Emotions and Choice: Mechanisms of Behavior Change

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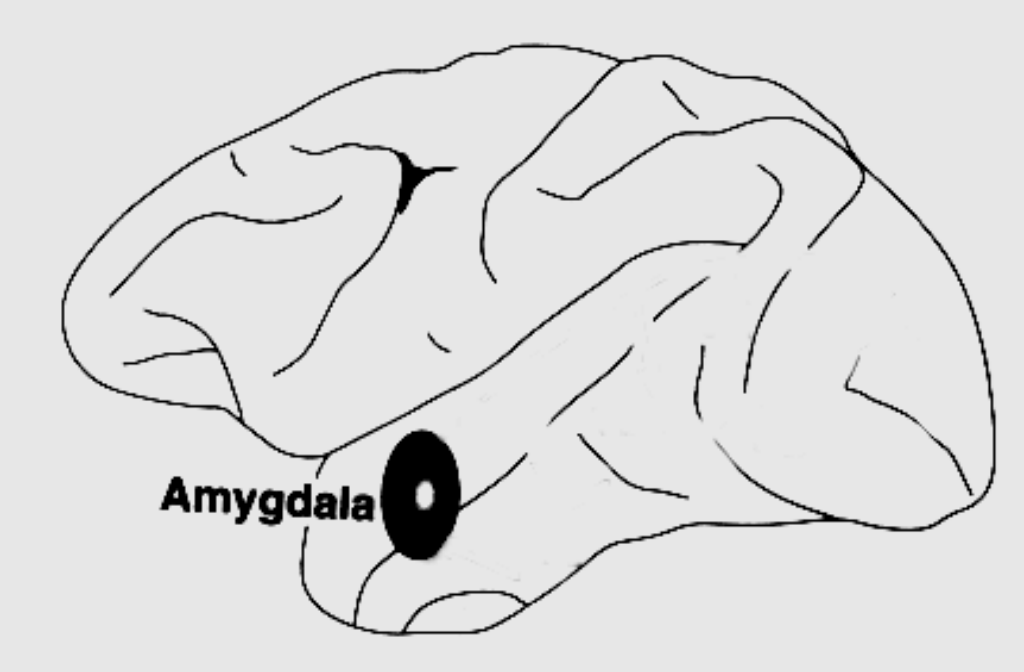
Emotion and Decision Making:

Competing Processes

Emotion and Decision Making: Insights from Affective Neuroscience

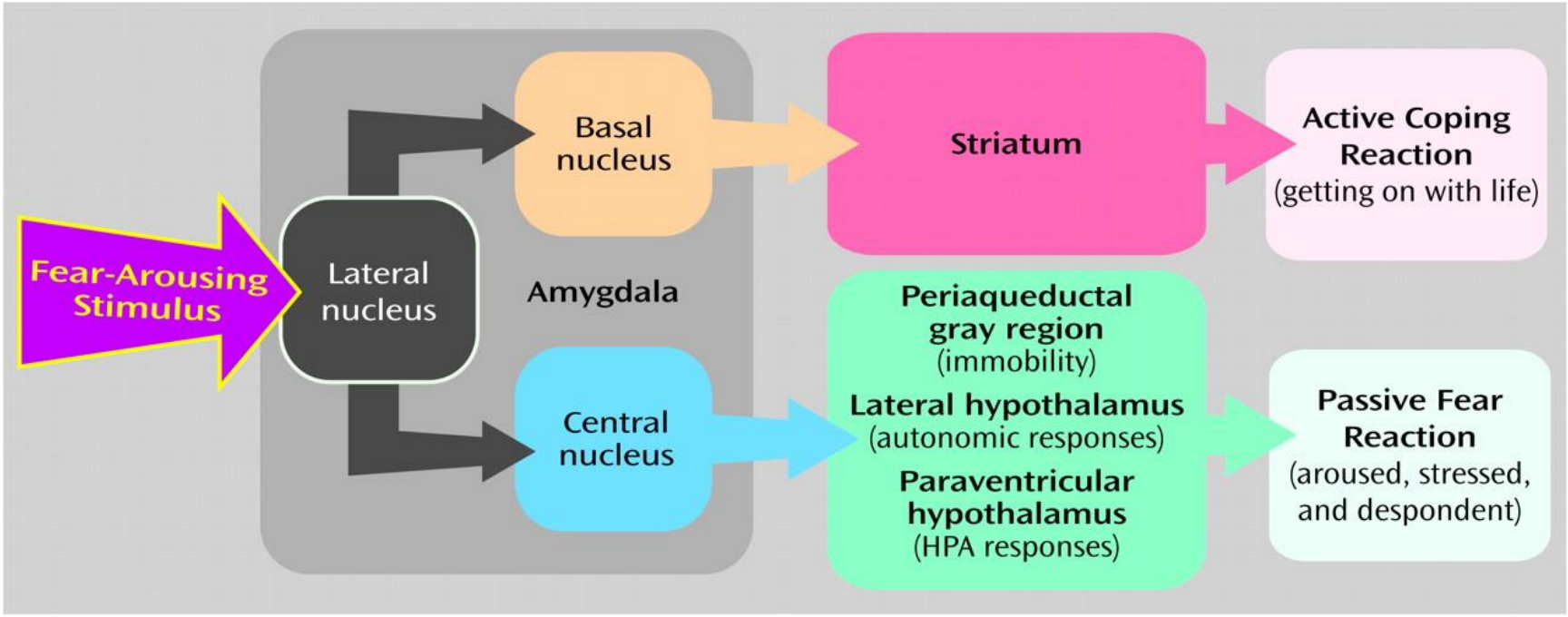
There are not separate brain "systems" of emotion and reason

Emotion has a modulatory role in cognition



Emotion and Decision Making

Emotion has a modulatory role in the value computation



Amygdala-Striatal Circuitry is one means for emotion to influence choices

Emotion and Decision Making

Emotion has a modulatory role decision-making

- Can we use the tools of affective neuroscience and neuroeconomics to characterize more precisely how and when emotion is incorporated into the computation of subjective value?

- Can we use the tools of affective science to change emotion and change choice?

Defining Affect Variables

Emotion:

Discrete response to an internal or external event

(Scherer, 2005)

Stress:

Response to real or imagined threat resulting in (relatively prolonged) physiological and neuroendocrine changes

(Ulrich-Lai & Herman, 2009)

Emotion

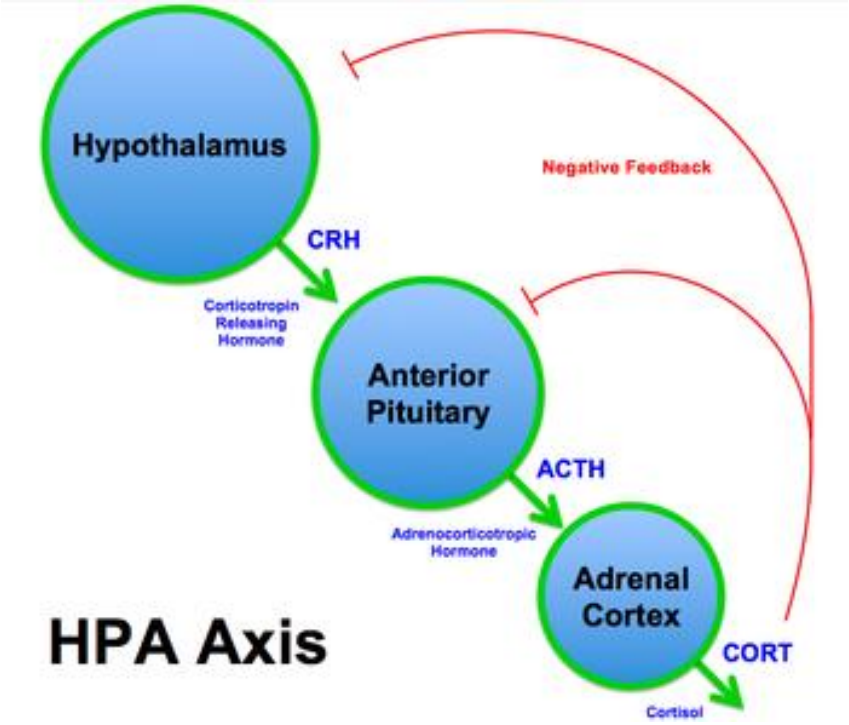
Components of Emotion

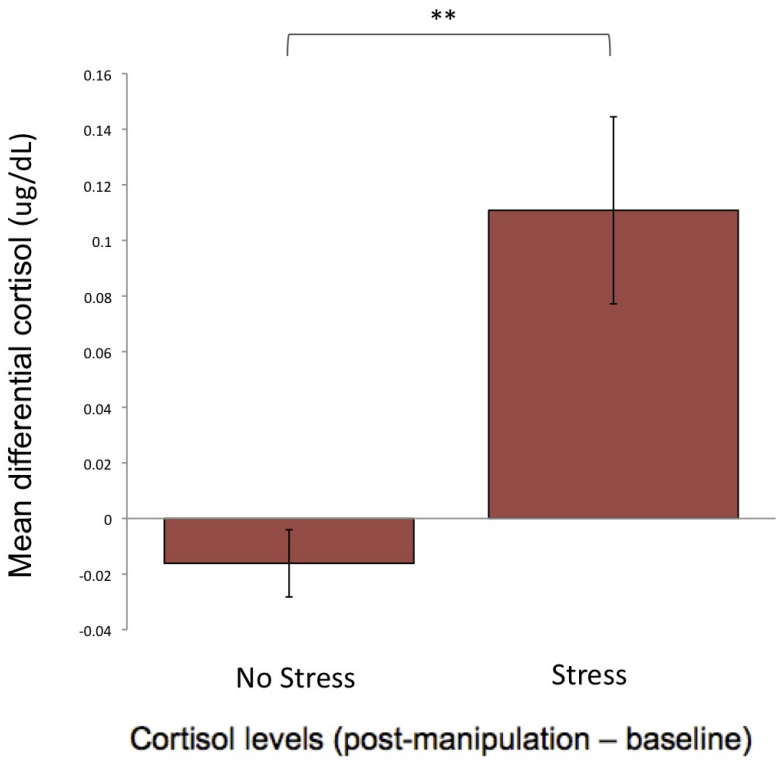
discrete response

(Scherer, 2005)

- **Subjective Feelings**
- **Bodily Response**
- **Expression**
- **Tendency to Action**

Stress


Hypothalamus
Negative Feedback
CRH
Corticotropin Releasing Hormone
Anterior Pituitary
ACTH
Adrenocorticotropic Hormone
Adrenal Cortex
CORT
Cortisol
HPA Axis


**
Mean differential cortisol (ug/dL)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
No Stress
Stress
Cortisol levels (post-manipulation – baseline)

Defining Decision Variables

Components of Decisions

Colin Camerer

- **Loss Aversion**
- **Risk Sensitivity**
- **Temporal Discount Rate**

Paul Glimcher

Specific Aims

- 1) Investigate the link between individual variability in loss aversion, risk sensitivity and temporal discounting and the physiological arousal response to choice options or outcomes

- 2) Examine the impact of altering arousal on these decision variables (emotion regulation and pharmacological manipulation)

- 3) Explore the impact of stress on these decision variables and the effectiveness of the techniques used to alter arousal

** *Identify the neural circuitry mediating these behaviors*

Loss Aversion and Risk Sensitivity

+$10.00 50%

-$12.00 50%

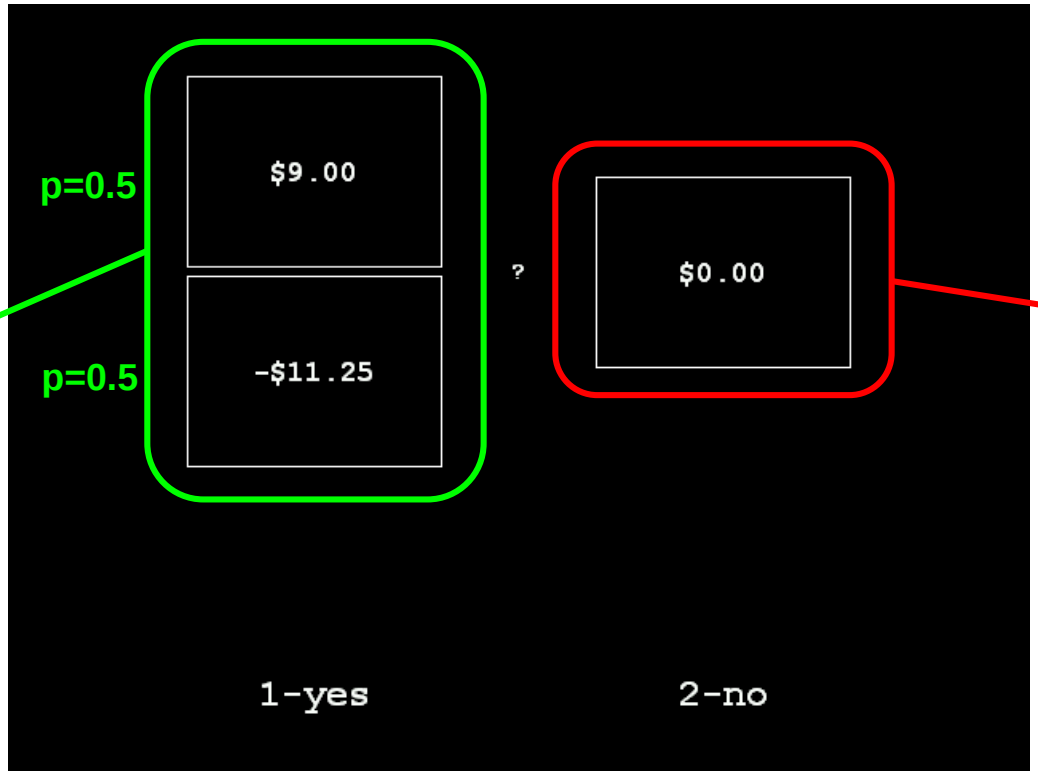
+$10.00 50%

-$2.50 50%

+$10.00 50%

-$7.50 50%

Task for assessing
Loss aversion (λ) & Risk sensitivity (ρ)



Risky Gamble

Guaranteed

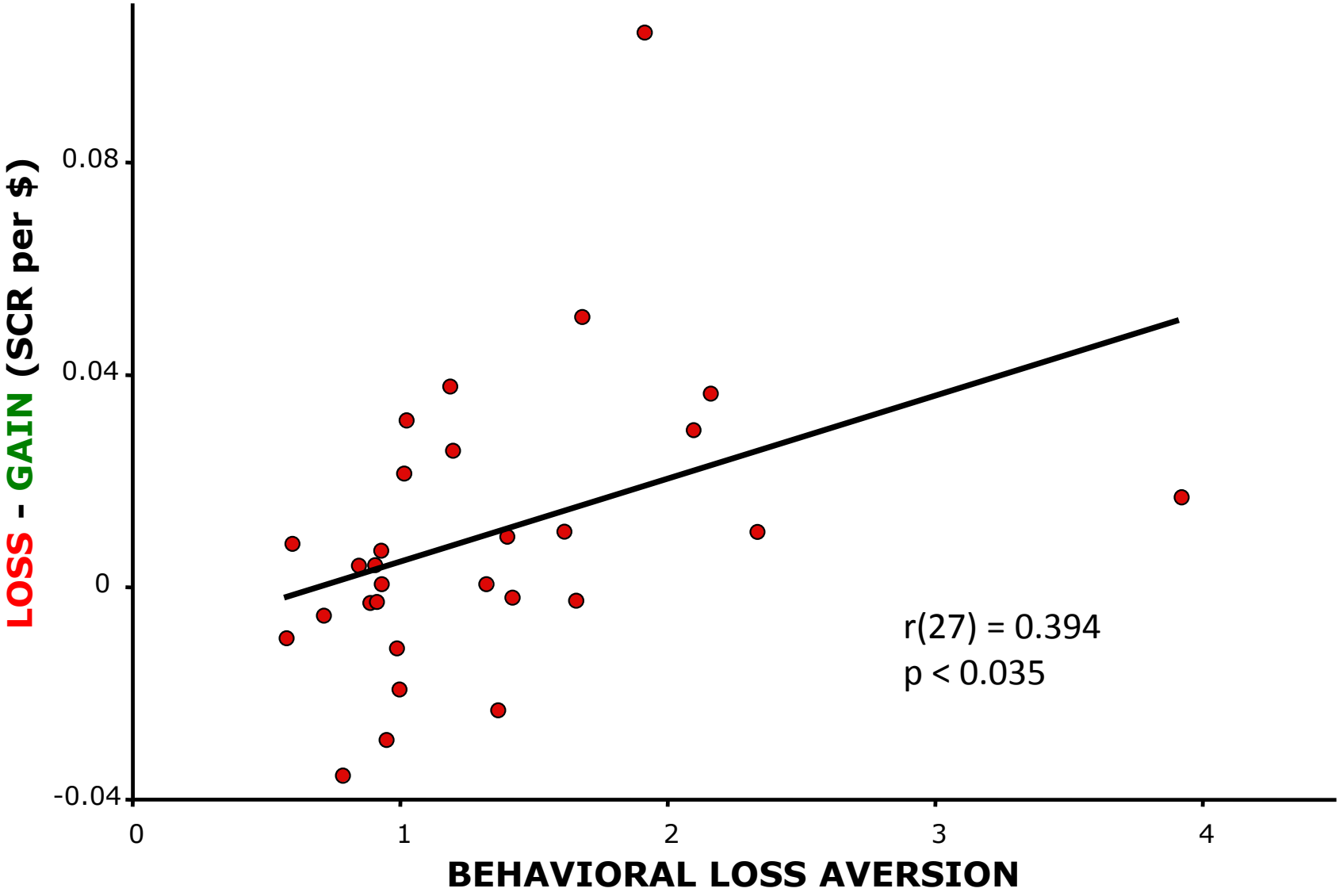
Accept the gamble?

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice

- 2) Do techniques to alter emotion through cognitive emotion regulation and drugs change loss aversion or risk sensitivity?

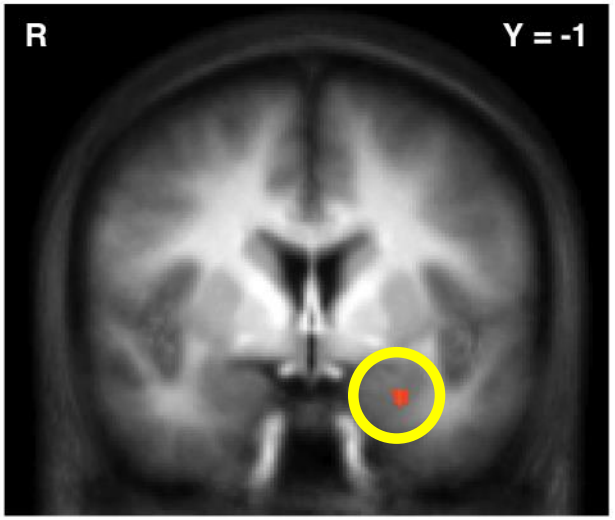
- 3) Does non-specific stress: a) impact loss aversion or risk sensitivity, b) alter the effectiveness of emotion regulation to change choices?

Arousal & Loss Aversion

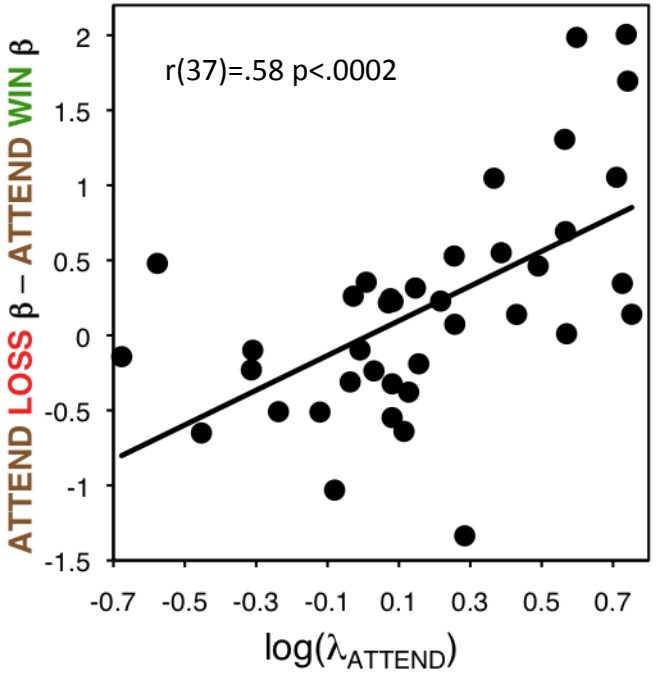


Sokol-Hessner et al., *PNAS*, 2009

Amygdala Activation & Loss Aversion



Left amygdala



Sokol-Hessner et al., *SCAN*, 2013

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice

  - Loss aversion correlates with arousal to losses vs. gains
  - Loss aversion correlates with amygdala activity to losses vs. gains
  - No correlations with risk sensitivity

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice
  - *Loss aversion, but not risk sensitivity, correlates with arousal and amygdala*

- 2) Do techniques to alter emotion through cognitive emotion regulation and drugs change loss aversion or risk sensitivity?

Emotion Regulation

- Re-evaluate or re-appraise a stimulus to alter our emotional response.

The regulation strategy

- One set: “ATTEND”

… The only choice
… In isolation
… Just this one

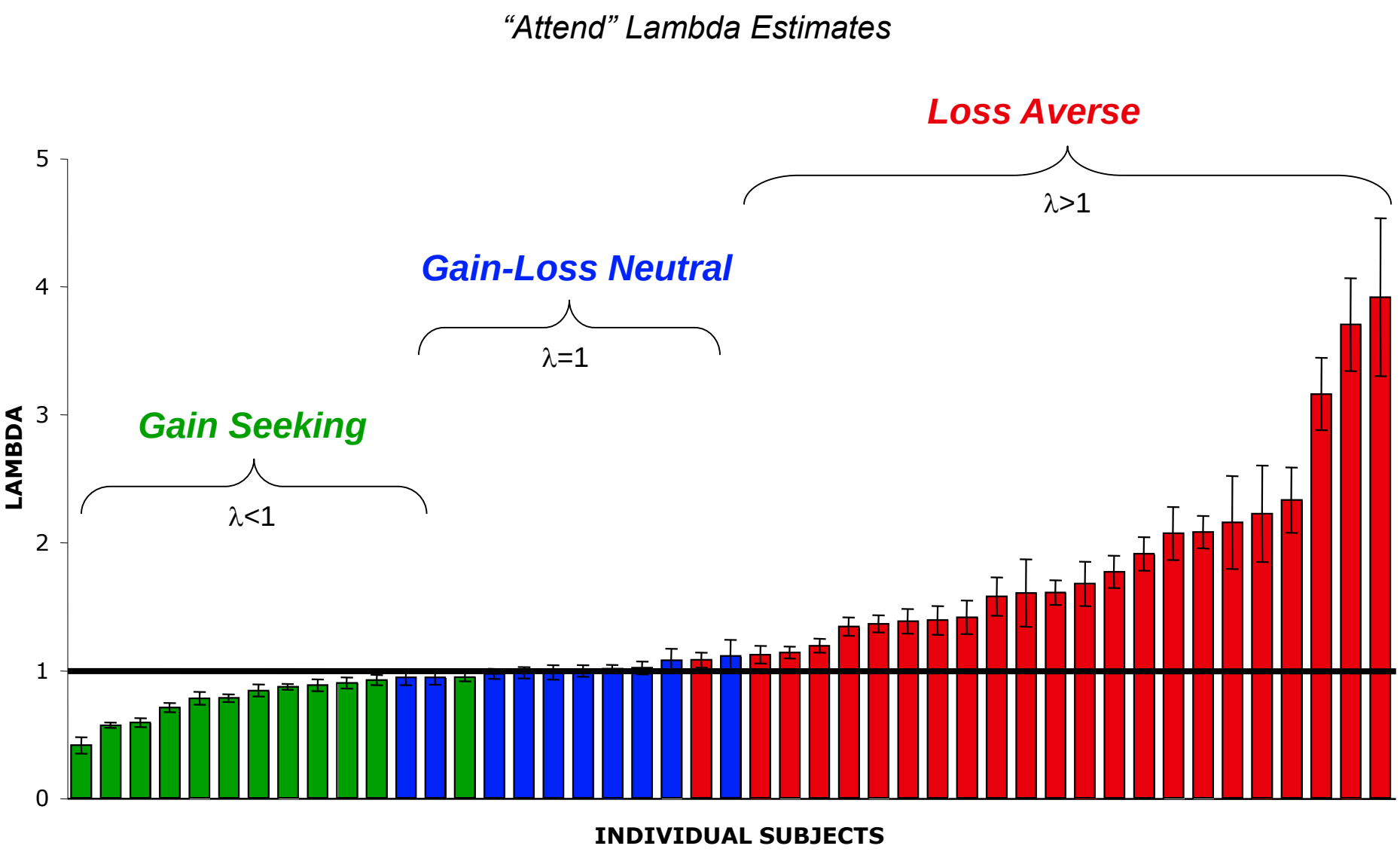
Attend λ, ρ

- A second set: “REGULATE”

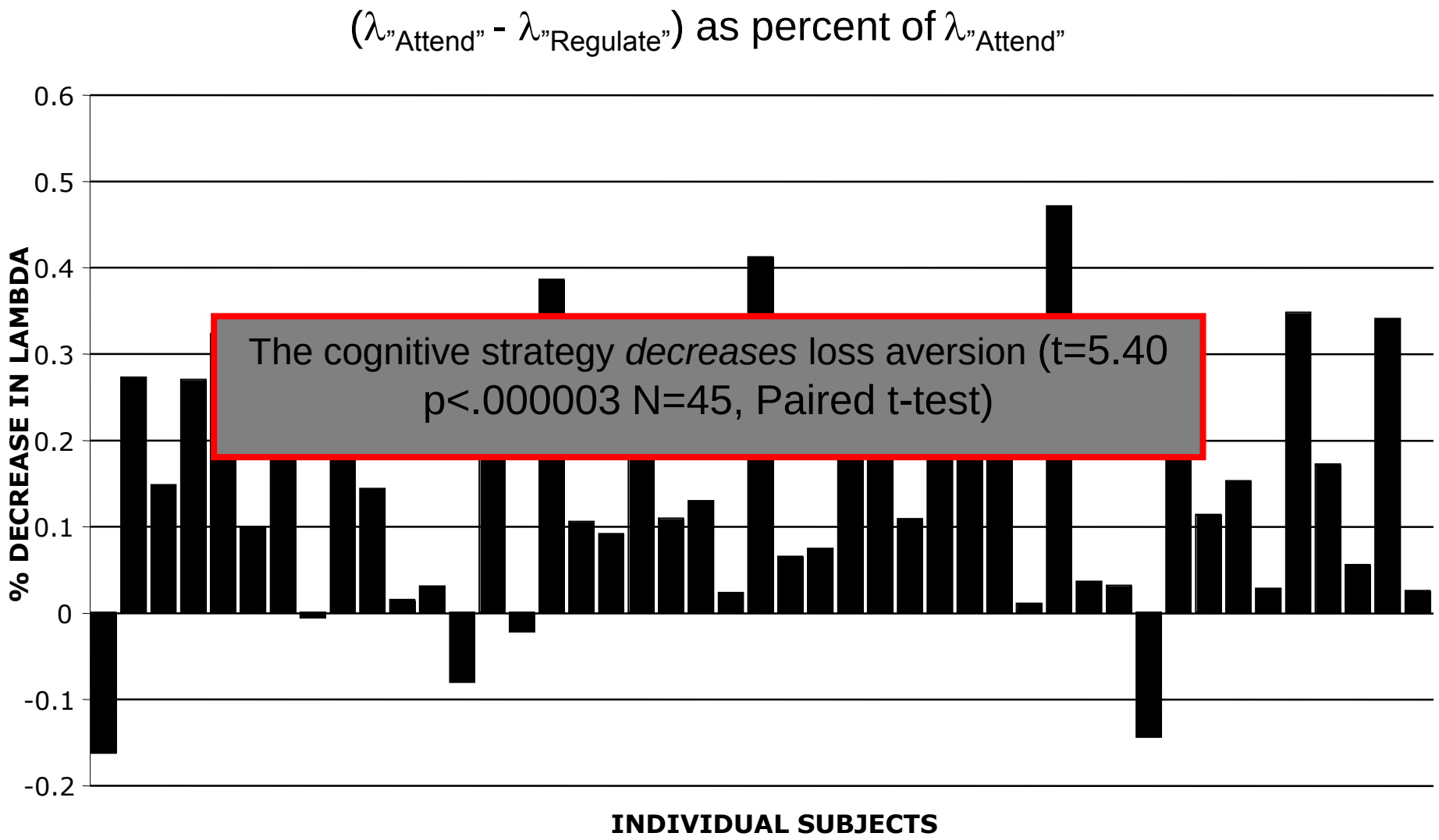
… Thinking like a trader
… Assembling a portfolio
… One of many

Regulate λ, ρ

Individual Lambdas

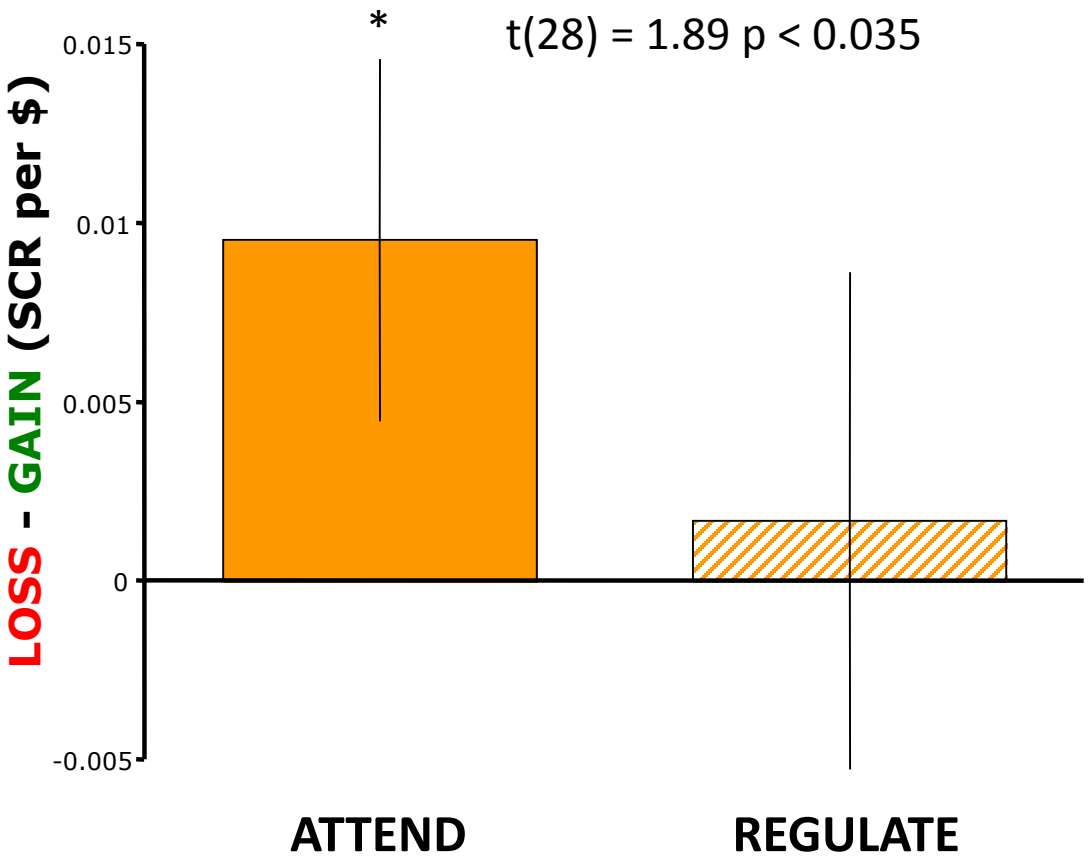


Regulation of Loss Aversion



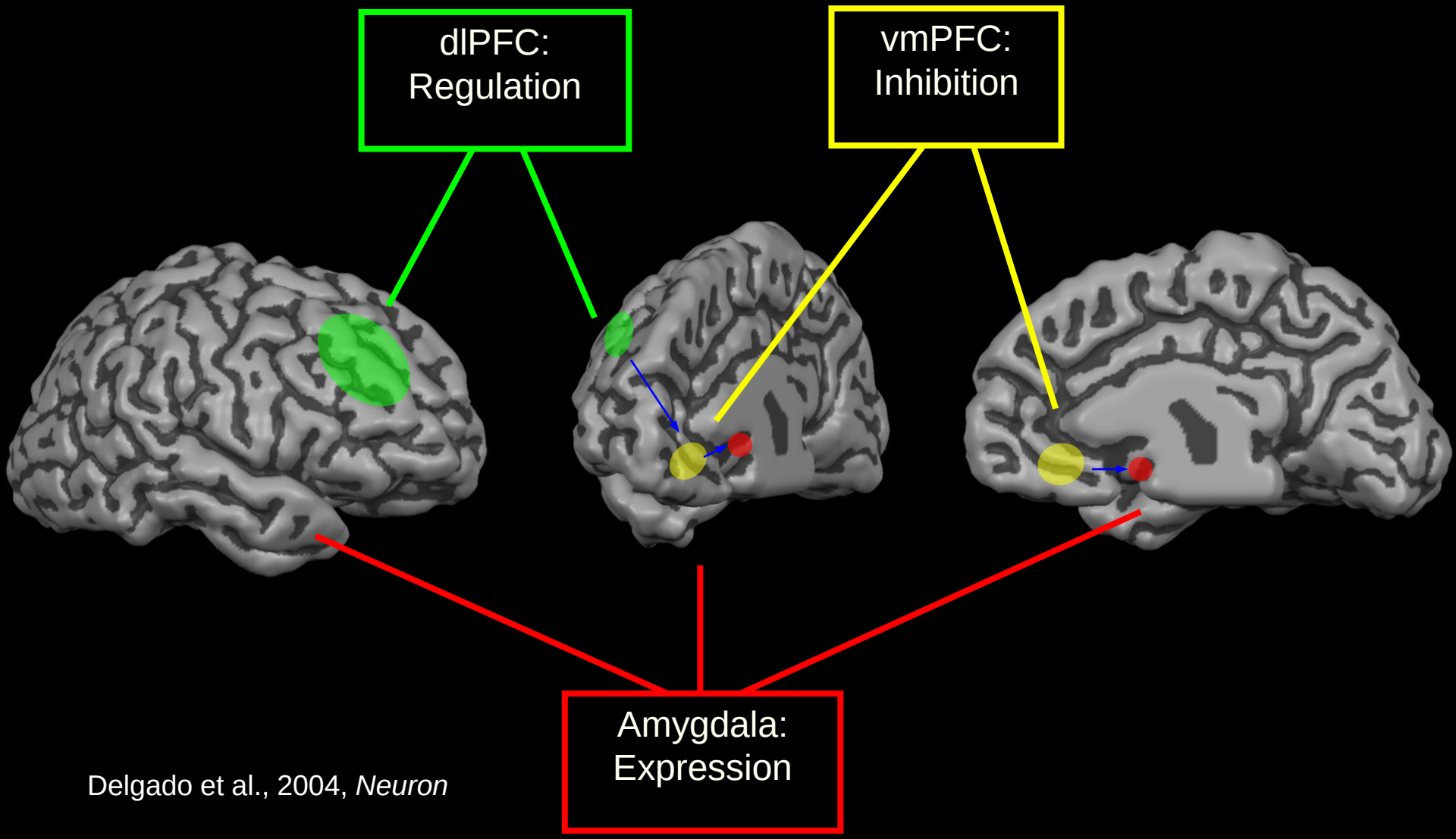
Sokol-Hessner et al., *PNAS*, 2009

Losses are more arousing than Gains



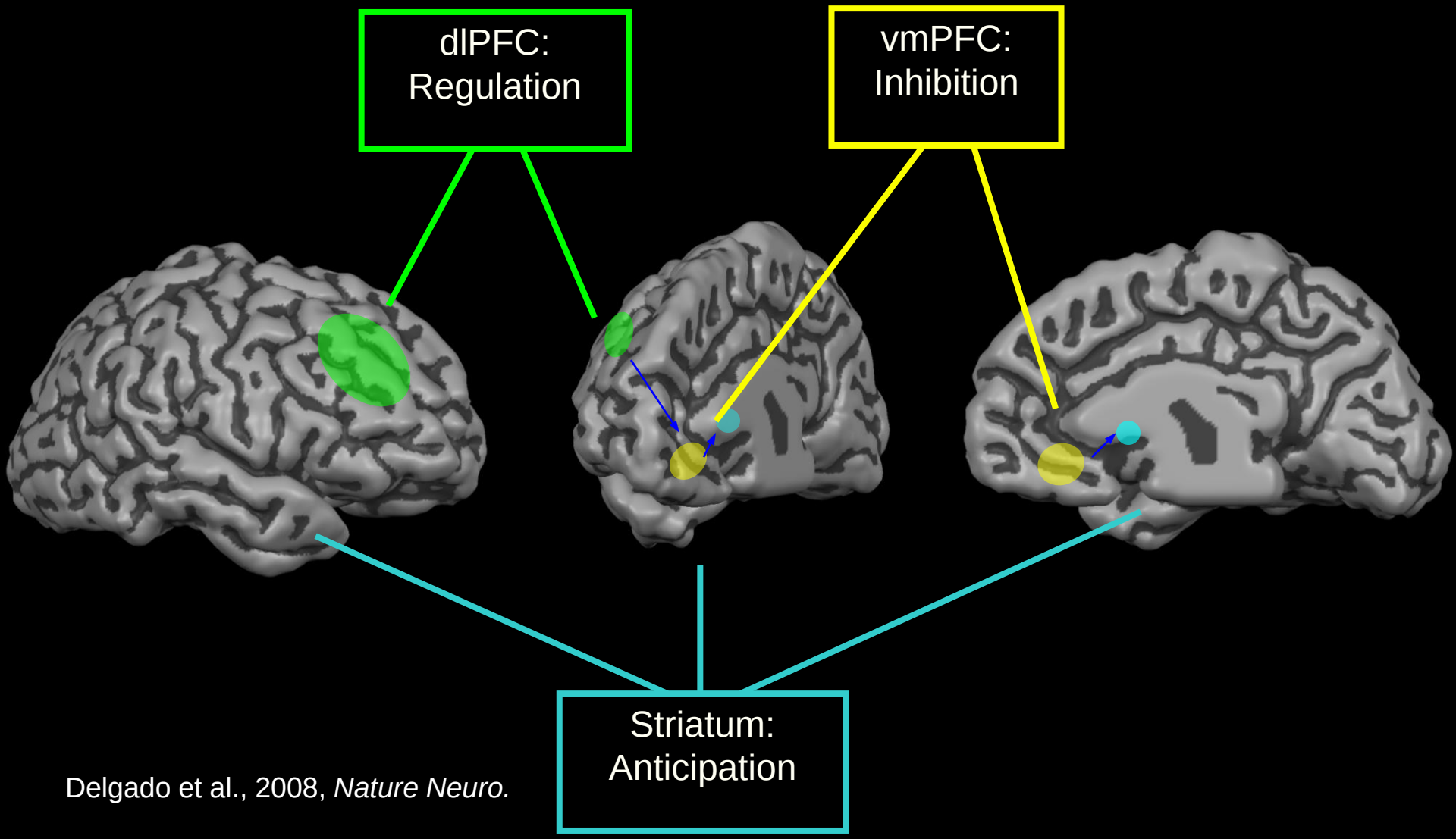
Sokol-Hessner et al., *PNAS*, 2009

Controlling Anticipation of Threat: *Emotion Regulation*



Delgado et al., 2004, *Neuron*

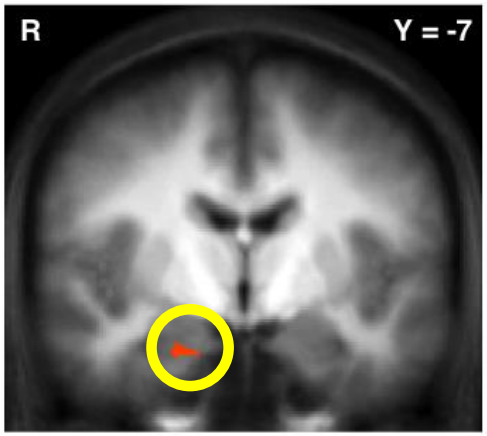
Controlling Anticipation of Reward: *Emotion Regulation*



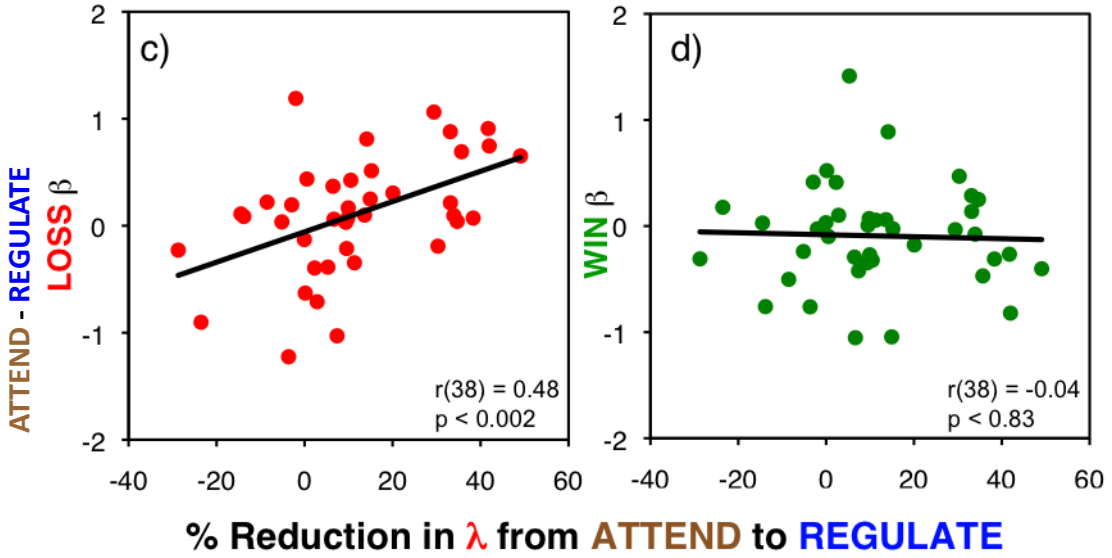
Delgado et al., 2008, *Nature Neuro.*

Controlling Loss Aversion
Emotion Regulation

Attend Loss - Regulate Loss

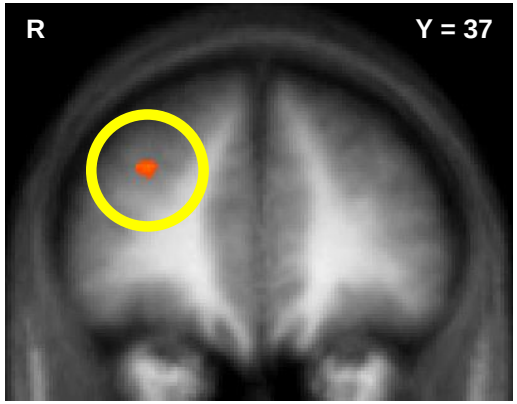


p<0.005 (unc); cluster threshold=3; N=14



Sokol-Hessner et al., *SCAN*, 2013

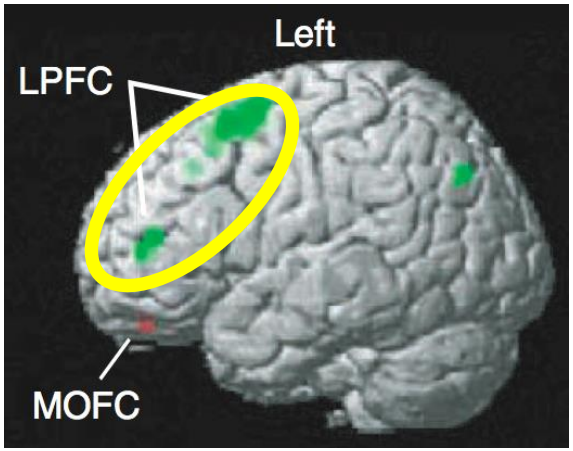
Controlling Loss Aversion
Emotion Regulation



p<0.005 (unc); cluster threshold=3; N=16

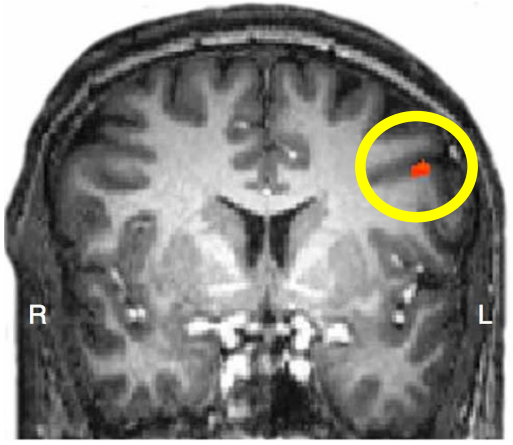
Dorsolateral prefrontal cortex shows a baseline increase in activity in **Regulate** versus **Attend**

Regulating **photos**



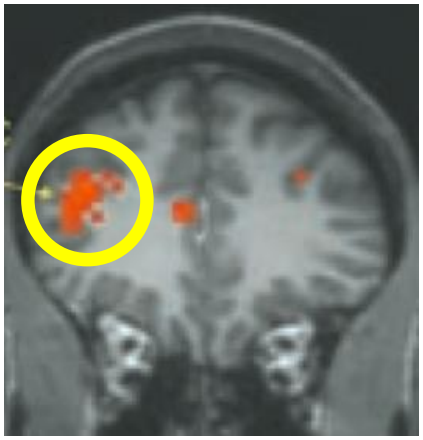
Ochsner et al 2002

Regulating **reward**

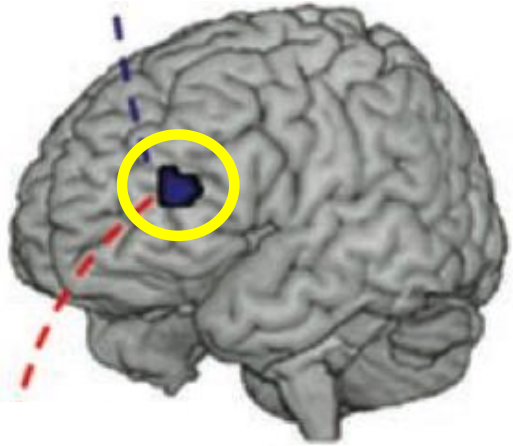


Delgado et al 2008

Regulating **unfair offers**

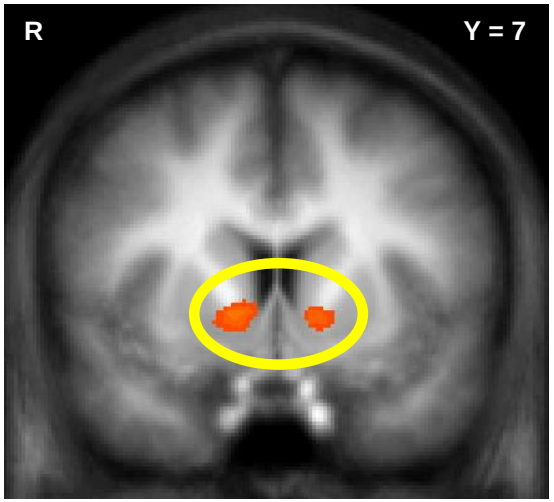

Sanfey et al 2003

Dieting self-control


Hare et al 2009

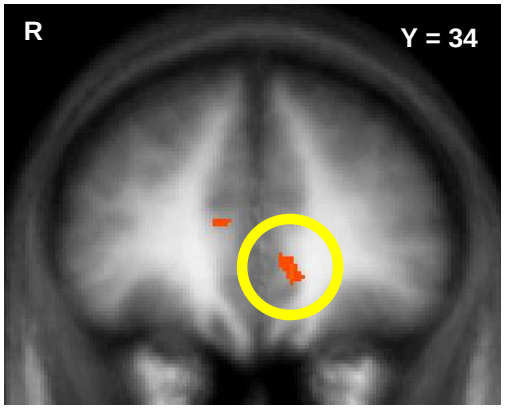
Controlling Loss Aversion
Emotion Regulation

Striatum



p<0.001 (unc); cluster threshold=3; N=40

VMPFC



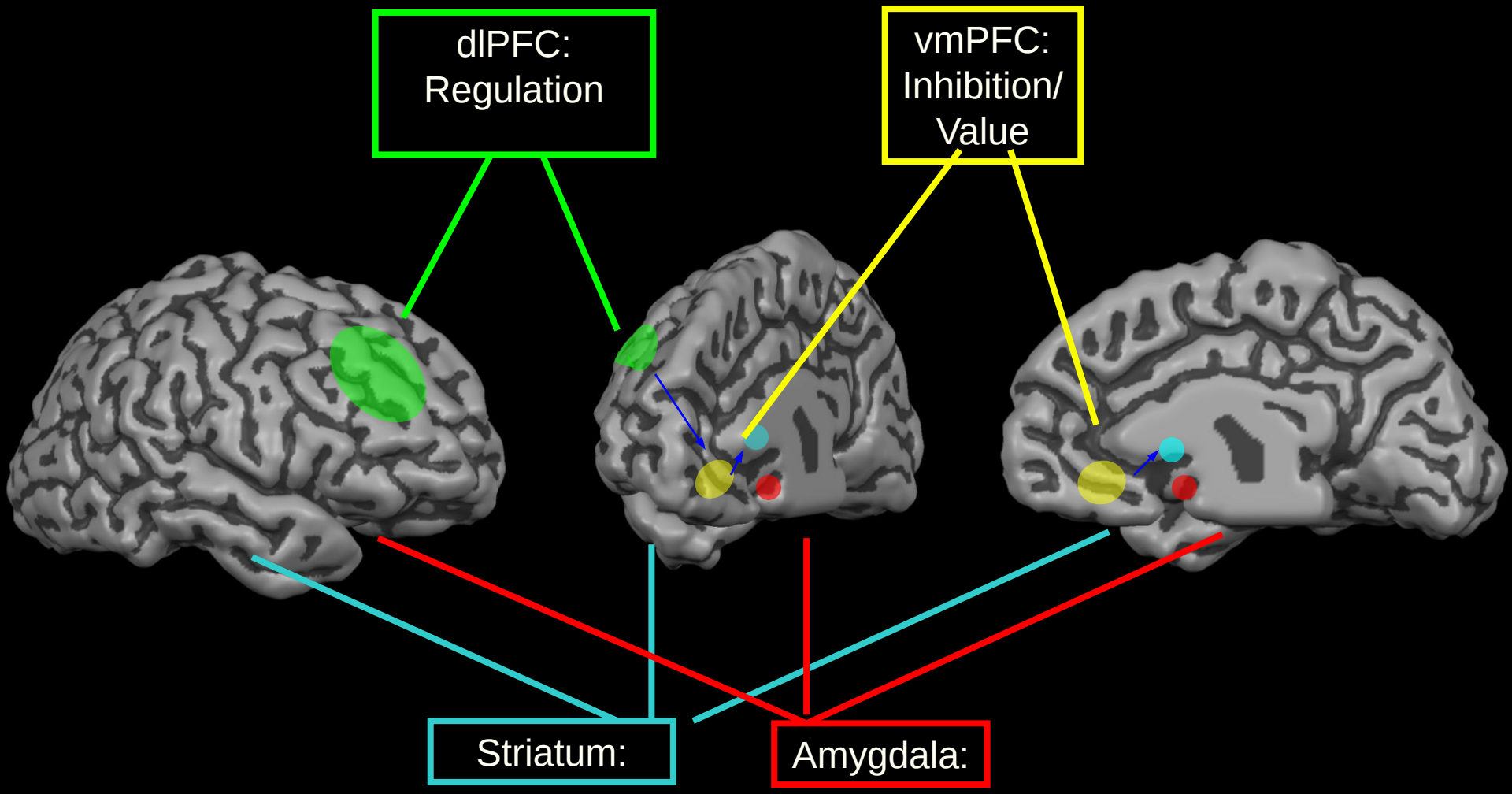
p<0.001 (unc); cluster threshold=3; N=40

Baseline increases in **Regulate** **vs.** **Attend** for decisions and outcomes (win vs. loss)

Sokol-Hessner et al., *SCAN*, 2013

Controlling Loss Aversion

Emotion Regulation



Controlling Loss Aversion
Pharmacology

Propranolol – non-selective β-adrenergic receptor antagonist ("beta blocker"), crosses blood-brain barrier.

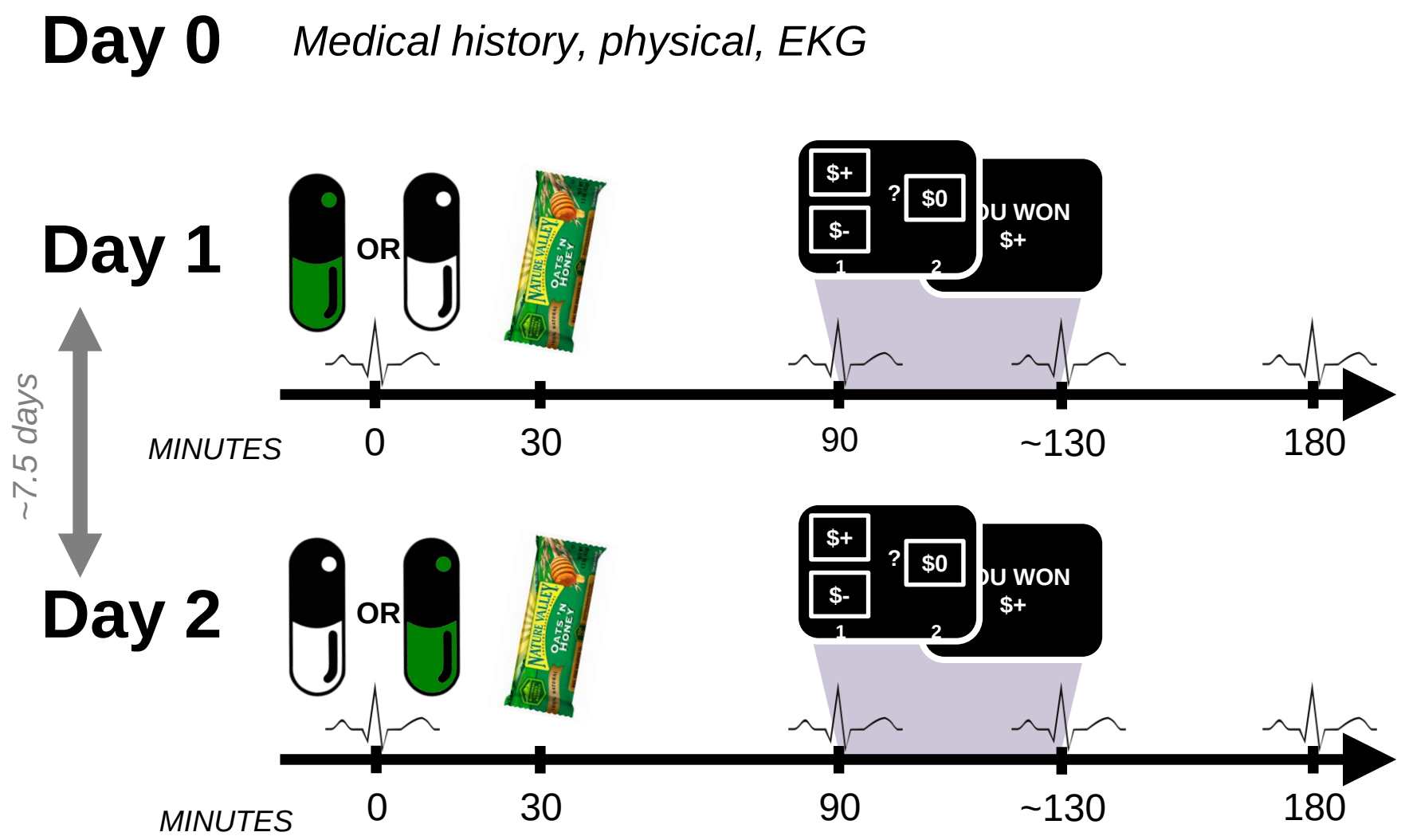
→ **Blunts arousal responses** without sedative effects.

Propranolol has been shown to:

… reduce effect of **emotion on memory** *(Cahill et al, 1994; van Stegeren et al, 1998; Strange et al, 2003; van Stegeren et al, 2005)*

Sokol-Hessner et al. (in prep)

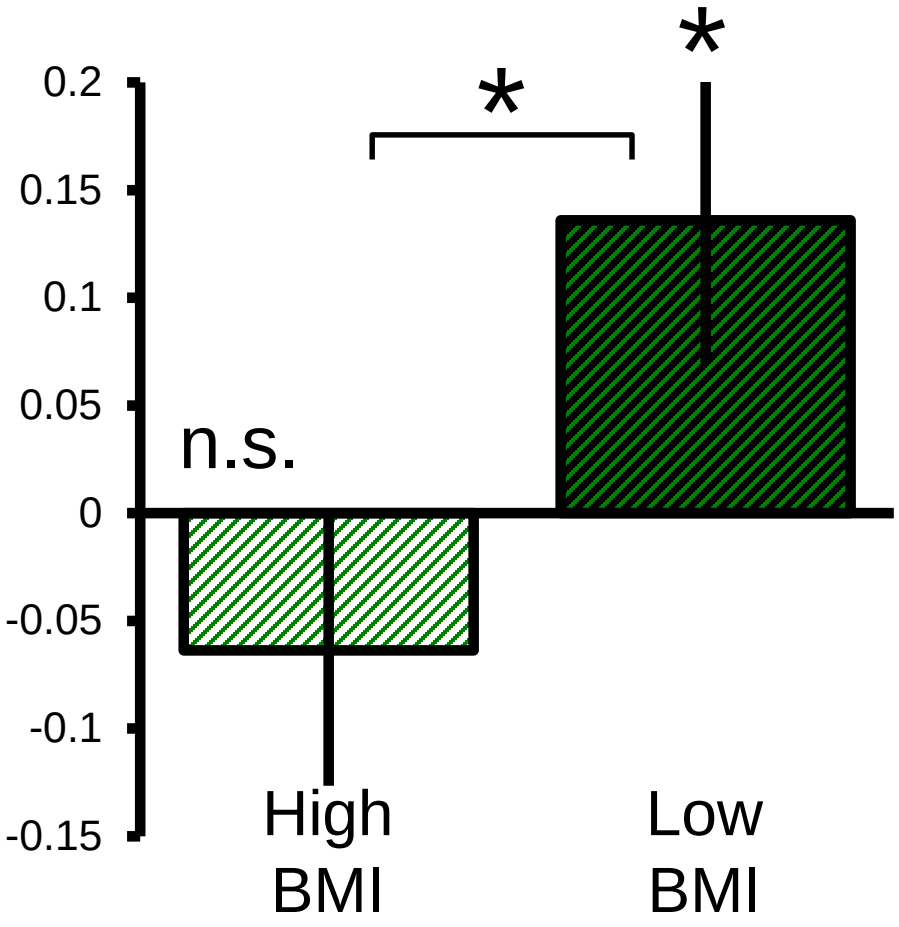
Double-blind, 2-day, **propranolol** (80mg) / **placebo**; N = 47 (22F, 26.6 [5.1] years old)



Controlling Loss Aversion

Pharmacology

Reduction in λ *due to* ***propranolol***



Sokol-Hessner et al. (in prep)

Controlling Loss Aversion
Pharmacology

- **Propranolol** reduces loss aversion for low-BMI participants, suggesting a *dose dependent* interaction.

- No change in **risk sensitivity.**

- Evidence that arousal (and/or its neural mediators) is **selectively** and **causally** linked to loss aversion.

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice?
  - *Loss aversion, but not risk sensitivity, correlates with arousal and amygdala*

- 2) Do techniques to alter emotion through cognitive emotion regulation and drugs change loss aversion or risk sensitivity?
  - Cognitive emotion regulation techniques (reappraisal) reduces loss aversion and arousal to losses
  - Reappraising choices engages an emotion regulation circuitry
  - Pharmacologically reducing arousal reduces loss aversion
  - No effect of regulation or drug on risk sensitivity

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice?
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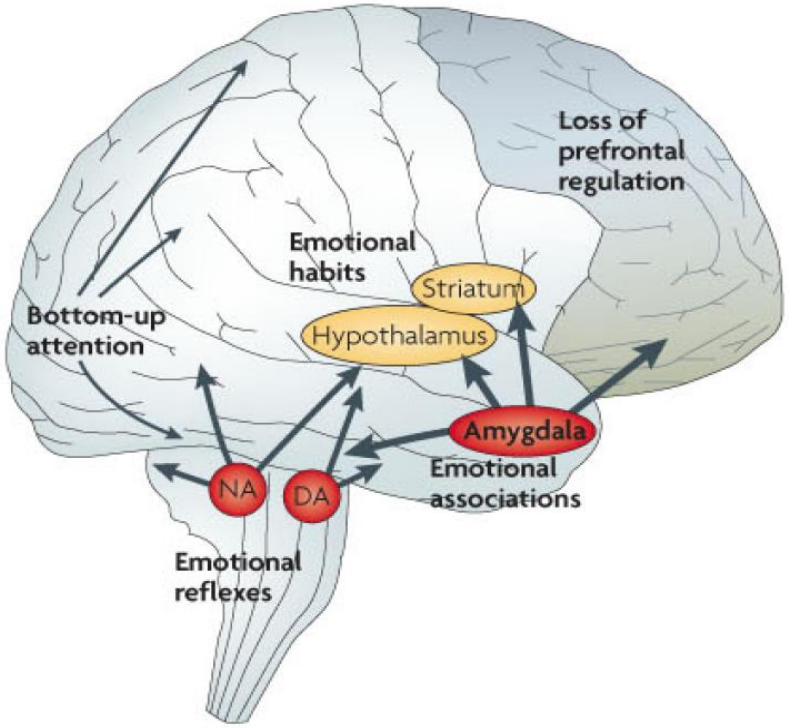
- 2) Do techniques to alter emotion through cognitive regulation and drugs change loss aversion or risk sensitivity?
  - *Reducing arousal through either cognitive emotion regulation or drugs reduces loss aversion, but has no effect on risk sensitivity*

- 3) Does non-specific stress: a) impact loss aversion or risk sensitivity, b) alter the effectiveness of emotion regulation to change choices?

Stress

- Cold Pressor Stress

- Increases cortisol
- Impairs PFC function
- May enhance amygdala function

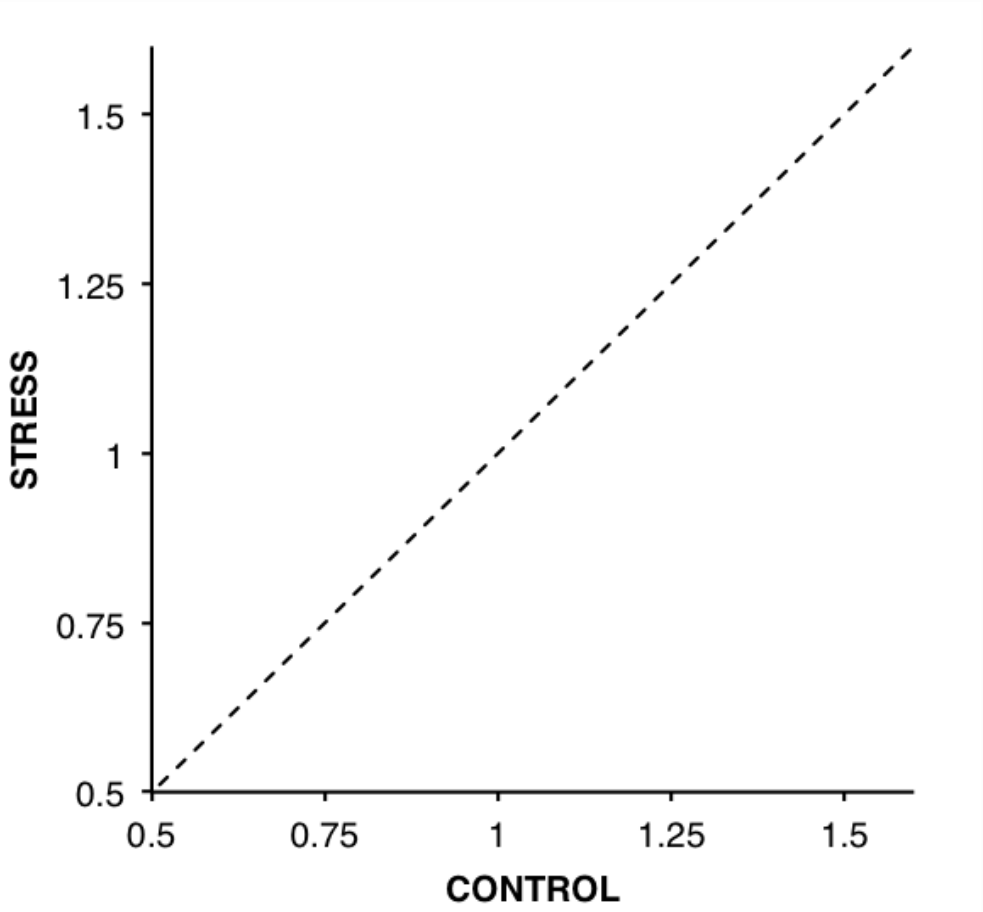


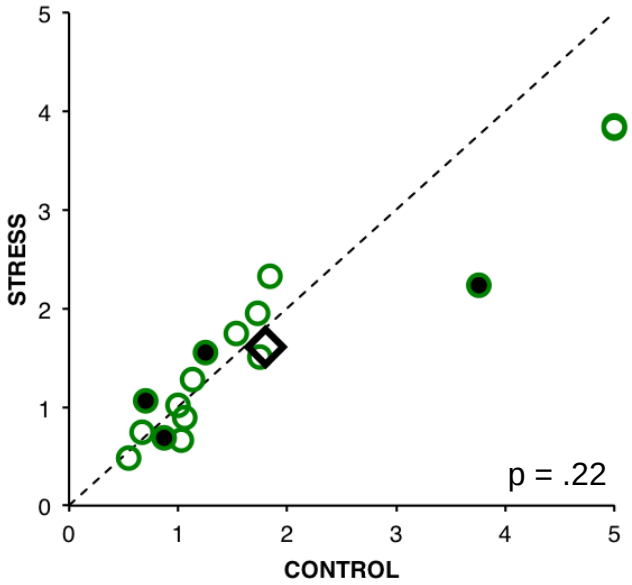
Arnsten, *NRN*, 2009

Does stress change decision parameters?

(Preliminary results)

Risk Attitudes (ρ)





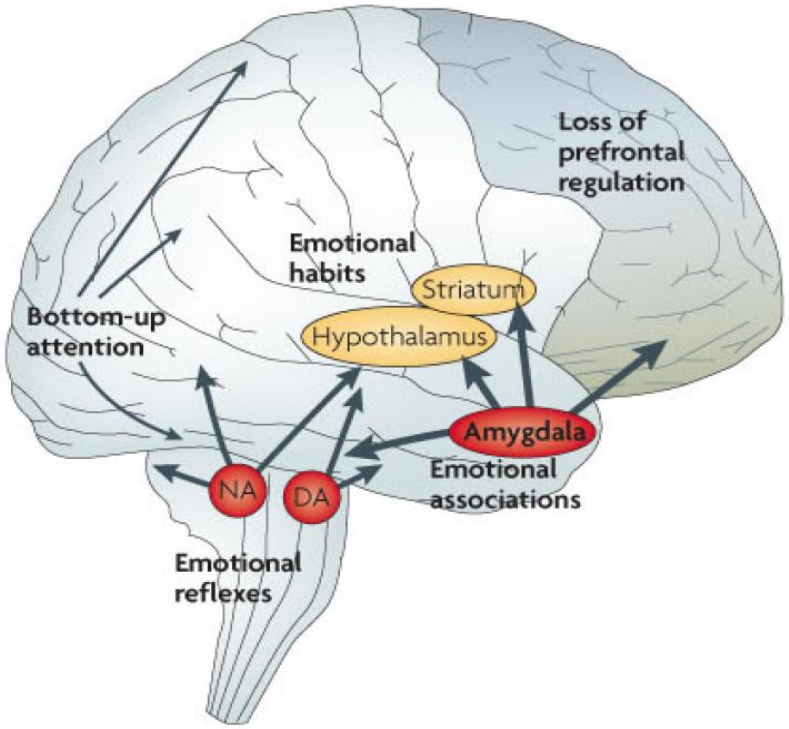
Individual participant (diff p > .05)

Individual participant (diff p < .05)

Group mean

Stress

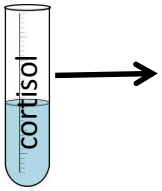
- Stress reduces sensitivity to risk (i.e. people are more risky), but does not change loss aversion
- Different affect variables impact distinct decision variables
- Does stress diminish the effectiveness of cognitive emotion regulation in reducing loss aversion?



Arnsten, *NRN*, 2009

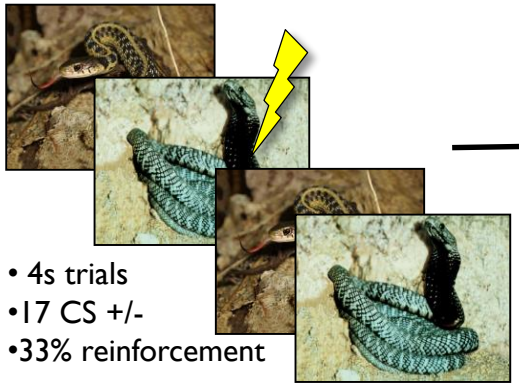
Emotion regulation of threat

Day 1



questionnaires

Fear Conditioning



- 4s trials
- 17 CS +/-
- 33% reinforcement

CRT Session

what emotion?
intensity (1-10)

thoughts → emotions

restructuring exercise

probability of shock is low

only a picture; shock is separate

focus on positive aspects of CS

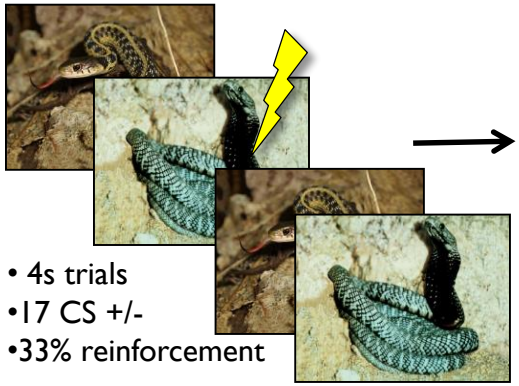
no uncertainty about tomorrow

Emotion regulation of threat

Day 2

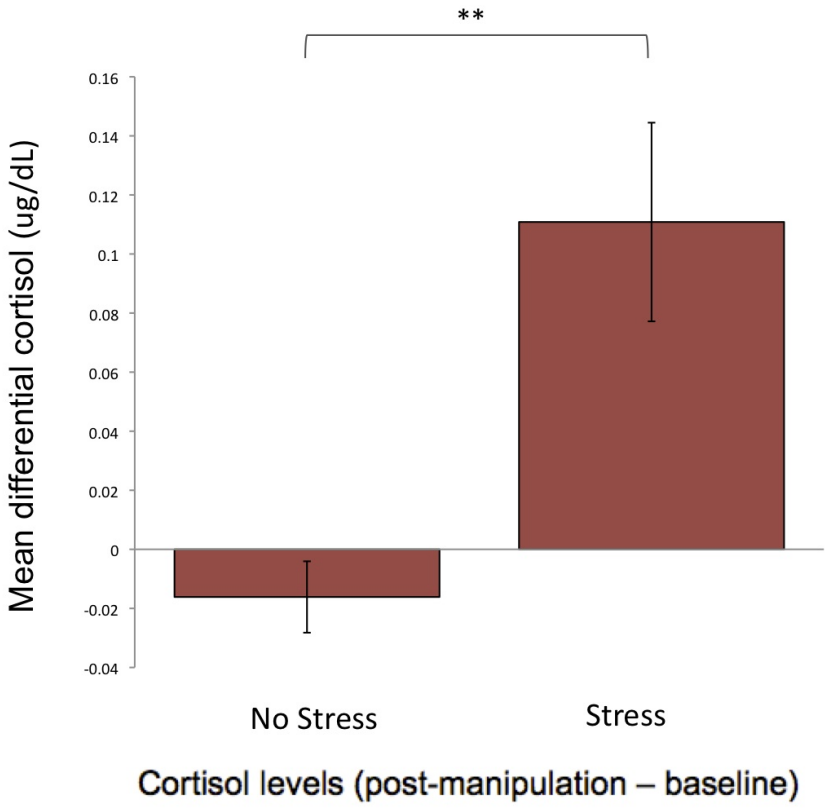
cortisol → questionnaires → **Stressor/Control** → cortisol → **Re-Conditioning** → cortisol

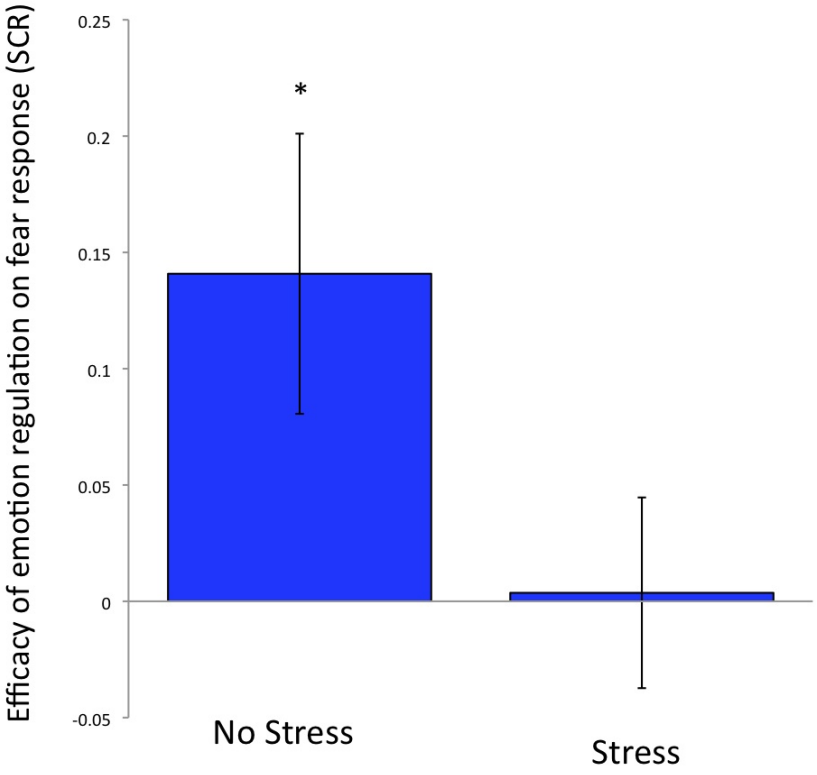
- 0-4°C or 25°C
- Three minutes
- Continuous submersion
- **Discomfort (1-10)**



- 4s trials
- 17 CS +/-
- 33% reinforcement

Cortisol and Regulation Success

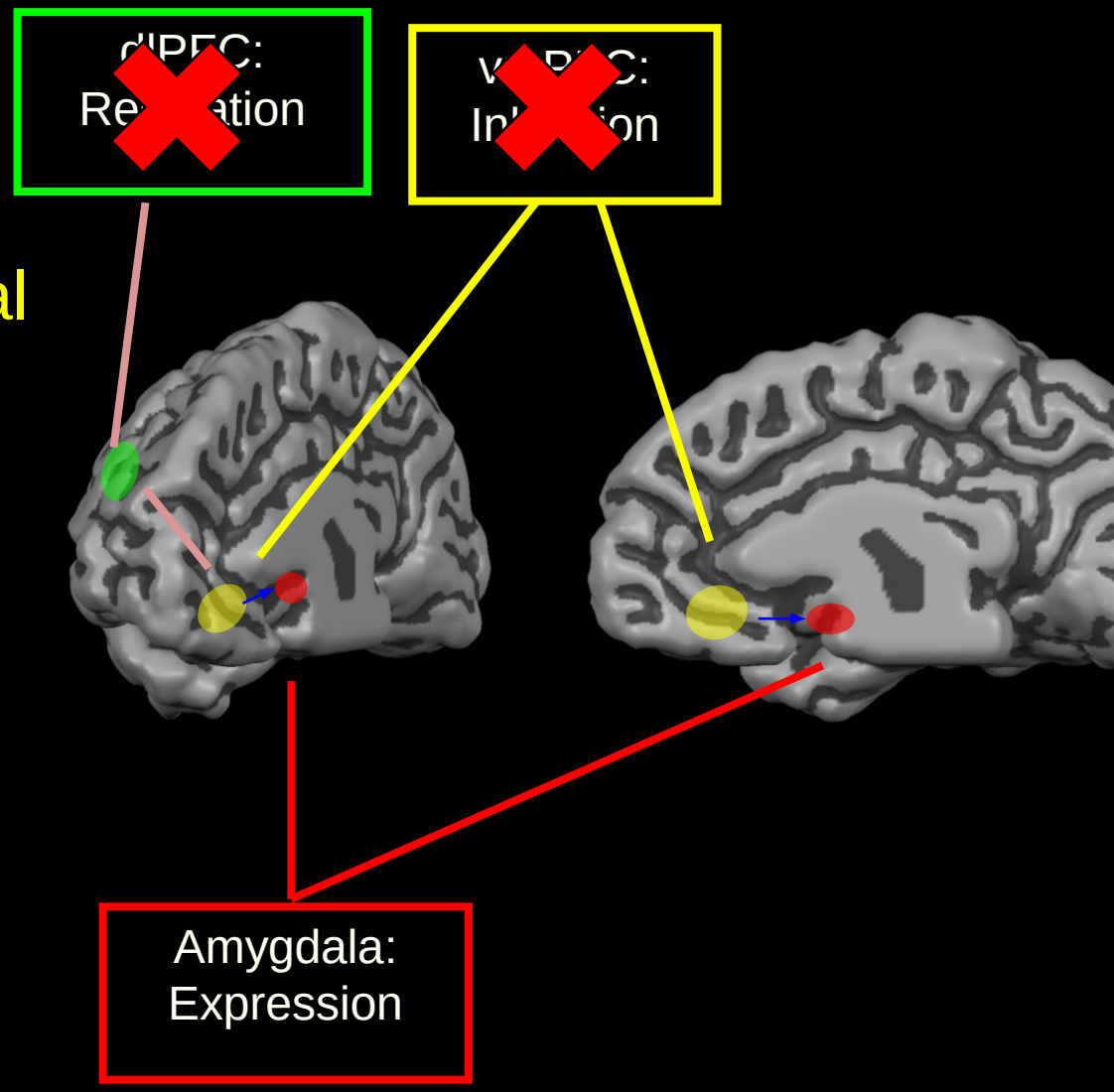




Raio et al. PNAS, (2013)

Stress & PFC

- Stress impairs cognitive emotion regulation, perhaps by impairing prefrontal cortex function
- This may extend to the regulation of loss aversion (underway)



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  - *Loss aversion, but not risk sensitivity, correlates with arousal and amygdala*

- 2) Do techniques to alter emotion through cognitive regulation and drugs change loss aversion or risk sensitivity?
  - *Reducing arousal through either cognitive emotion regulation or drug reduces loss aversion, but has no effect on risk sensitivity*

- 3) Does non-specific stress: a) impact loss aversion or risk sensitivity, b) alter the effectiveness of emotion regulation to change choices?
  - Stress alters risk sensitivity (i.e., more risky), but has no effect on loss aversion
  - Stress diminishes the effectiveness of cognitive emotion regulation techniques that reduce arousal to threat

- 1) Does variability in loss aversion and/or risk sensitivity correlate with physiological arousal to the choice
  - *Loss aversion, but not risk sensitivity, correlates with arousal and amygdala*

- 2) Do techniques to alter emotion through cognitive regulation and drugs change loss aversion or risk sensitivity?
  - *Reducing arousal through either cognitive emotion regulation or drugs reduces loss aversion, but has no effect on risk sensitivity*

- 3) Does non-specific stress: a) impact loss aversion or risk sensitivity, b) alter the effectiveness of emotion regulation to change choices?
  - *Stress impacts risk sensitivity, but not loss aversion, and diminishes the efficacy of cognitive emotion regulation*

Specific Aims

- 1) Investigate the link between individual variability in loss aversion, risk sensitivity and *temporal discounting* and the physiological arousal response to choice options or outcomes

- 2) Examine the impact of altering arousal on these decision variables (emotion regulation and pharmacological manipulation)

- 3) Explore the impact of stress on these decision variables and the effectiveness of the techniques used to alter arousal

** *Identify the neural circuitry mediating these behaviors*

- 1) Does individual variability in temporal discounting correlate with physiological arousal to the choice

- 2) Do techniques to alter emotion through cognitive regulation and drugs change temporal discounting?

- 3) Does non-specific stress: a) impact discount rates, b) alter the effectiveness of emotion regulation to change choices?

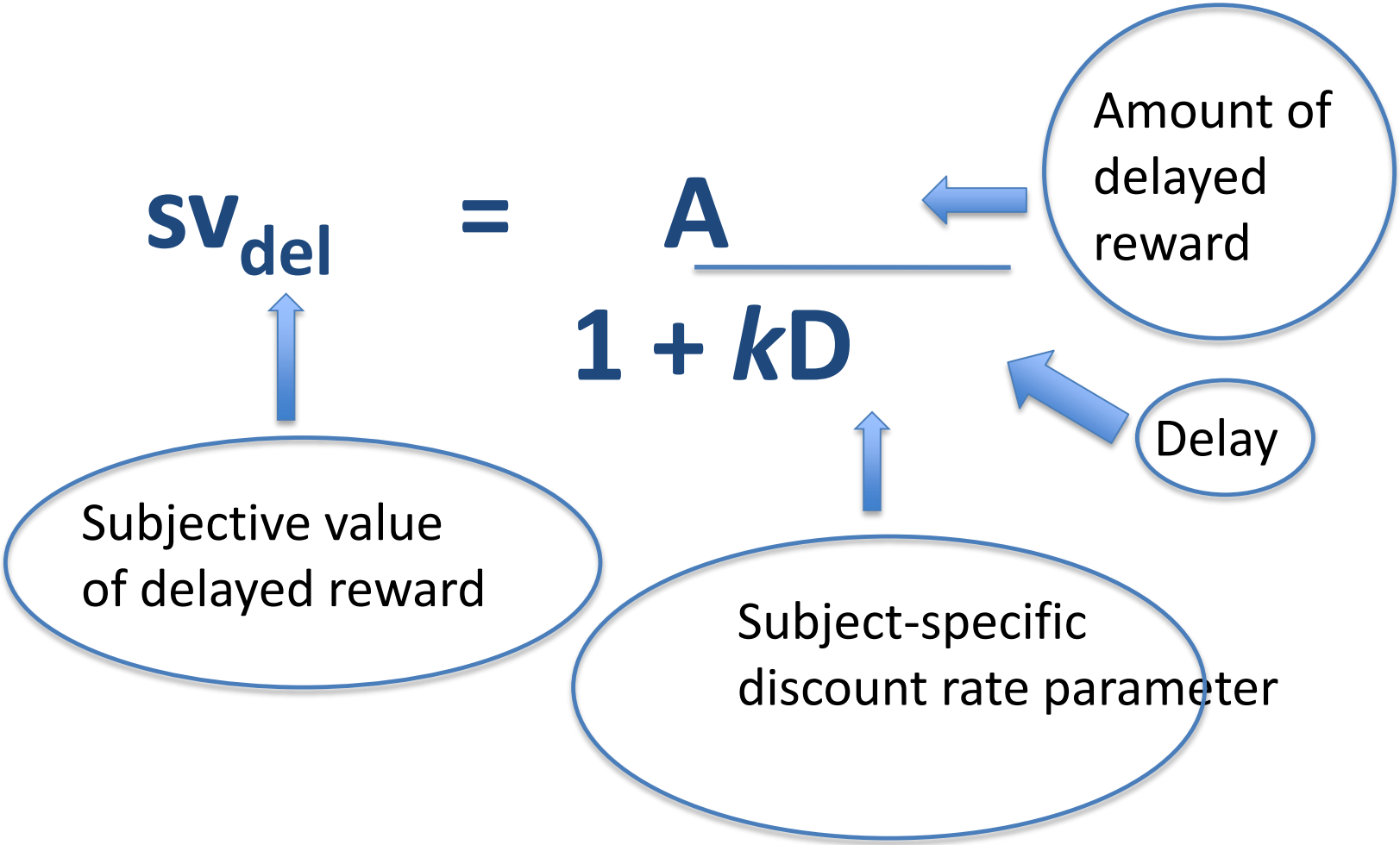
Intertemporal Choice

$10
today

+

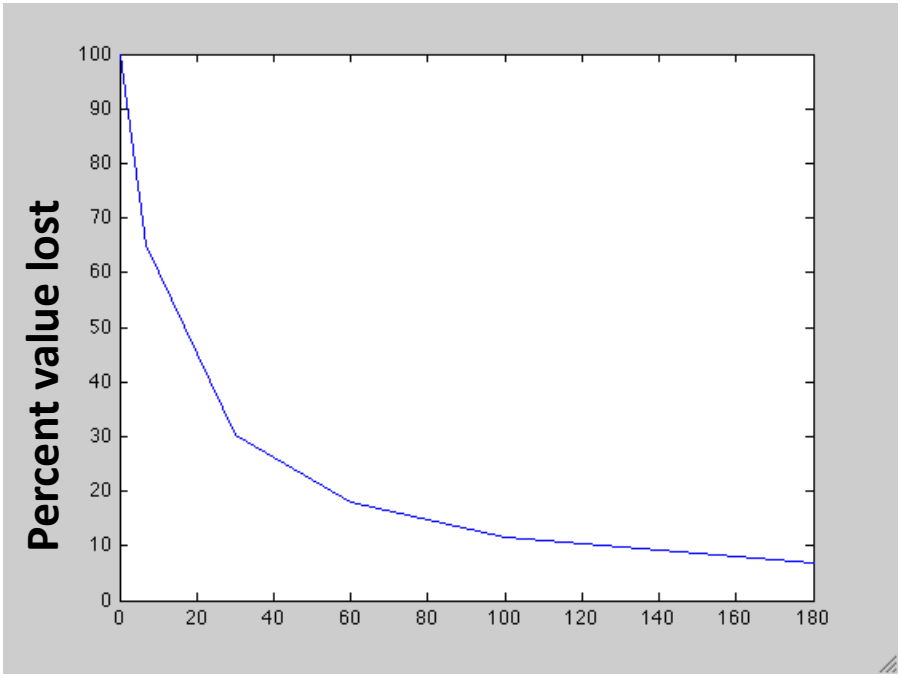
$20
30 days

Hyperbolic model

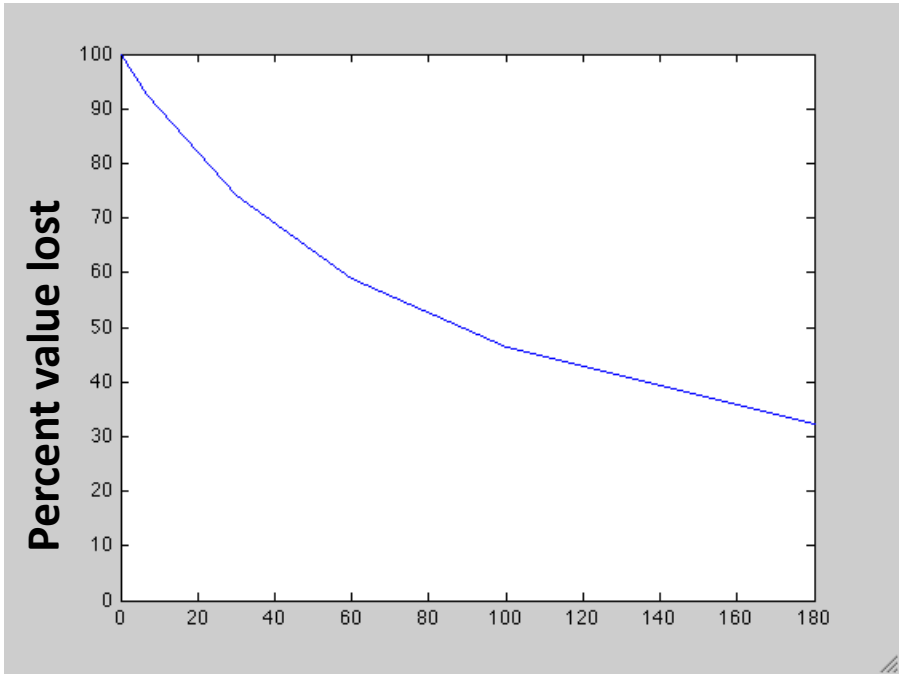


Example discounting curves

Higher discount rate (k = 0.0763)



Lower discount rate (k = 0.0116)

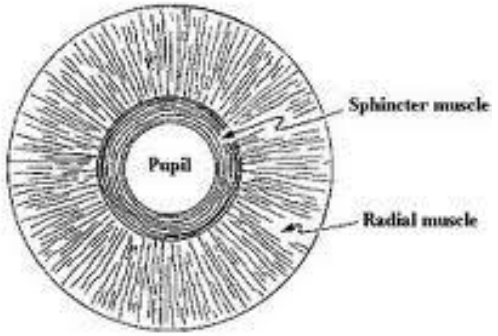


Arousal & Discount Rate (*k*)

Hypothesis:

Higher arousal (greater pupil dilation) to immediate reward predicts steeper discount rate

(e.g., McClure et al., *Science*, 2004)



Arousal and Temporal Discounting

$10 today + $20 30 days

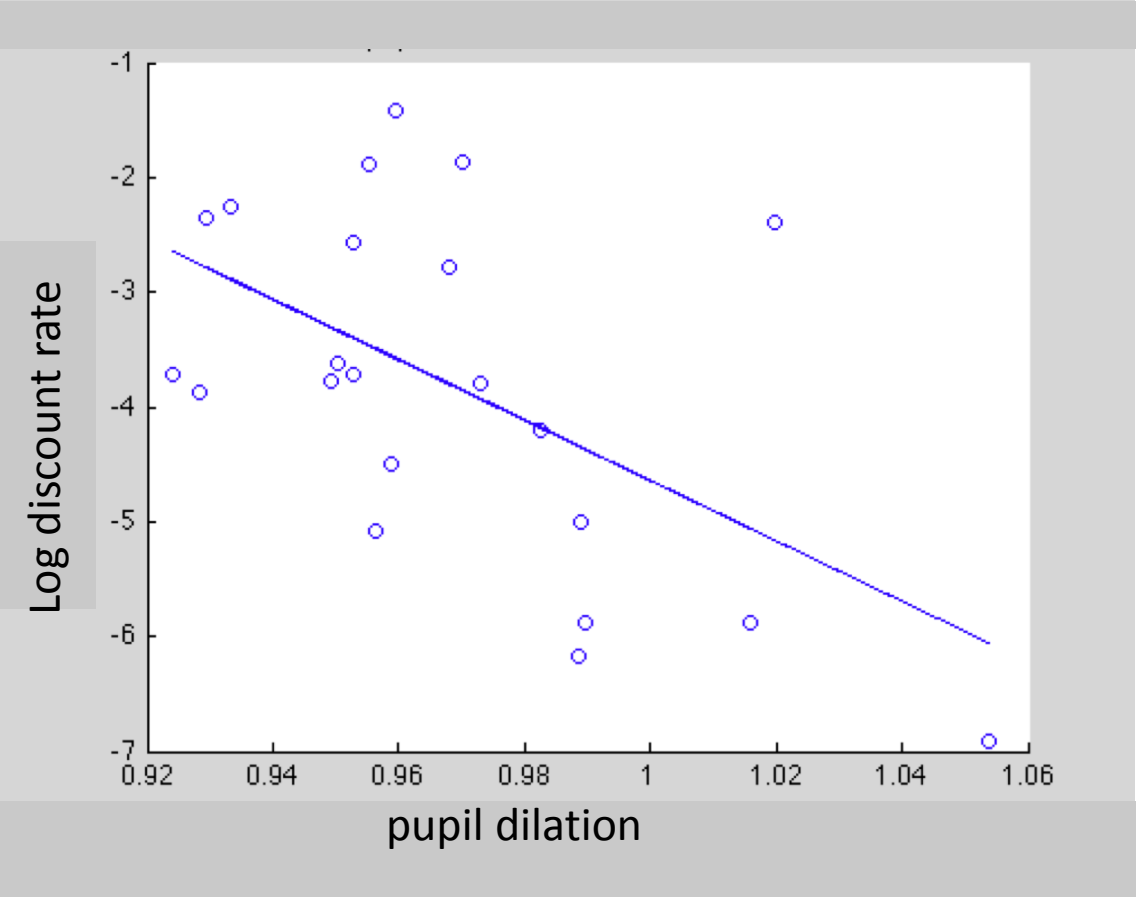
120 trials total
(60 trial types, repeated 2x)

Immediate Reward Magnitude	Delayed Reward Magnitudes			
$10	$11	$15	$20	$30
$20	$22	$30	$40	$60
$30	$33	$45	$60	$90

Each trial immediate and delayed reward: 7, 30, 60, 100 or 180 day delays

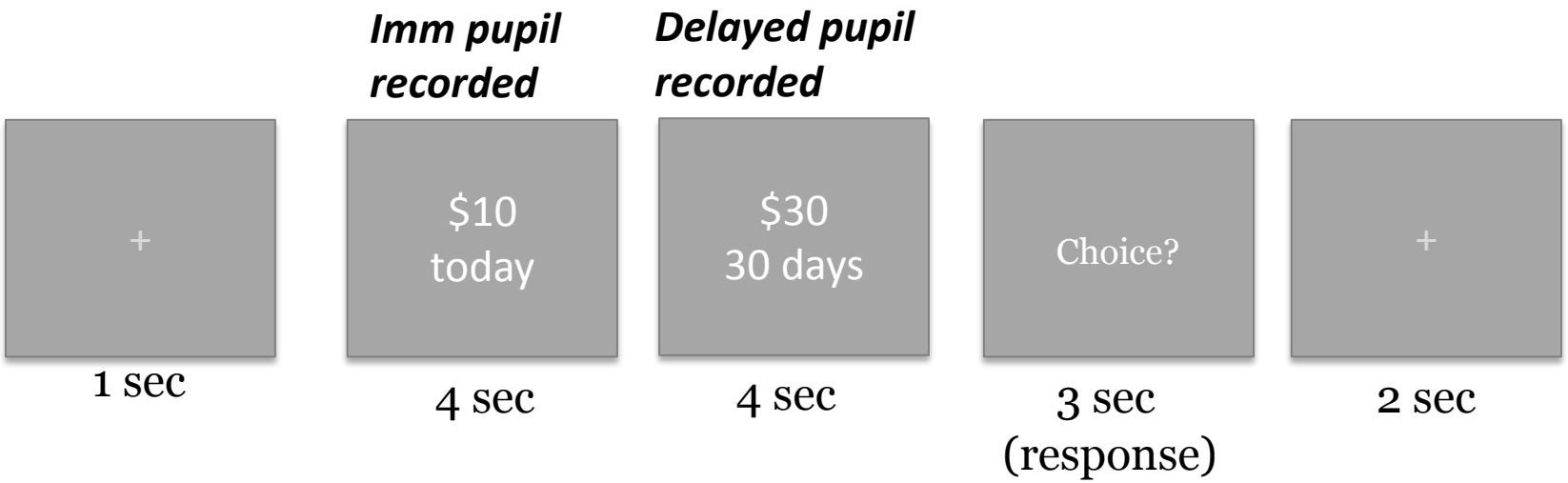
Arousal & Discount Rate (*k*)

- Pupil dilation correlates with less discounting (more patient); r = -0.547, p=.008



- **Contrary to our hypothesis, the greater arousal at choice the higher the subjective value of delayed reward**

Alternative Task layout



- Replicates previous result
- Discount rate and choice is predicted by arousal to the delayed, not immediate reward option
- Falsifies dominant view of the impact of emotion on discount rate

Arousal & Discount Rate (*k*)

- *One possible caveat:* There is more variability in the range of delayed rewards

Immediate Reward Magnitude	Delayed Reward Magnitudes			
$10	$11	$15	$20	$30
$20	$22	$30	$40	$60
$30	$33	$45	$60	$90

Each trial immediate and delayed reward: 7, 30, 60, 100 or 180 day delays

Choice Set 1
"Delay Vary"

Method summary:

- 3 levels of immediate reward ($10, $20 and $30) each presented with 20 different delayed rewards, which varied in delay (7 d – 180 d) and magnitude ($11 - $90).

Results summary:

- Correlation between pupil diameter and ***subjective value of the delayed reward*** ($p < 0.05$).

Choice Set 2
"Immediate Vary"

Method summary:

- 3 levels of delayed reward ($45 in 30 d, $60 in 30 d, $90 in 30 d) each presented with 20 different immediate rewards.

Results summary:

- Correlation between pupil diameter and ***immediate reward value*** ($p < 0.05$).

Choice Set 3
“All Rewards Vary”

Method summary:

- 2 levels of delayed reward ($45 in 30 d, $60 in 30 d) each presented with 15 different immediate rewards
- 2 levels of immediate reward ($10, $20) each presented with 15 different delayed rewards.

Results summary: Nothing

Arousal & Discount Rate (*k*)

What's going on?

Arousal seems to code for choices that are 'better' than average

When delay rewards vary more, subjective value of delay rewards are more likely to vary from average

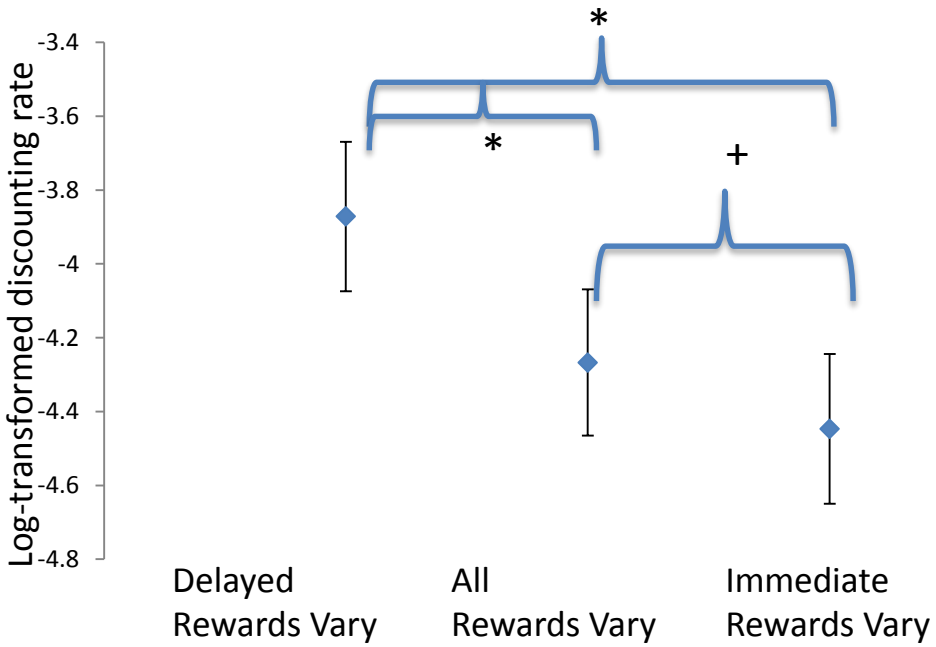
When immediate rewards vary more, value of immediate rewards are more likely to vary from average

When both vary equally, neither varies more

**** Choice set alters the relation between arousal and discount rate**

Choice set also alters discount rate

	Delay Vary	All Vary	Immediate Vary
Mean TD rate	0.0364300	0.0220107	0.0192795
SD of TD rate	0.04668123	0.01751591	0.01751591
Mean log-transformed TD rate	-3.8714589	-4.2671113	-4.4467805



Lempert et al. (under review)

Discount rate and arousal are reference dependent

- vary delay rewards more than immediate
  - more impulsive
  - arousal to delayed reward value correlates with discount rate
- vary immediate rewards more than delay
  - more patient
  - arousal to immediate reward value correlates with discount rate
- vary immediate and delay equally – in the middle

Arousal & Discount Rate (*k*)

- Arousal indicates ‘better than average’ and this is related to reference dependence (history of choice set) shifts in discount rate

- Perhaps we tend to select the most common (default) choice, *unless* the alternative is unusually good

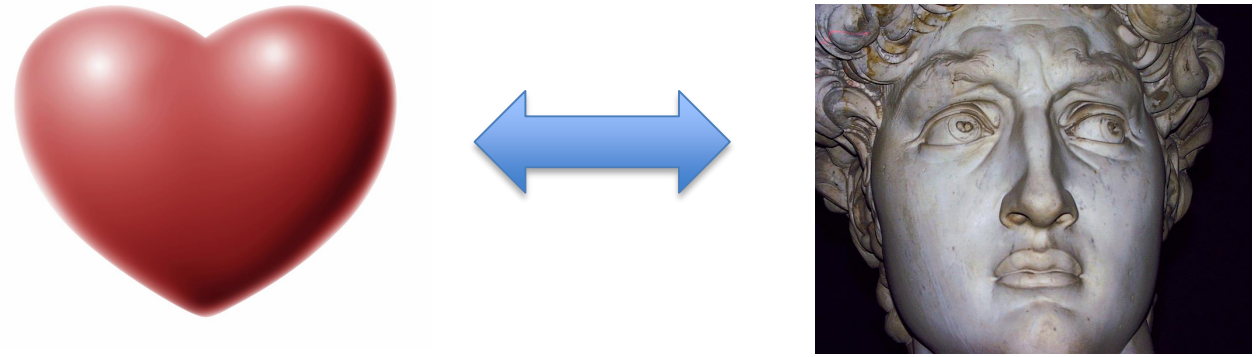
- 1) Does individual variability in temporal discounting correlate with physiological arousal to the choice?
  - Arousal, and discount rate, are reference dependent
  - Falsifies a predominant theory of emotion in temporal discounting
  - Introduces a new, malleable factor that underlies the tendency to discount future rewards

- 1) Does individual variability in temporal discounting correlate with physiological arousal to the choice?
  - *Arousal, and discount rate, are reference dependent*
  - *Introduces a new, malleable factor that underlies the tendency to discount future rewards*

- 2) Do techniques to alter emotion through cognitive regulation and drugs change temporal discounting?
  - *Preliminary evidence that altering choice options to change arousal is linked to change in choices*

- 3) Does non-specific stress: a) impact discount rates, b) alter the effectiveness of emotion regulation to change choices?

Emotion and Decision Making:



- Emotion modulates the computation of subjective value and decisions

- Characterizing the relation between affective factors and decision variables informs our understanding of choice behavior and suggests novel approaches for behavior change

Thank You

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Thank You