Individual Differences in Dietary Self Control in Health and Disease

OECD Workshop “The State of Mind in Economics”

October 31, 2017

Hilke Plassmann

The Problem:
Increasing Obesity Rates In Europe and the World

Source: OECD Report 2017
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

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?
Trade-offs in Dietary Choices

McClure et al. (2004) Science

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

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

Hare et al. (2009) Science

Neuroeconomic Theories of (Dietary) Self-Control
Neuroanatomy in the vmPFC and dIPFC predicts individual differences in self-control ability of dietary decision-making

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Anita Tusche, HSS, California Institute of Technology
Cendri Hutcherson, Department of Psychology, University of Toronto
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)
Dietary Self-Control Task Data Set 1 (N=91)

Consider the healthiness

Consider the taste

Make decisions naturally

5 s RT 0.5 s 3 s – RT + ITI

adapted from Hare et al. J Neuro 2011

Behavioral Results Data Set 1

Beta Estimates Stimulus Value (a.u.)

Schmidt et al. (in prep.)
GM Volume Correlating with Regulatory Success

\[ \text{p < .001 unc.} \]

Schmidt et al. (in prep.)

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

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

Behavioral Results Data Set 2

Regulatory Success = SV(Natural – Distance)

Schmidt et al. (in prep.)
Overview
Out-of-Sample Prediction Approach

Participants of Data Set 1

\[ \text{Regulatory Success} = \beta_{HR*HC} - \beta_{TR*HC} \]

\[ \beta_{\text{vmPFC}} = 6.92 \]
\[ \beta_{\text{dlPFC}} = 6.68 \]

Participants of Data Set 2

\[ \text{Predicted Regulatory Success} = \beta_0 + \beta_{\text{dlPFC}} \text{GM}_{\text{dlPFC}} + \beta_{\text{vmPFC}} \text{GM}_{\text{vmPFC}} + \epsilon \]

Out-of-Sample Prediction Data Set 2

<table>
<thead>
<tr>
<th>Predicted</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>-1.5</td>
<td>-3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

R = 0.35, p = 0.04, Chance R = 0.29

Schmidt et al. (in prep.)
Interim Conclusions

- Individual differences in the anatomy of the vmPFC and dIPFC 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)

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

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Karine Clément, Institute Cardiometabolism (ICAN) & Nutrition, Université Pierre et Marie Curie
Christine Poitou, Institute Cardiometabolism (ICAN) & Nutrition, Université Pierre et Marie Curie
The Interdisciplinary Model of Dietary Self-Control

Decision Neuroscience & Neuroendocrinology & Gut Microbiology

Eating Decisions

Research Question

Decision Neuroscience

Health

Eating goals

Energy balance

Expenditure Intake

Hormones (leptin)

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

![Graphs showing correlation between baseline fasted-state leptin and regulatory success behavior in the dlPFC.](image)

*Schmidt et al. (in prep.)*

*corrected for % Body Fat

**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
Impact of Bariatric Surgery on Delay Discounting

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Liane Schmidt, Brain and Spine Institute (ICM), Sorbonne University & INSERM

Sample Indifference Point Study

<table>
<thead>
<tr>
<th>Group (All Females)</th>
<th>T0 Pre-op</th>
<th>T1 3-month post-op</th>
<th>T2 12-month post-op</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese Patients</td>
<td>72</td>
<td>45</td>
<td>37</td>
</tr>
<tr>
<td>Age: 33.7±1.8, BMI&gt;30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean Controls</td>
<td>39</td>
<td></td>
<td>33</td>
</tr>
<tr>
<td>Age: 38.6±2.5, BMI: 22±0.40</td>
<td></td>
<td></td>
<td>(6 months after)</td>
</tr>
<tr>
<td>Obese controls (no surgery)</td>
<td>29</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Age: 37.6±2.4, BMI: 31.8±0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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?

Indifference Points Differences for Money

Indifference Point

Euros needed to wait 1 week

T0 (Pre-op)  T1 (3-month post-op)  T2 (12-month post-op)

Lean Controls  Obese Patients  Obese Control (T0 SAMPLE)
### Indifference Points Differences for Money

Candies needed to wait 1 week

- **T0 (Pre-op)**
- **T1 (3-month post-op)**
- **T2 (12-month post-op)**

- Lean Controls
- Obese Patients
- Obese Control (T0 SAMPLE)

### Sample Delay Discounting Task

<table>
<thead>
<tr>
<th>Group (All Females)</th>
<th>T0 Pre-op</th>
<th>T1 6-month post-op</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese Patients</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Age: 34.6±1.8, BMI: 44.2±2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean controls</td>
<td>45</td>
<td>34</td>
</tr>
<tr>
<td>Age: 38±13, BMI: 21.7±1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese controls (no surgery)</td>
<td>29</td>
<td>------</td>
</tr>
<tr>
<td>Age: 37.6±2.4, BMI: 31.8±0.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Design for Delay Discounting Task (Money)

<table>
<thead>
<tr>
<th>Immediate condition 36 X</th>
<th>Not now condition 36 X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer</td>
<td>Decision</td>
</tr>
</tbody>
</table>

RT | 0.5 sec | 3 sec – RT + ITI

Design for Delay Discounting Task (Food)

<table>
<thead>
<tr>
<th>Immediate condition 36 X</th>
<th>Not now condition 36 X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer</td>
<td>Decision</td>
</tr>
</tbody>
</table>

RT | 0.5 sec | 3 sec – RT + ITI
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

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

Subjective Value Functions (for Food)

IN 14 DAYS

NOW | T0 | NOW | T6

Subjective Value Functions for Lean, Obese Patient, and Obese Control subjects over time.
Discounting Rates for Food

Discounting Parameter for Food, ASAP Model (Kable & Glimcher)

<table>
<thead>
<tr>
<th></th>
<th>T0 (Pre-op)</th>
<th>T1 (6 months post-op)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean</td>
<td>0.12±0.02</td>
<td>0.08±0.02</td>
</tr>
<tr>
<td>Obese Patient</td>
<td>0.10±0.02</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td>Obese Control (T0 SAMPLE)</td>
<td>0.08±0.02</td>
<td>0.04±0.02</td>
</tr>
</tbody>
</table>

Discounting Rates for Food Correlates With BMI

Discounting Parameter k asap

![Graph showing the correlation between BMI and discounting parameter k asap.](image)

- Lean
- Obese patient
- Obese no patient
- Fitted values

\[ r = 0.18 \]
\[ p = 0.05 \]
Discounting Rates for Money

Money Discounting Parameter $k$ ASAP

<table>
<thead>
<tr>
<th></th>
<th>Lean Control</th>
<th>Obese Patient</th>
<th>Obese Control (T0 SAMPLE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0 (Pre-op)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 (6 months post-op)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correlation Hunger State and Discounting Rates Food

<table>
<thead>
<tr>
<th>Lean Controls</th>
<th>DV: $k$ (food)</th>
<th>Coeff.</th>
<th>t</th>
<th>p</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change in Hunger, T0</td>
<td>0.0012</td>
<td>-0.2000</td>
<td>0.8430</td>
<td>-0.0133, 0.0109</td>
</tr>
<tr>
<td></td>
<td>Change in Hunger, T1</td>
<td>0.0038</td>
<td>0.5600</td>
<td>0.5780</td>
<td>-0.0100, 0.0175</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obese Controls</th>
<th>DV: $k$ (food)</th>
<th>Coeff.</th>
<th>t</th>
<th>p</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change in Hunger, T0</td>
<td>0.0321647</td>
<td>2.36</td>
<td>0.035</td>
<td>0.0027036, 0.0616258</td>
</tr>
<tr>
<td></td>
<td>Change in Hunger, T1</td>
<td>0.019198</td>
<td>1.04</td>
<td>0.318</td>
<td>-0.0209801, -0.059376</td>
</tr>
</tbody>
</table>
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.

General conclusions

- Individual differences in brain anatomy in vmPFC and dIPFC 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.
Impact of Bariatric Surgery on Resting State Connectivity

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Evelyn Medawar, Laboratoire des Neurosciences Cognitives, Ecole Normale Superieure & INSERM U960

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?
**Group Differences vmPFC rsfMRI Connectivity**

<table>
<thead>
<tr>
<th>Obese patients &gt; Lean controls</th>
<th>Lean controls &gt; Obese patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /> vmPFC – IFG &amp; IOFC, dlPFC (p_{FWE} &lt; 0.05)</td>
<td><img src="image2.png" alt="Image 2" /> vmPFC - vStr &amp; dStr</td>
</tr>
</tbody>
</table>

- **T0** before bariatric surgery
- **T6** after bariatric surgery

**Effect of Bariatric Surgery on vmPFC rsMRI Connectivity**

Obese patients(T6 > T0) > Lean controls(T6 > T0)

- ![Image 3](image3.png) \(p_{FWE} < 0.05\)

- svmPFC - ventral striatum rsMRI connectivity across participants

- **Circle** Lean controls
- **Circle** Obese patients

- **X-axis** Participants
- **Y-axis** Connectivity estimate (a.u.)
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

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
Thank you!

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ICAN

SORBONNE UNIVERSITÉS

Agence Nationale de la Recherche

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

Weight loss (kg)

Connectivity estimate (a.u.)

R=0.4881
95% CI chance correlation = [-0.47 – 0.47]
P=0.09 (two-tailed)