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Individual Differences in Dietary Self Control in Health and Disease

OECD Workshop "The State of Mind in Economics"

October 31, 2017

Hilke Plassmann

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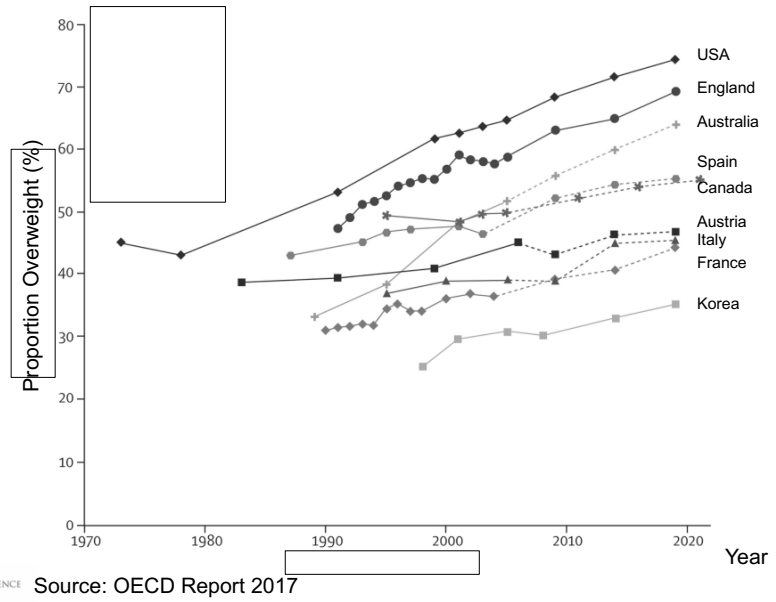
The Problem: Increasing Obesity Rates In Europe and the World



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Source: OECD Report 2017

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Loosing Weight Temporarily is Easy, BUT…

- National Weight Control Registry (NWCR) tracks people who successfully lose weight and keep it off:
  - ➤ Not one "killer diet or exercising regime" but individual differences in what works and what not
  - ➤ similarities among them: 98% of the people in the study say they modified their diet in some way, 94% increased their physical activity
- "Why don't they just eat less and exercise more?"
  - ➤ Individual differences in biology, not simply a lack of willpower, that makes it so hard to loose weight
  - ➤ Overall goal of my research is to study the interaction between biological factors and self-control ability

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Research Questions

1. Do individual differences in brain anatomy exist that predict dietary self-control?
2. Can individual differences in metabolic markers be linked to dietary self-control?
3. Are there differences in dietary self-control between lean and obese?
4. If yes, how do weight loss interventions altering such metabolic markers (i.e., bariatric surgery) impact dietary self-control and its neural signatures?

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Trade-offs in Dietary Choices

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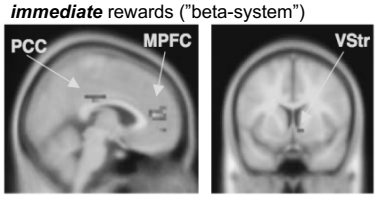
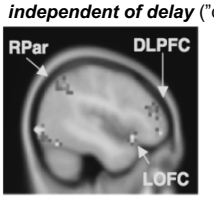
Neuroeconomic Theories of (Dietary) Self-Control

Regions more active for choice for ***immediate*** rewards ("beta-system")

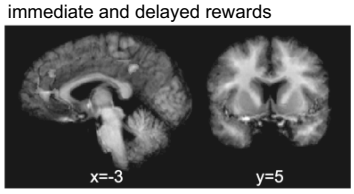


McClure et al. (2004) *Science*

Regions more active for choice that are ***independent of delay*** ("delta-system")

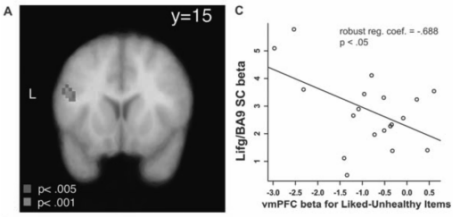


BUT: evidence for ***one single system*** encoding immediate and delayed rewards



Kable & Glimcher (2007) *Nature Neuroscience*

dlPFC modulates vmPFC valuation signal during dietary self-control



Hare et al. (2009) *Science*

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Neuroanatomy in the vmPFC and dlPFC predicts individual differences in self-control ability of dietary decision-making

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Cendri Hutcherson, Department of Psychology, University of Toronto

Anita Tusche, HSS, California Institute of Technology

Todd Hare, Department of Economics, University of Zuerich

Research Question 1

1. Are there neuroanatomical markers associated with dietary self-regulation ?
   - Used VBM to correlate gray matter volume with dietary self-control behavior based on an explicit regulatory strategy (i.e., focusing on healthiness)

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Dietary Self-Control Task Data Set 1 (N=91)

adapted from Hare et al. J Neuro 2011

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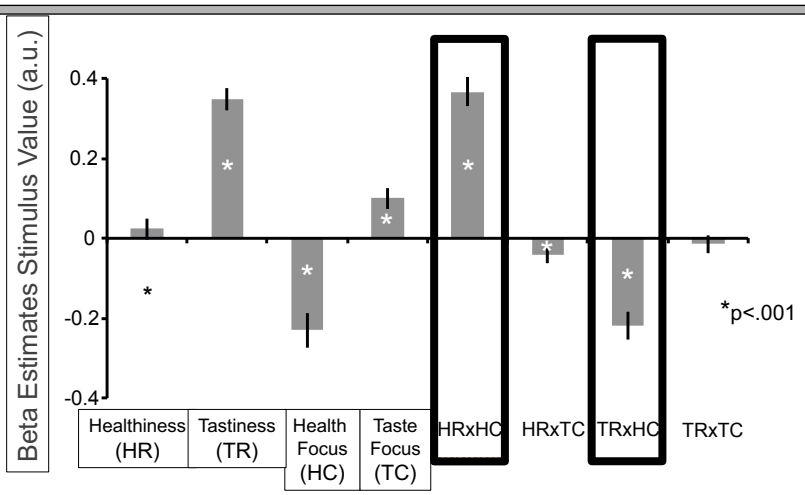
Behavioral Results Data Set 1



Regulatory Success = $\beta_{HR*HC} - \beta_{TR*HC}$

Schmidt et al. (in prep.)

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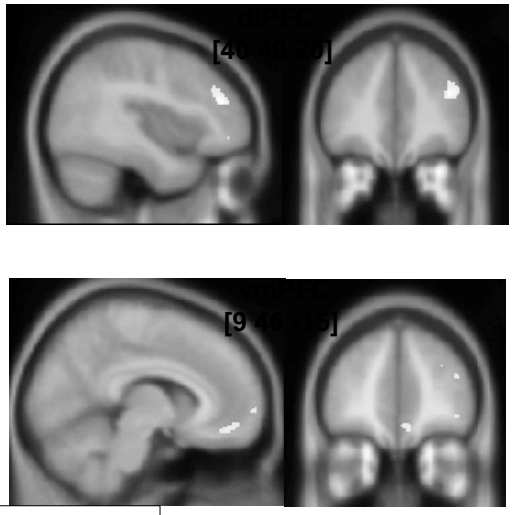
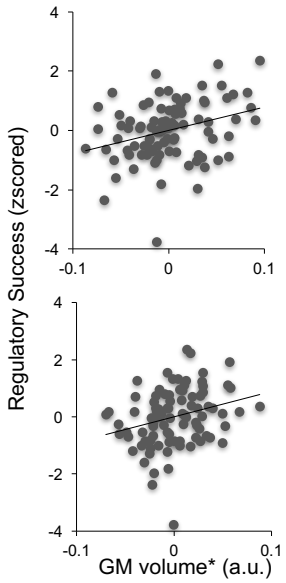
GM Volume Correlating with Regulatory Success





p < .001 unc.

Schmidt et al. (in prep.)

* Corrected for global GM, age, gender, scanner, study

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Research Question 2

2. Do these neuroanatomical markers generalize to different regulatory strategies?
   - ➢ Out-of-sample prediction of dietary self-control in an independent group of participants who performed a different dietary self-control task

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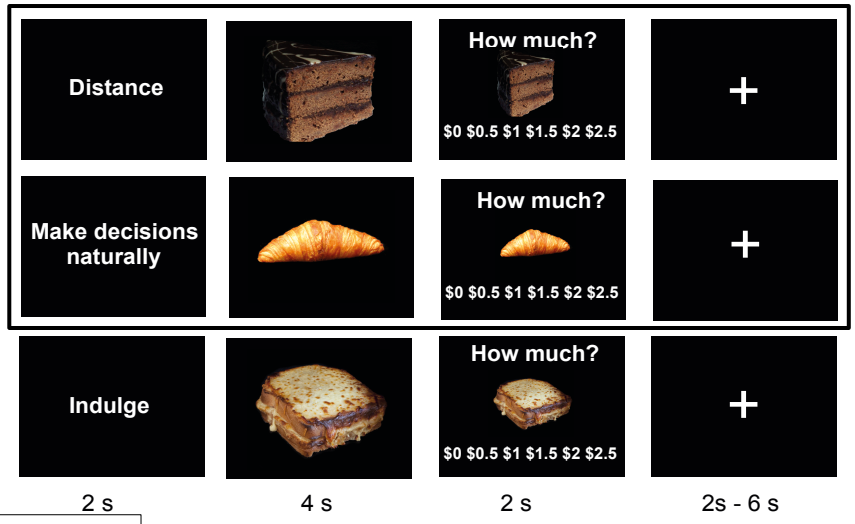
Dietary Self-Control Task Data Set 2 (N=32)



adapted from Hutcherson et al. J Neuro 2012

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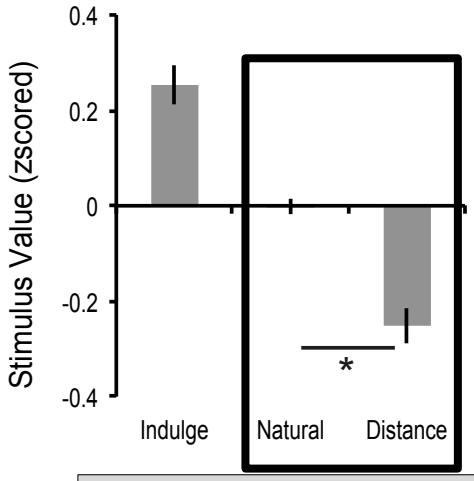
Behavioral Results Data Set 2



Regulatory Success =
SV(Natural – Distance)

Schmidt et al. (in prep.)

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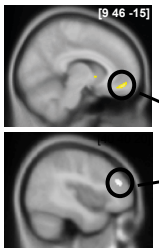
Overview
Out-of-Sample Prediction Approach

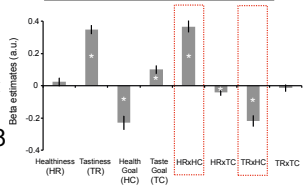
Participants of Data Set 1



β_{vmPFC}=6.92

β_{dlPFC}=6.68

Regulatory Success = $\beta_{HR*HC} - \beta_{TR*HC}$



Participants of Data Set 2

Predicted Regulatory Success(GM_{dlPFC}, GM_{vmPFC})
=
$\beta_0 + \beta_{dlPFC}\, GM_{dlPFC} + \beta_{vmPFC}\, GM_{vmPFC} + \varepsilon$

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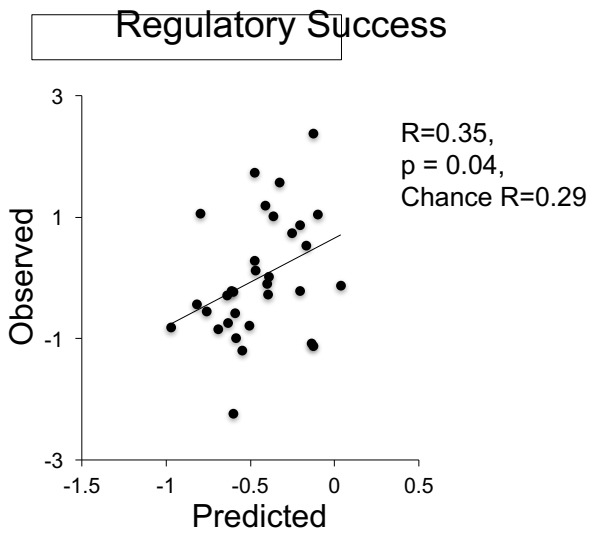
Out-of-Sample Prediction Data Set 2



Schmidt et al. (in prep.)

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Interim Conclusions

- Individual differences in the anatomy of the vmPFC and dlPFC play a role for dietary self-control success
- This role is independent and of the same magnitude
- Anatomical findings are generalizable across populations and dietary regulation strategies

➤ Opens the window toward targets for therapy of dietary self-control failures (cognitive training, neuro-feedback)

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Individual Differences in Baseline Leptin is linked to Dietary Self-Control in Health

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Judith Aron-Wisnewsky, Institute Cardiométabolism (ICAN) & Nutrition, Université Pierre et Marie Curie

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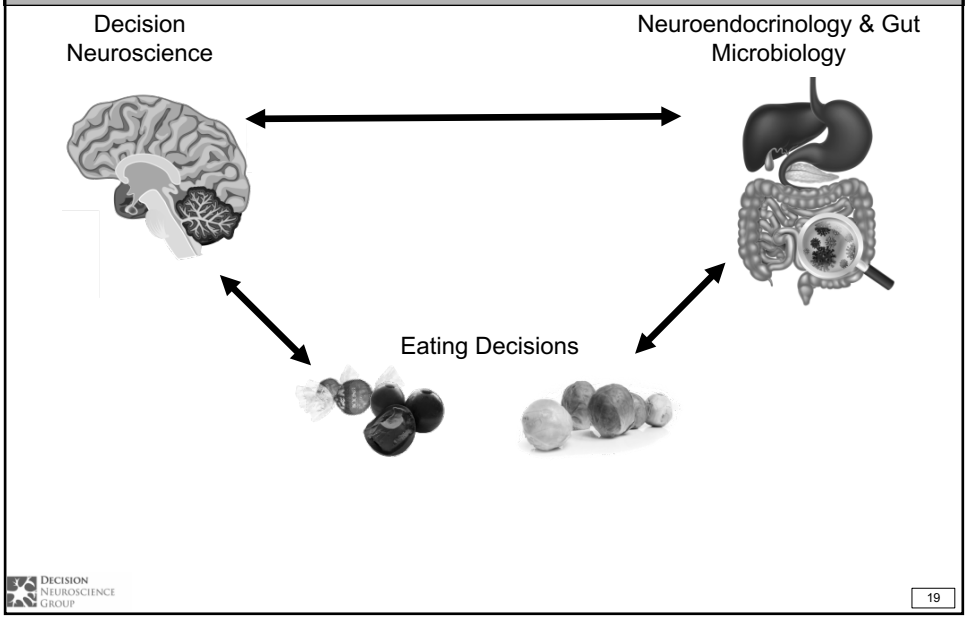
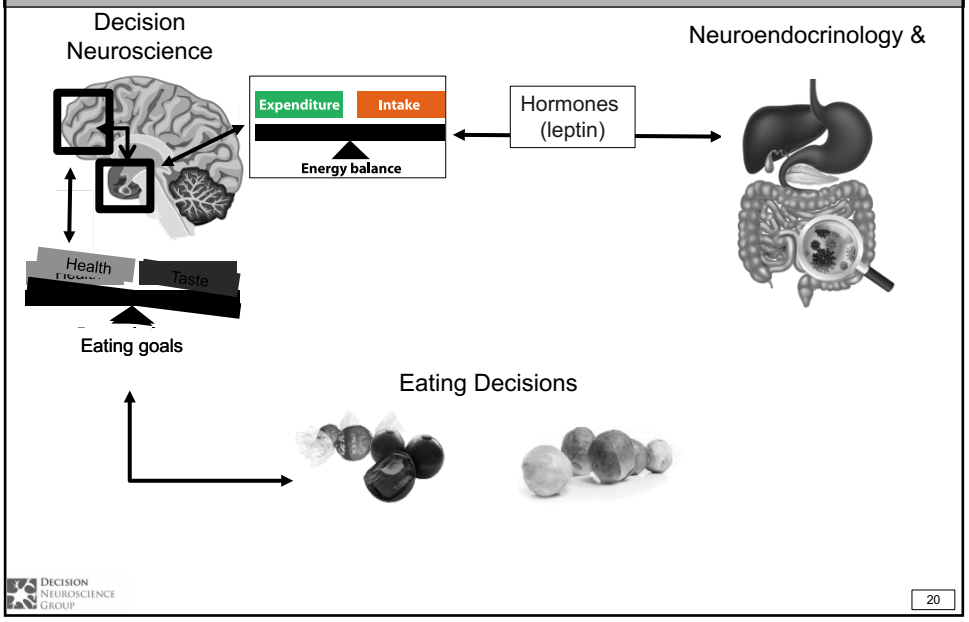
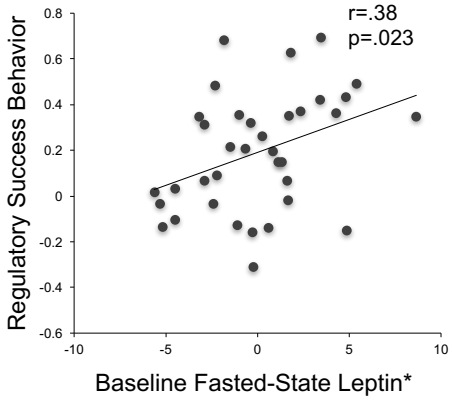
The Interdisciplinary Model of Dietary Self-Control

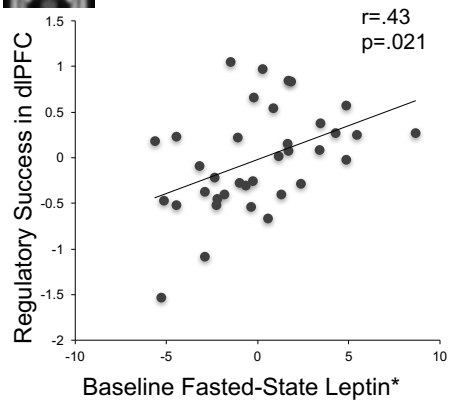


Research Question



Dietary Self-Control is Positively Correlated with Baseline Leptin in Lean (N=40)





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Schmidt et al. (in prep.)

*corrected for % Body Fat

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Interim Conclusions

- High baseline leptin levels (i.e., the “Satiety Hormone”) correlate with behavioral and neural measures of dietary self-control in lean participants,
- but not in obese that are mostly leptin resistant

➤ Imbalance of hedonic and homeostatic control systems of food in take

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Impact of Bariatric Surgery on Delay Discounting


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Sample Indifference Point Study

Group (All Females)	T0 Pre-op	T1 3-month post-op	T2 12-month post-op
Obese Patients Age: 33.7±1.8 , BMI>30	72	45	37
Lean Controls Age: 38.6±2.5, BMI: 22 ±0.40	39	33 **(6 months after)**	
Obese controls (no surgery) Age: 37.6±2.4, BMI: 31.8±0.5	29	---	

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Task Indifference Point Study

- Do you prefer receiving 4 candies (Euros) now, or 4 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 5 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 6 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 7 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 8 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 9 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 10 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 11 in a week?
- Do you prefer receiving 4 candies (Euros) now, or 12 in a week?

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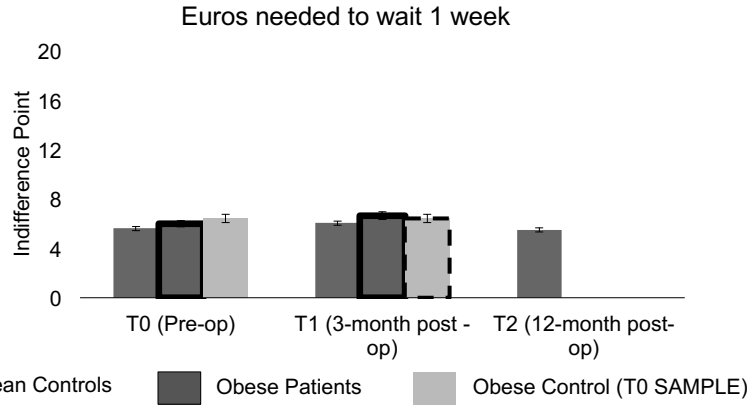
Indifference Points Differences for Money



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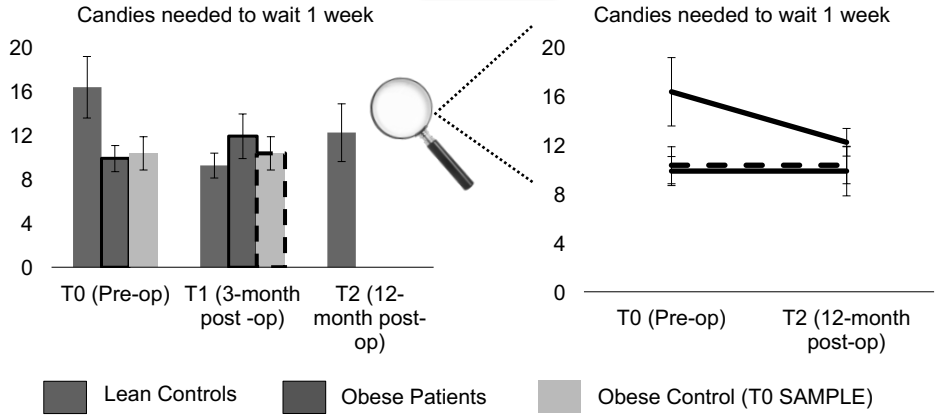
Indifference Points Differences for Money



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Sample Delay Discounting Task

Group (All Females)	T0 Pre-op	T1 6-month post-op
Obese Patients Age: 34.6±1.8, BMI: 44±2.5	17	17
Lean controls Age: 38±13, BMI: 21.7±1.4	45	34
Obese controls (no surgery) Age: 37.6±2.4, BMI: 31.8±0.5	29	-----

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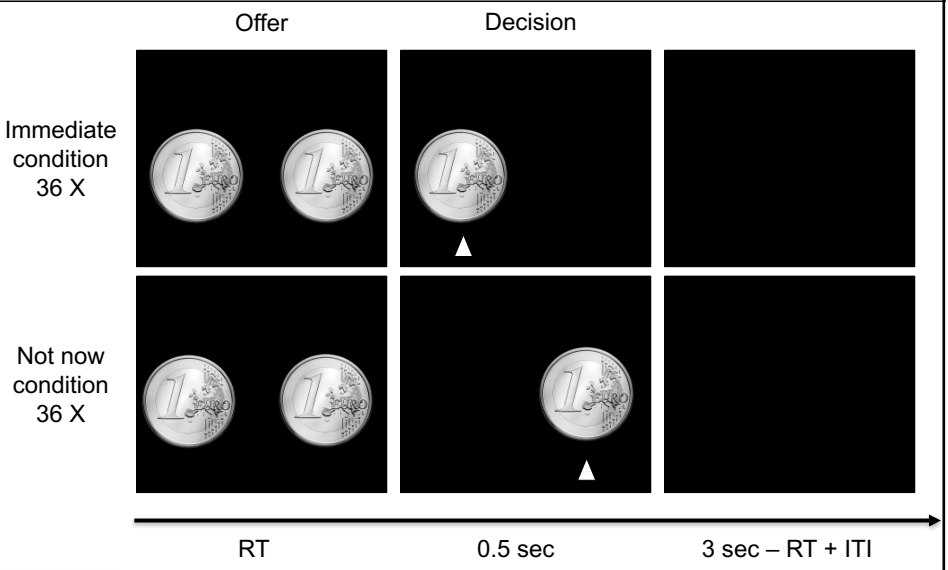
Design for Delay Discounting Task (Money)



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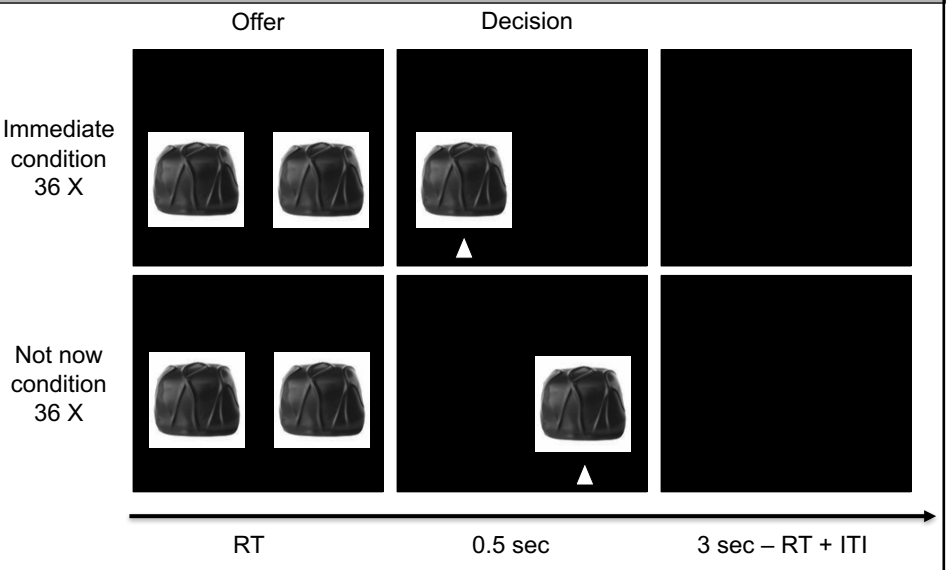
Design for Delay Discounting Task (Food)



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The ASAP model (Kable & Glimcher)

$$SV = g(D_{ASAP})\frac{A}{1 + k_{ASAP}(D - D_{ASAP})}$$

Gain factor to represent delay to earliest reward

$$SV = \frac{1}{1 + k_{ASAP}D_{ASAP}} * \frac{A}{1 + k_{ASAP}(D - D_{ASAP})}$$

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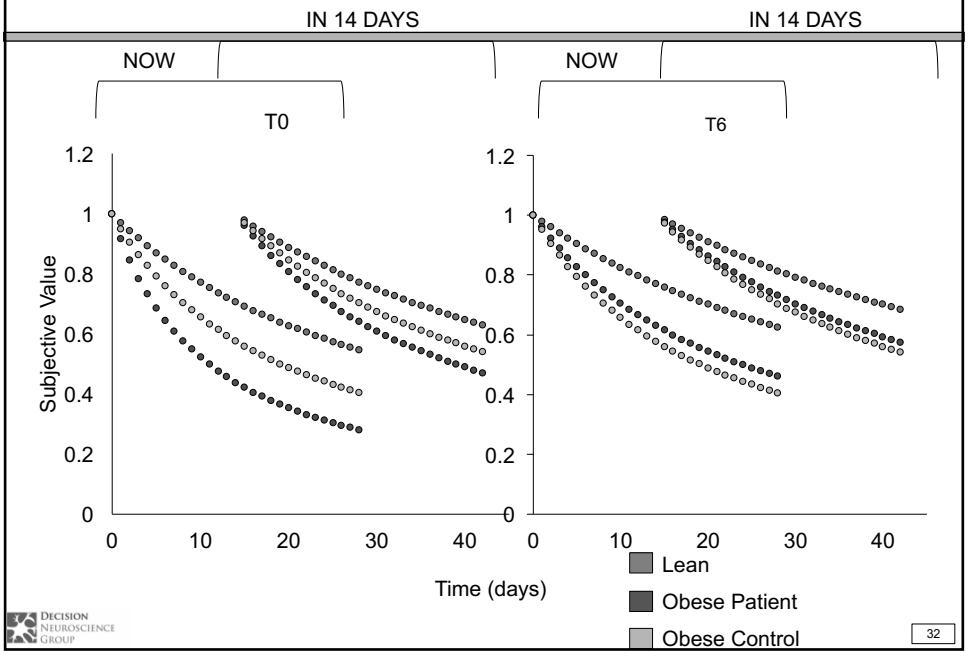
Subjective Value Functions (for Food)



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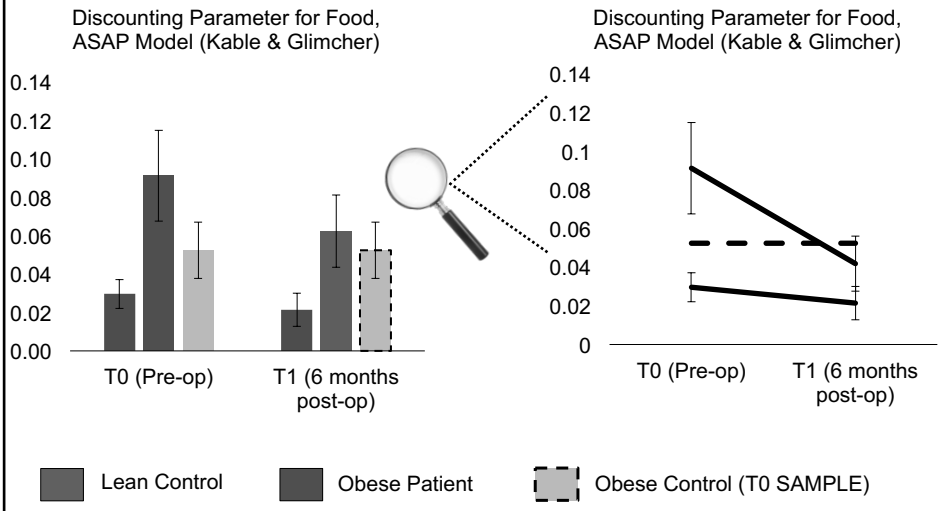
Discounting Rates for Food



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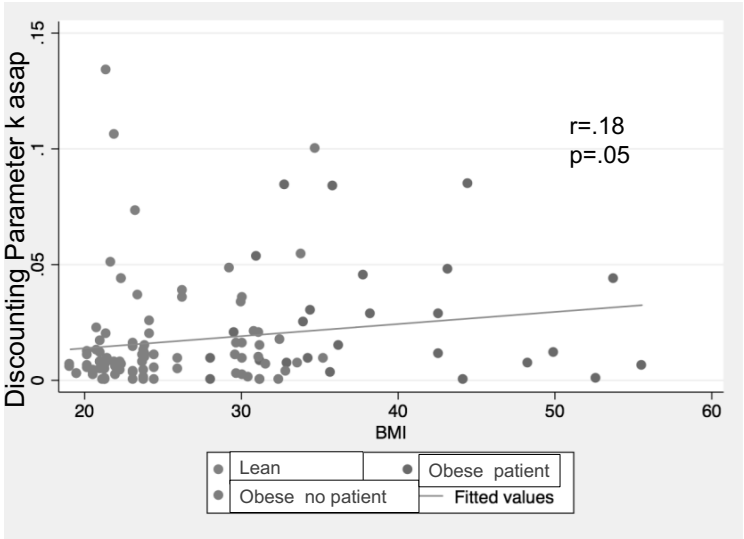
Discounting Rates for Food Correlates With BMI



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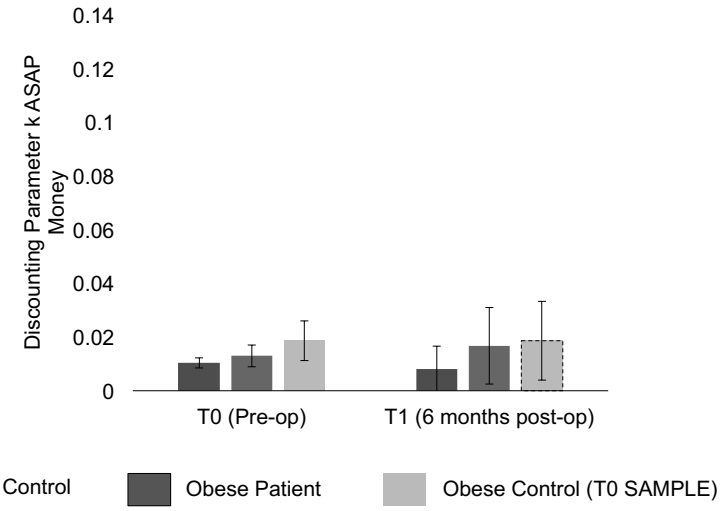
Discounting Rates for Money



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Correlation Hunger State and Discounting Rates Food

Lean Controls

DV: k (food)	Coeff.	t	p	[95% Conf. Interval]	
Change in Hunger, T0	0.0012	-0.2000	0.8430	-0.0133	0.0109
Change in Hunger, T1	0.0038	0.5600	0.5780	-0.0100	0.0175

Obese Controls

DV: k (food)	Coeff.	t	p	[95% Conf. Interval]	
Change in Hunger, T0	0.0321647	**2.36**	**0.035**	0.0027036	0.0616258
Change in Hunger, T1	.019198	1.04	0.318	-0.0209801	-0.059376

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Interim Conclusions

- Obese participants discount future food rewards significantly more than lean
- Obese and lean participants exhibit similar discounting behaviors for monetary rewards
- After bariatric surgery obese participants exhibit discounting behaviors closer to those of lean control participants

No time

some time

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General conclusions

- Individual differences in brain anatomy in vmPFC and dlPFC predict dietary self-control
- Individual differences in homeostatic control markers (i.e., leptin) correlate with behavioral and neural measures of dietary self-control in lean but are dysfunctional in obese
- Discounting rates (=impatience) for food but not money correlates with BMI
- Gastric bypass surgery that restores dysfunctionality of such homeostatic control markers renders discounting behaviors for food of obese closer to those of lean

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Impact of Bariatric Surgery on Resting State Connectivity

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Karine Clément, Institute Cardiométabolism (ICAN) & Nutrition, Université Pierre et Marie Curie

Research Questions

- Does obesity affect resting state connectivity in neural pathways linked to valuation (i.e., vmPFC as seed)?
- How does bariatric surgery change the resting state connectivity in these neural pathways ?

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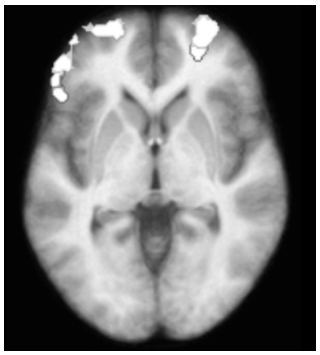
Group Differences vmPFC rsfMRI Connectivity

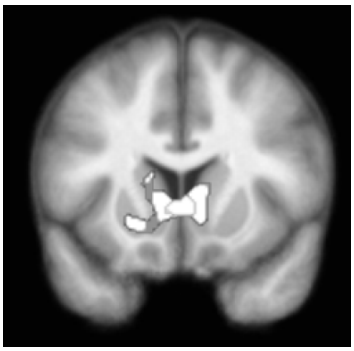
obese patients > lean controls



vmPFC – IFG & lOFC, dlPFC

$p_{FWE}<0.05$

lean controls > obese patients



vmPFC - vStr &dStr

T0 before bariatric surgery

T6 after bariatric surgery

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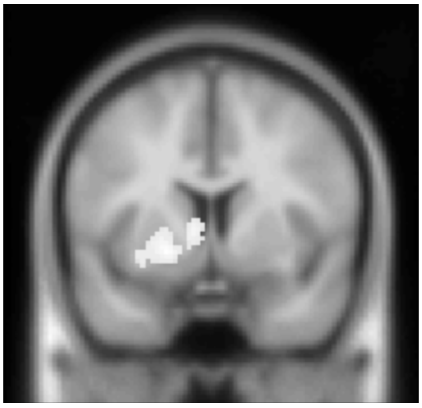
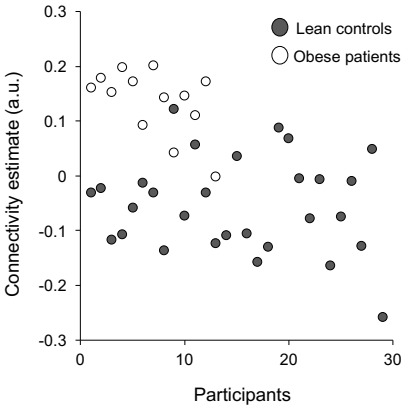
Effect of Bariatric Surgery on vmPFC rsMRI Connectivity

obese patients(T6>T0) > lean controls(T6 >T0)



$p_{FWE}<0.05$

vmPFC - ventral striatum rsMRI connectivity across participants



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Interim Conclusions

- enhanced resting state connectivity between the vmPFC and lateral and central frontal brain regions linked to taste perception & emotion regulation in obese
- attenuated resting state connectivity in obese within reward and motivation related pathways, potentially in line with the reward deficiency syndrome supposedly existing for addictions (i.e., blunted striatal activation, due to repetitive exposure to a "addictive" stimulus)
- Bariatric surgery reintegrated the resting state connectivity vmPFC - vStr

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General conclusions

- Individual differences in brain anatomy in vmPFC and dlPFC predict dietary self-control
- Individual differences in homeostatic control markers (i.e., leptin) correlate with behavioral and neural measures of dietary self-control in lean but are dysfunctional in obese
- Discounting rates (=impatience) for food but not money correlates with BMI
- Gastric bypass surgery that restores dysfunctionality of such homeostatic control markers
  - renders discounting behaviors for food of obese closer to those of lean
  - re-integrates vmPFC-vStr connectivity at rest

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Thank you!

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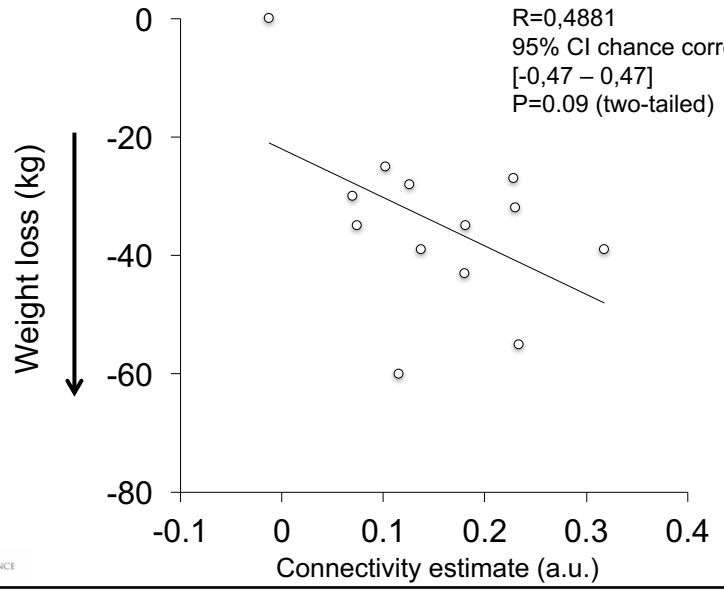
Agence Nationale de la Recherche ANR

Correlation between Weight Loss and vmPFC-ventral striatum rsMRI Connectivity in Obese



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