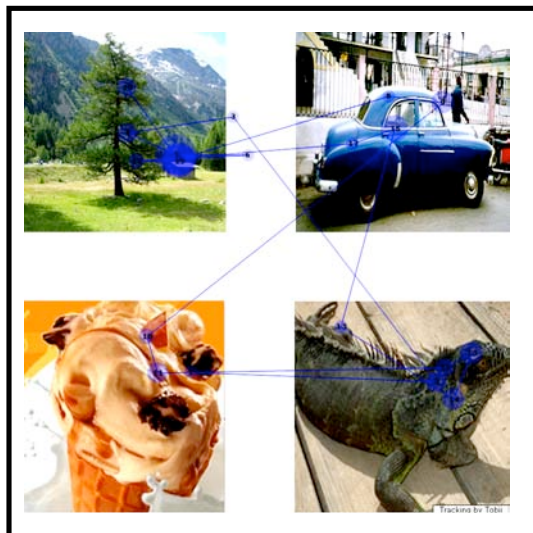
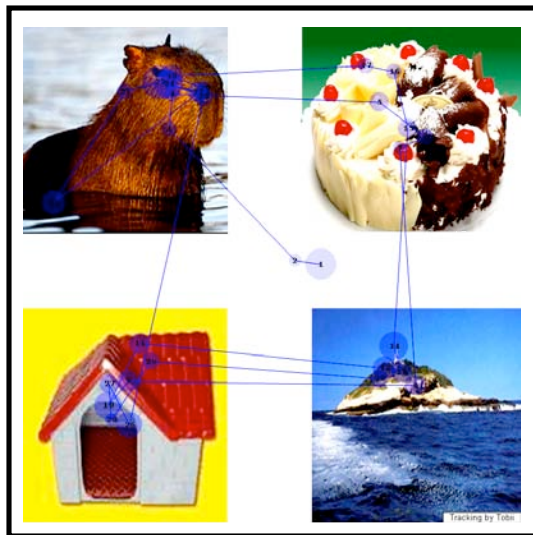
Anodal stimulation over the R DLPFC reduces ingested calories as libitum



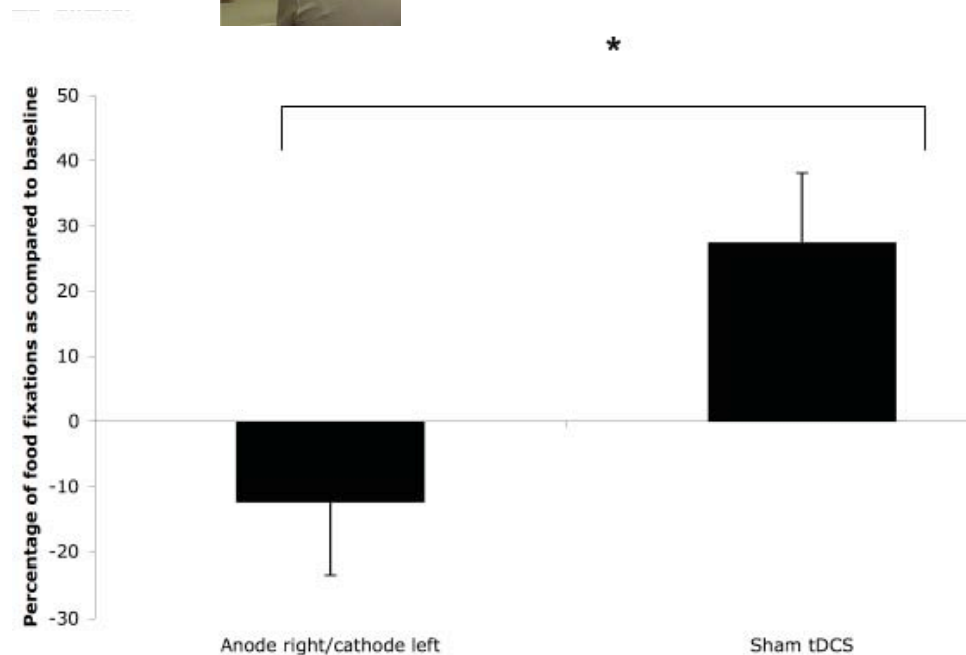
invitation to eat



Anodal stimulation over the R DLPFC reduces fixation time on food



Fixation on food items during movie



Fregni et al. *Appetite* 2008

Conclusions

- **Lateral Prefrontal Cortex (right)**
 - Exerts a ‘repressive’ control onto self-centered behaviors / impulses
 - Switch between reflexic and reflective modes of operation
- **Translational (Clinical) Cognitive Neuroscience**

Insights from Cognitive Neuroscience can be translated into clinical applications addressing uniquely human aspects of behavior
- **Noninvasive Brain Stimulation** offers a unique methodology to study and modulate causal brain-behavior relations