Neural Dynamics of Decision-Making in a Financial Trading Task

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Introduction

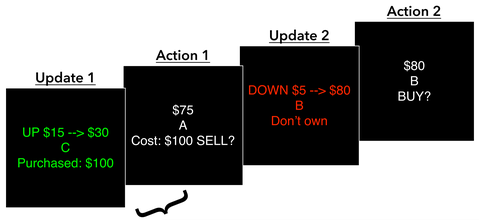
- **Disposition effect**
  - *Sell winning stocks* more often than losing stocks
  - Deviation from optimal financial decision-making
- Realization Utility theory
  - Pleasure from sale relative to purchase cost (**capital gain**)
  - It hurts to sell at a loss, but "locking in" a gain is satisfying
- **When** and **how** does financial decision-making occur in the brain?
  - Value signals related to capital gain
  - Neural correlates of optimal vs. suboptimal trading choice

Predictions

- Participants will exhibit behavioral disposition effect (DE)
- Capital gain (CG) at sell decision correlates with neural value signal
  - Ventromedial prefrontal cortex (vmPFC)
  - From ~400 ms after stimulus onset
  - Neural sensitivity to CG associated with selling "winners"
- Optimal choice requires overcoming realization utility bias
  - Analogous to regulating behavioral/cognitive conflict
  - Anterior cingulate cortex (ACC)

Methods

- N = 60
- Investing in stock market with stocks A, B, C
  - Update period: Price change
  - Action period: Buy or sell decision

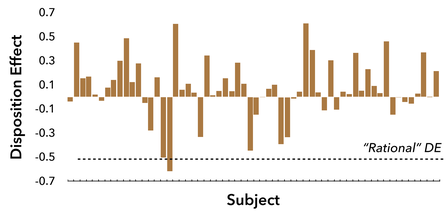


Trial structure			
Update *2 s*	Prep (Fixation) *1-2 s*	Action *RT (max 3 s)*	ITI (Fixation) *3 * RT*

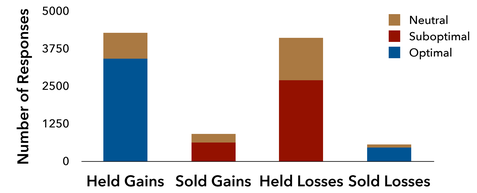
- Procedure
  - 128-channel EEG
  - Could only hold 0 or 1 units of each stock
  - Informed of stock market properties at start of experiment
    - Good state: *p*(up) = 0.7, *p*(down) = 0.3
    - Bad state: *p*(up) = 0.3, *p*(down) = 0.7
    - 20% chance of changing from good to bad state or vice versa
  - Payoff at end of experiment based on stock holdings and sales

Behavioral Results

$$Disposition\ Effect = \left(\frac{realized\ gains}{realized\ gains + paper\ gains}\right) - \left(\frac{realized\ losses}{realized\ losses + paper\ losses}\right)$$



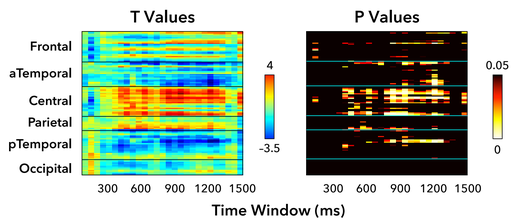
- Average DE = 0.07 significantly greater than zero (p = 0.04)
- Suboptimal behavior compared to "rational" Bayesian agent



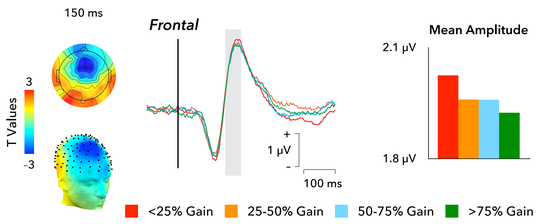
ERP Results: Capital Gain

- EEG data time-locked to Action period onset
- Subject-level linear regression:

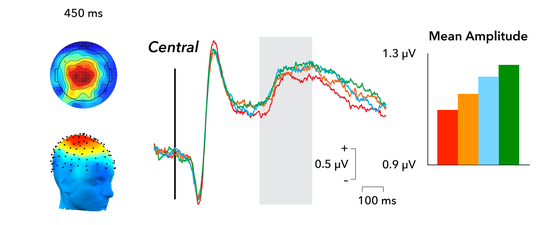
Capital Gain: $y_{sensor,time} = \beta_0 + \beta_1 CapitalGain + \beta_2 BayesianPosterior + \varepsilon$



150 to 200 ms post-stimulus

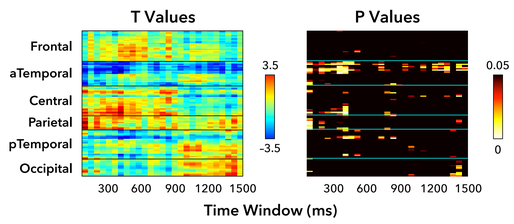


400 to 650 ms post-stimulus

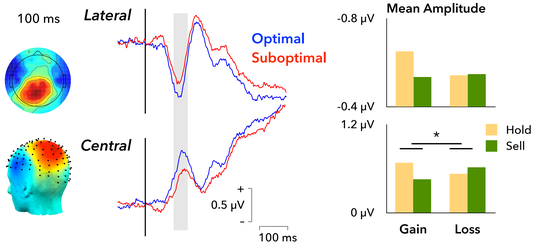


ERP Results: Choice Optimality

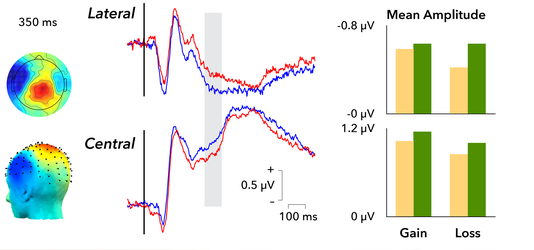
- EEG data time-locked to Action period onset
- Paired t test on optimal vs. suboptimal choice
  - Optimal: hold if $b_i(good) > 0.5$, sell if $b_i(good) < 0.5$



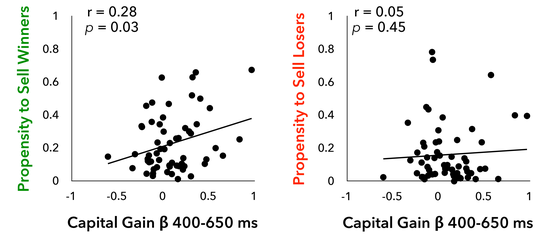
100 to 150 ms post-stimulus



350 to 450 ms post-stimulus



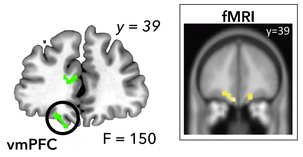
Correlating ERP with Behavior



ERP Source Reconstruction

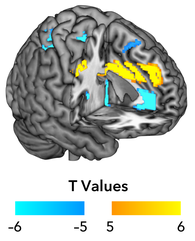
- Distributed source reconstruction in SPM8 (group inversion)

Capital Gain, 400-650 ms post-stimulus



- Linear ordering of CG quartiles
- Localized to vmPFC
- Consistent with fMRI (Frydman et al., 2014)

Optimal vs. Suboptimal, 100-150 ms post-stimulus



- **Optimal > Suboptimal**
  - Left dorsal ACC
  - Bilateral precentral gyrus
  - Left anterior insula
- **Suboptimal > Optimal**
  - Genual ACC
  - Right anterior insula
  - Bilateral parietal lobe

Conclusions

- **Disposition effect exists despite being financially suboptimal**
- **Capital gain at sell decision correlates with ERP value signal**
  - Emerges 400-650 ms after stimulus onset
  - Localized to vmPFC
  - Neural CG signal correlates with propensity to sell winners
- **Optimal choice requires overcoming realization utility bias**
  - Neural signals as early as 100-150 ms after stimulus onset
  - Localized to ACC

➡ ERP provides insight into time course of disposition effect

➡ Supports role of neural value signals in realization utility bias