Consumer Neuroscience Research beyond fMRI: The Importance of Multi-Method Approaches for understanding Goal Value Computations

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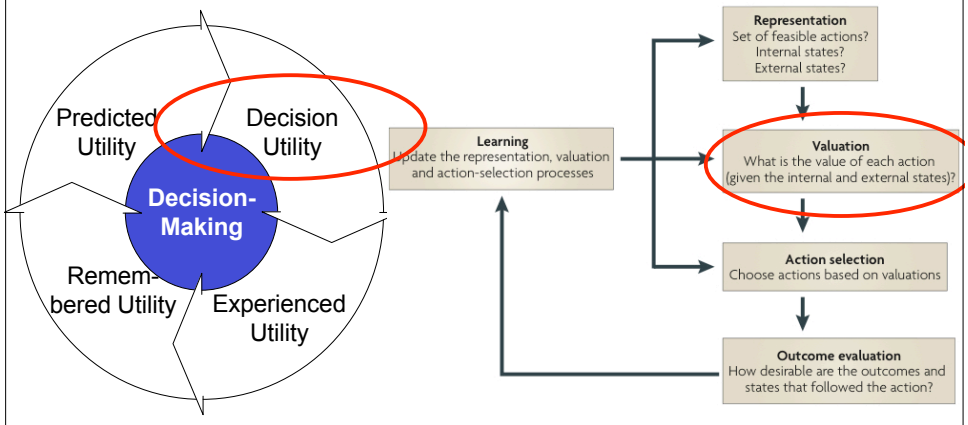
Decision-Making related Value Signals

Behavioral Decision-Making

Neuroeconomics



Kahneman et al. 1997

Rangel et al. 2008

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Goal Values and Why They Matter

Ducati Monster: $9,000

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Big Picture Questions & Agenda

- Is there a specific neural system that tracks GV computations (study **1** of today's talk)?
- *If yes*, can we change behavioral measures of revealed preferences by manipulating brain activity in that neural system? (study **2** of today's talk)
- *If yes*, can we track down the specific role and contribution of different brain regions in this neural system (study **3** and some more in progress)?
- *If yes*, do different contexts modulate activity in the neural network encoding GV's? Or do they affect GV through other mental mechanisms (in progress)?

➔Relevant to understand how and why context effects might bias 'stable' economic preferences

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H. Plassmann, J. O'Doherty, A. Rangel (2007), "Orbitofrontal Cortex encodes Willingness to Pay in Everyday Economic Transactions", *Journal of Neuroscience*, 27(37), 9984-8.

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Question & Background

- *Question:*

  Is there a specific neural system that tracks appetitive GV computations?

- *Background:*
  - Findings in the neuroscientific literature reveal that medial parts of the orbitofrontal cortex (OFC) are involved in representation of economic value:
    - Monkey electrophysiology studies of binary choice found that medial parts of the OFC encode the non-relative value of options for choice (Padoa-Schioppa and Assad, 2006, Padoa-Schioppa and Assad, 2008)
    - fMRI studies found that mOFC activity during a hypothetical liking rating task increased with the reported attractiveness of the stimuli (e.g. Erk et. al., 2002, Arana et al. 2003)

  ➔A priori hypothesis: the higher the appetitive GV the higher activity changes in mOFC

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Study Design

- Subjects:
  19 Caltech students (3f/16m), 18 - 46 years, screened for liking & occasionally eating junk food
- Stimuli:
  three $1 bills to bid on 50 different junk food items (sweet and salty)
- Task:
  - Free bid trials: bid either either $0, $1, $2, or $3 on food items according to subjective valuation (WTP)
  - Forced bid trials: instructed to bid either $0, $1, $2, or $3 on the same food items
  - Becker-Degroot-Marschak auction (BDM, Becker et al. 1964) to ensure that subjects bid their 'true' GV
- Measures:
  - Bids as measure for appetitive GV
  - Functional magnetic resonance imaging signal changes as neural correlate of GV computation

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Becker-Degroot-Marschak (BDM) auction

- Important to have a real time, incentive compatible, reliable measure of appetitive GV to correlate with neural activity changes
- BDM auction rules:
  - random trial number n drawn from an urn
  - random $ amount p drawn from urn
  - if $bid_n > p$, get food item and pay $p
  - if $bid_n \leq p$, don't get food item and pay $0

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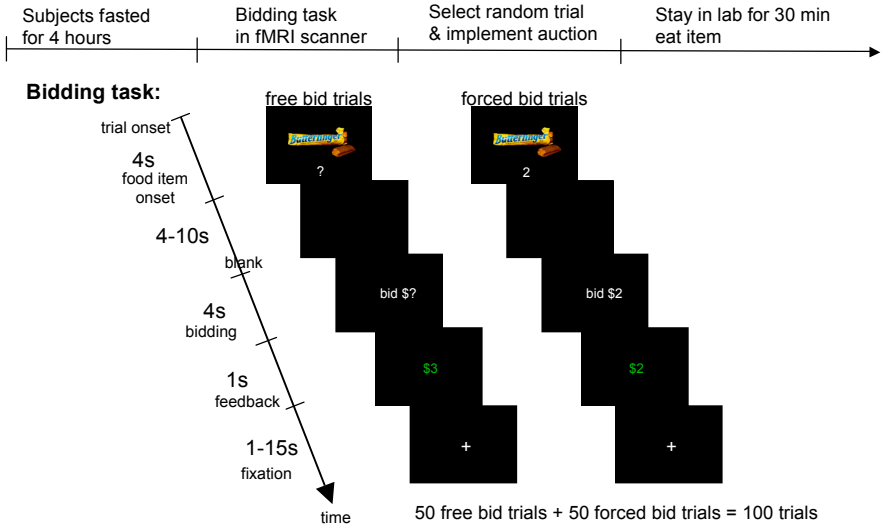
Functional Magnetic Resonance Imaging (fMRI) task



50 free bid trials + 50 forced bid trials = 100 trials

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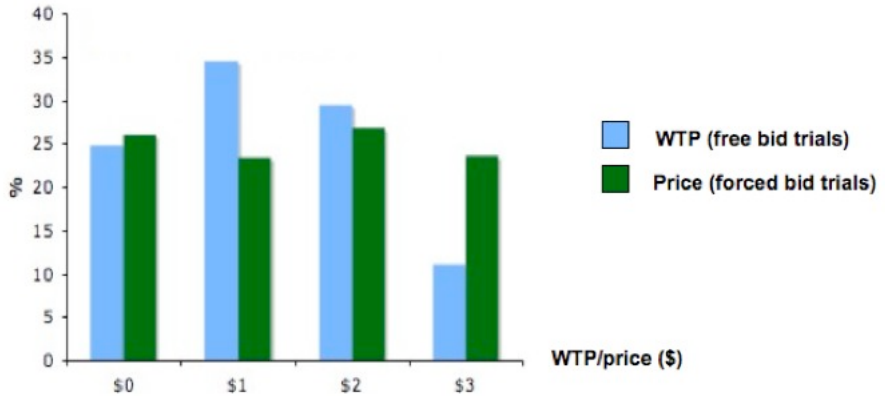
Bid Distribution



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Statistical Model fMRI Data Analysis

Step 1: Fit individual GLMs with following independent variables:

- $I_{\text{free bid}} * I_{\text{@item presentation}}$
- $I_{\text{free bid}} * I_{\text{@item presentation}} * \text{GV}$
- $I_{\text{free bid}} * I_{\text{@response}}$
- $I_{\text{free bid}} * I_{\text{@response}} * \text{GV}$
- $I_{\text{forced bid}} * I_{\text{@item presentation}}$
- $I_{\text{forced bid}} * I_{\text{@item presentation}} * \text{GV (from free bid trials)}$
- $I_{\text{forced bid}} * I_{\text{@item presentation}} * \text{Price (from forced bid trials)}$
- $I_{\text{forced bid}} * I_{\text{@response}}$
- $I_{\text{forced bid}} * I_{\text{@response}} * \text{GV (from free bid trials)}$
- 2 regressors of no interest
- 6 motion regressors
- sessions constants

Step II: Estimate group models for contrasts of interest using Random Effects Models

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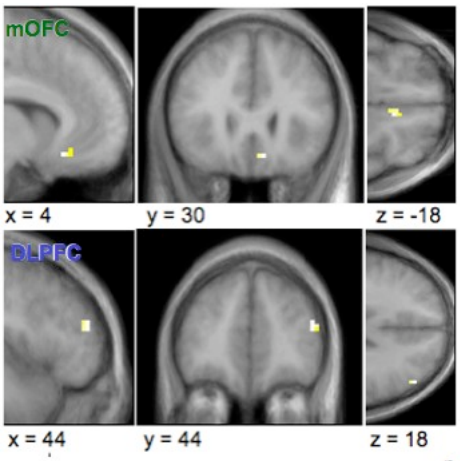
Areas Increased Activity Modulated by GV (Free - Forced Bid Trials)



p < 0.001 (unc.), 5 voxel

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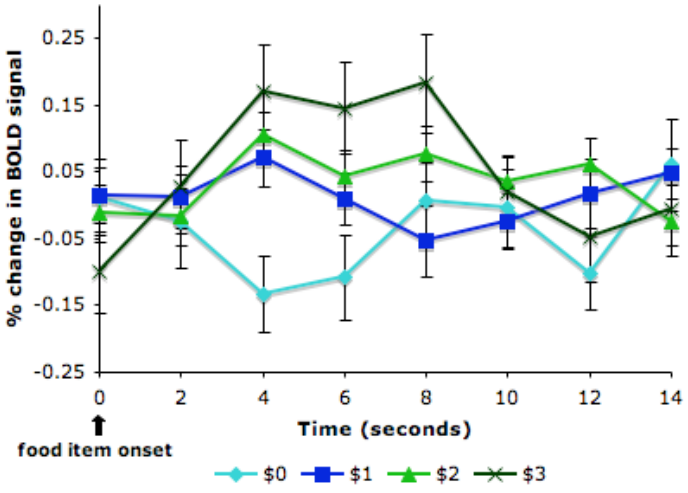
Time Courses fMRI Signal in mOFC by GV in Free Bid Trials



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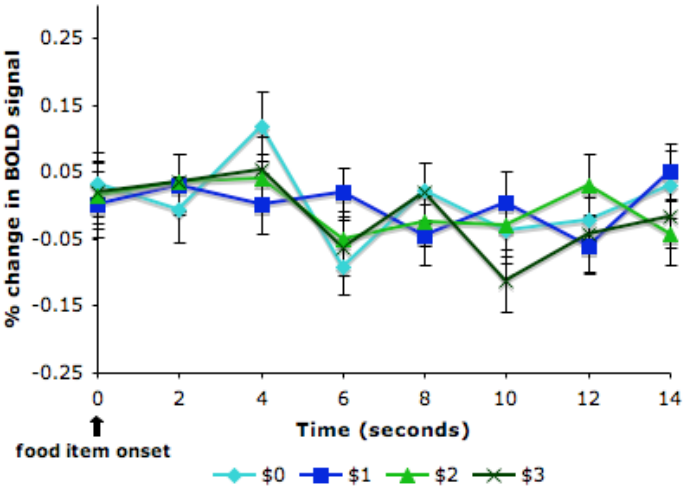
Time Courses fMRI Signal in mOFC by GV in Forced Bid Trials



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Conclusion

GV computation correlate with activity changes in the medial orbitofrontal cortex (mOFC) and the dorsolateral prefrontal cortex (DLPFC)

- In these brain areas a variety of other input variables important for decision-making are integrated into a single representation of appetitive GVs
- Decision-making biases might work either through a modulation of these areas or connected areas
- Specific contributions of DLPFC and mOFC in computing GV's?

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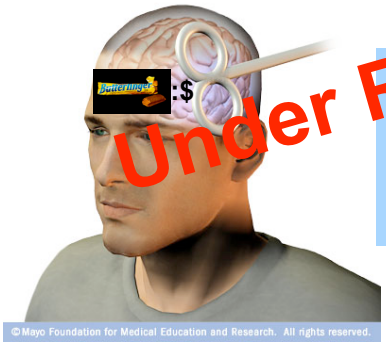

Under Review!!!!

M. Camus, N. Halelamien, H. Plassmann, S. Shimojo, J. O'Doherty, C. Camerer, A. Rangel (under review), "rTMS over the right dorsolateral prefrontal cortex decreases goal values during decision-making"

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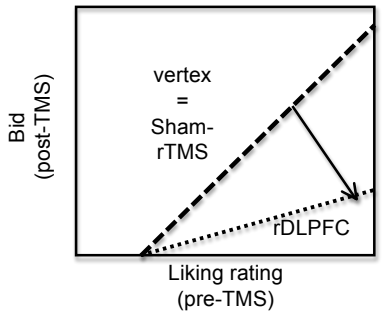
Question & Background

- *Question:*

  Does DLPFC play a causal role for GV computations and how does it interact with activity changes in mOFC?

- *Prediction:*

  Application of inhibitory TMS in rDLPFC as compared to active and inactive sham will decrease behavioral measure of GV



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Study Design

- Subjects: 56 Caltech students, 30 males, aged between 19-26 years, Between-Subjects Design:
  - Subject Group 1 receives rTMS on right DLPFC (N=14)
  - Subject Group 2 receives active sham rTMS on vertex (N=14)
  - Subject Group 3 receives rTMS on right DLPFC (N=14)
  - Subject Group 4 receives inactive sham on right DLPFC (N=14)
- Stimuli: three $1 bills to bid on 50 different junk food items (sweet and salty)
- Task:
  - Pre-TMS: ratings of how much they would enjoy eating the food items, visual analog scale
  - Post-TMS: bid either either $0, $1, $2, or $3 on food items according to subjective valuation (GV)
  - Becker-Degroot-Marschak auction (BDM, Becker et al. 1964) was implemented to ensure that subjects bid their 'true' GV

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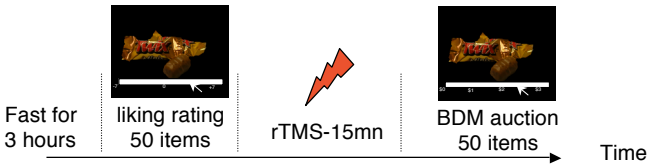
rTMS Task



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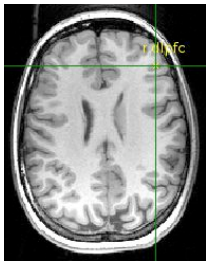
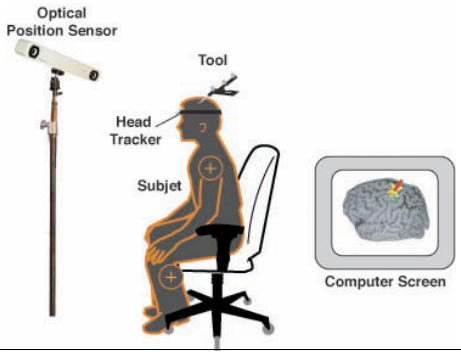
Target Localization

- Based on study 1 we targeted the rDLPFC, active sham was applied to vertex, and inactive sham to rDLPFC
- Peak coordinates of group level activation were projected on individual anatomy (inversed wrapping in MNI space)
- Individual position of target area was determined using image-guided frameless neuro-navigation system





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rTMS Set-Up

- Magstim-200 Stimulator (max 2.0 T)
- Figure-of-eight coil (7cm diameter)
- Coil positioned tangentially to scalp, in antero-medial direction, 45° angle to mid-sagittal plan axis
- repetitive TMS train (single pulse, 1Hz, 900 pulses = 15 min), 50% stimulation intensity

➔ suppression of excitability in target region for ~ 15 min

- for inactive sham stimulation same coil w/ metal plate to shield magnetic field while inducing same noise and sensation will be used

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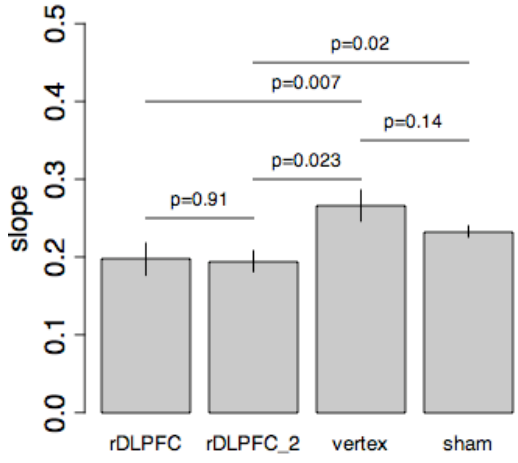
Results



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Study Design

- Subjects:
  - 15 Caltech students, 8 males, aged between 19-25 years,
  - Between-Subjects Design:
    - Subject Group 1 receives rTMS on right DLPFC (N=7)
    - Subject Group 2 receives rTMS on vertex (N=8, active sham)
- Stimuli:
  50 different junk food items (sweet and salty)
- Task:
  - Pre-TMS: Guess the caloric content (1=light to 6=heavy)
  - Post-TMS: Guess the caloric content (100 cal to 600+ cal)

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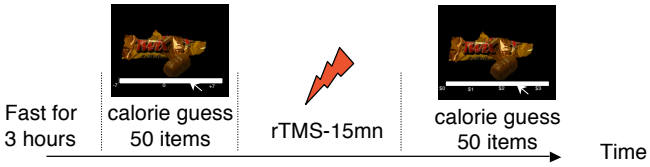
rTMS Task



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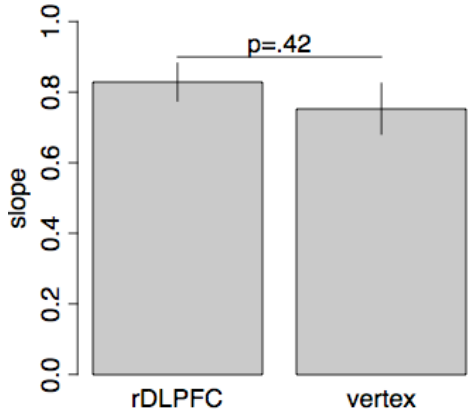
Results



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Conclusion & Next Steps

Activity changes in the right dorsolateral prefrontal cortex (DLPFC) play a crucial role for behavioral measures of GV's, but not for other non-valuation numerical computations

- ➔ How does the application of rTMS in right DLPFC vs. sham affect the neural representation of GV computations?
- ➔ What is the functional connectivity between the mOFC and DLPFC during GV computations?
- ➔ Given these results what is the exact role of mOFC activations for GV computations?
- ➔ Is that the first step towards understanding why context effects (contexts that engage DLPFC activity such as executive control, cognitive load) and individual differences (different cognitive capacities in DLPFC?) modulate 'stable' economic preferences?

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Preliminary!!!!

J. Plassmann, A. Rangel, Antoine Bechara "Goal Value Computations in Lesion Patients"

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Question & Design

- *Question:*

  Do patients with lesions in DLPFC and vmPFC as compared to control show differences in value computations and decision-making consistency?

- *Study:*

  DLPFC (n=6), vmPFC (n=6) and lesion control (n=5) patients engaged in a goal valuation and subsequent purchasing task

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Big Picture Conclusion

To understand the neuropsychological processes underlying decision-making in decision neuroscience we need to look at the same phenomenon using different methods and from different perspectives!

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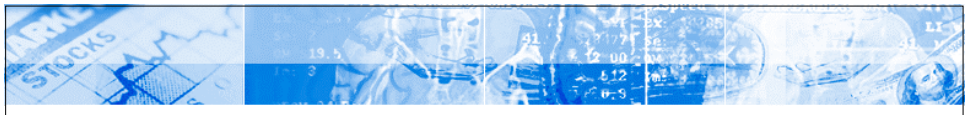

Thanks to ….

… my co-authors Antonio Rangel, Antoine Bechara, John O'Doherty, Mickael Camus, Cendri Hutcherson, Colin Camerer, Neil Halelamien & Shin Shimojo

… YOU for your attention!

BACK-UP SLIDES

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