Neural Dynamics of Decision-Making in a Financial Trading Task

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Introduction

- **Disposition effect** (DE)
  - *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* does realization utility emerge during financial choice?
  - *How* do neural signals correlate with individual differences in financial decision-making?

Background

- fMRI correlates of sensitivity to capital gain (CG)
  - Ventromedial prefrontal cortex (vmPFC)
  - Neural sensitivity to gain correlated with selling "winners"
- ERP correlates of sensitivity to losses
  - Frontal midline theta, gamma activity (4-8, 30-80 Hz)
  - Associated with attention, cognitive control
- <u>Predictions</u>: ERP of financial decision-making
  - CG-correlated activity 400-650 ms post-stimulus
    - Localized to vmPFC
    - Correlated with increased tendency to sell gains
  - Early frontal midline sensitivity to loss
    - May reflect individual differences in attention

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	Prep (Fixation)	Action	ITI (Fixation)
2 s	1-2 s	RT (max 3 s)	3 * RT
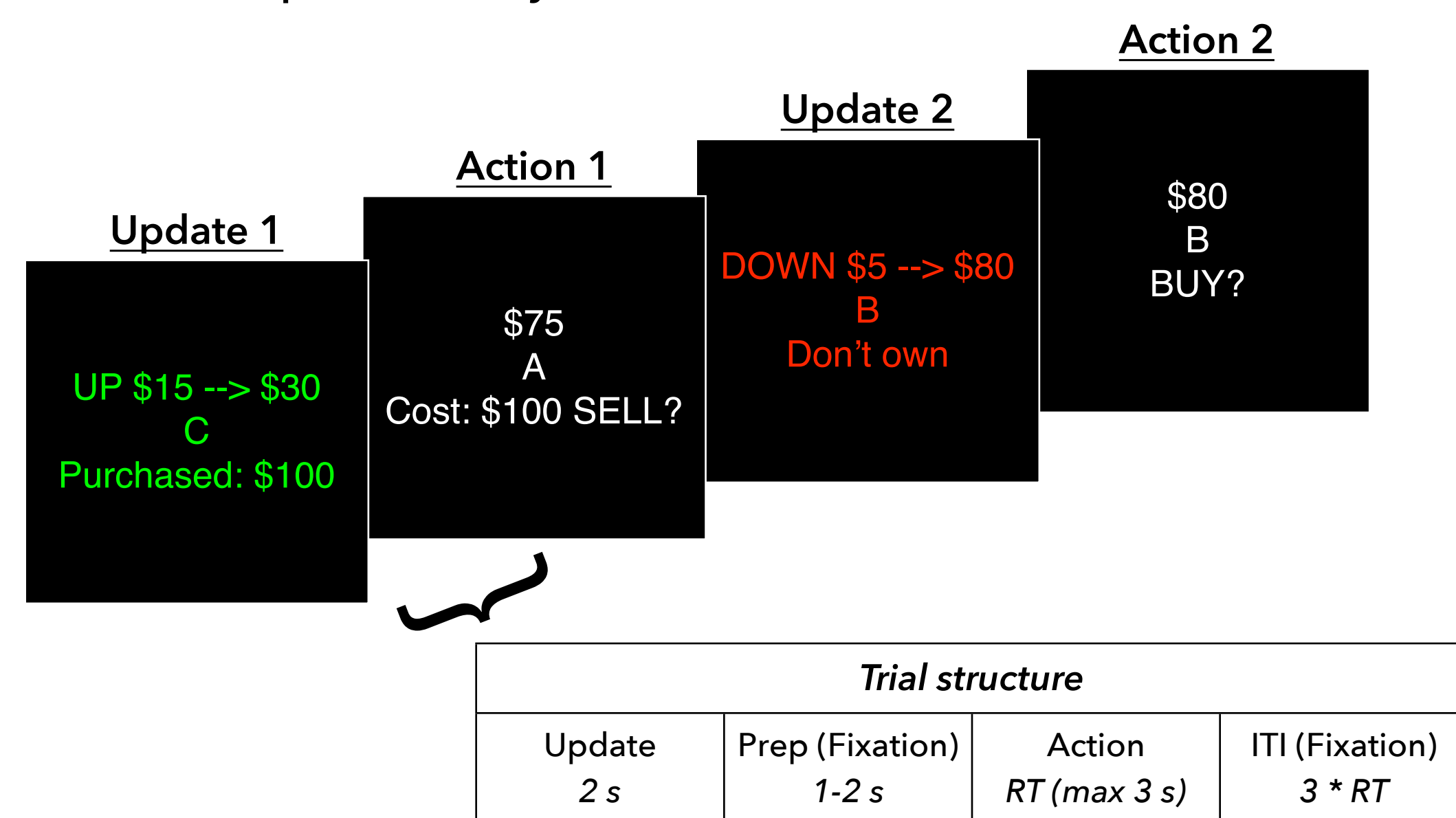
- Procedure
  - 128-channel EEG
  - Could only hold 0 or 1 units of each stock
  - Informed of stock market properties at start of experiment
    - Good state: $p(up) = 0.7$, $p(down) = 0.3$
    - Bad state: $p(up) = 0.3$, $p(down) = 0.7$
    - 20% chance of changing from good to bad state or vice versa
  - Payoff after experiment based on stock holdings and sales

Behavioral Results

$$Disposition\ Effect = \left(\frac{realized\ gains}{realized\ gains + paper\ gains}\right) - \left(\frac{realized\ losses}{realized\ losses + paper\ losses}\right)$$
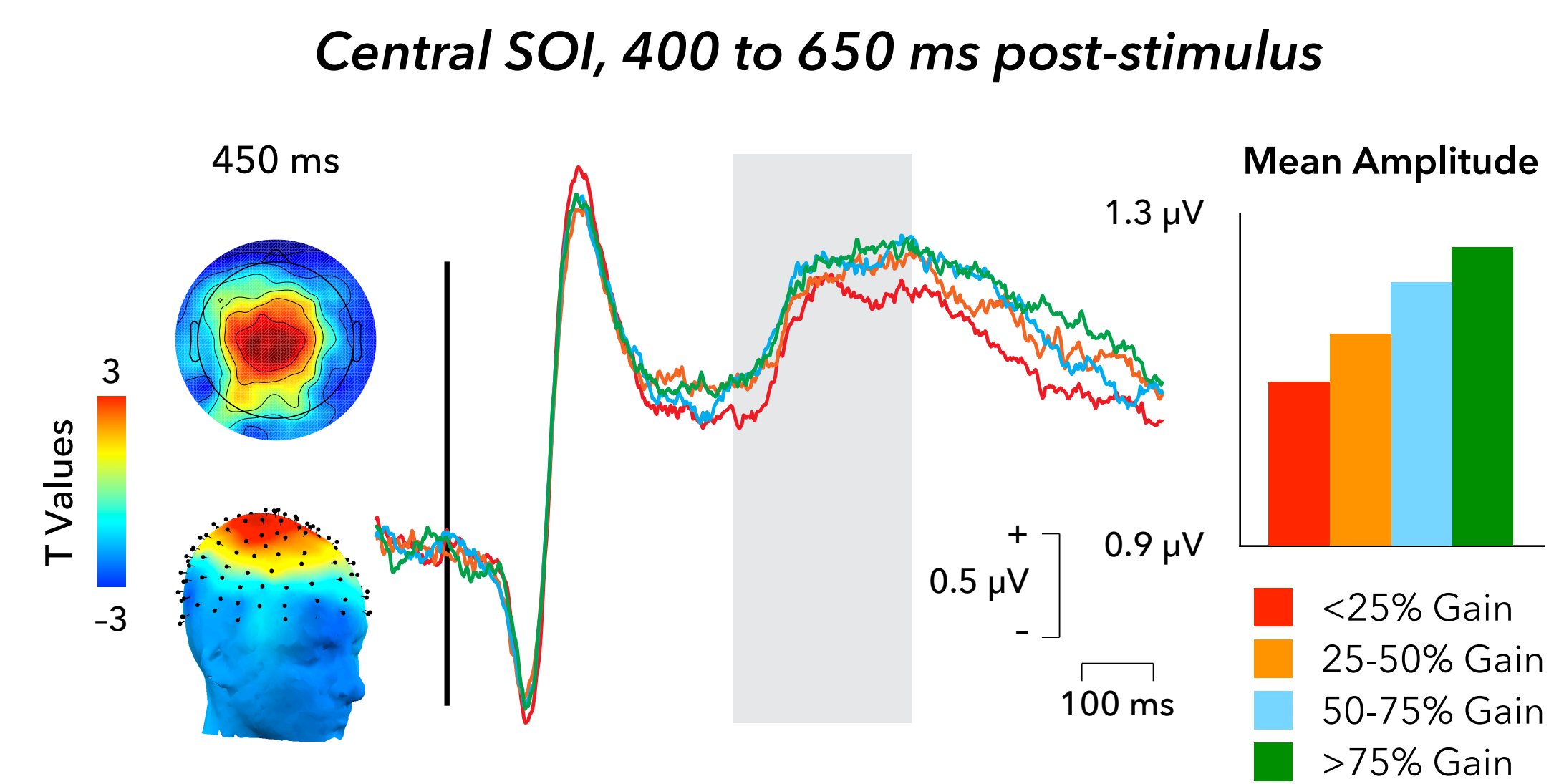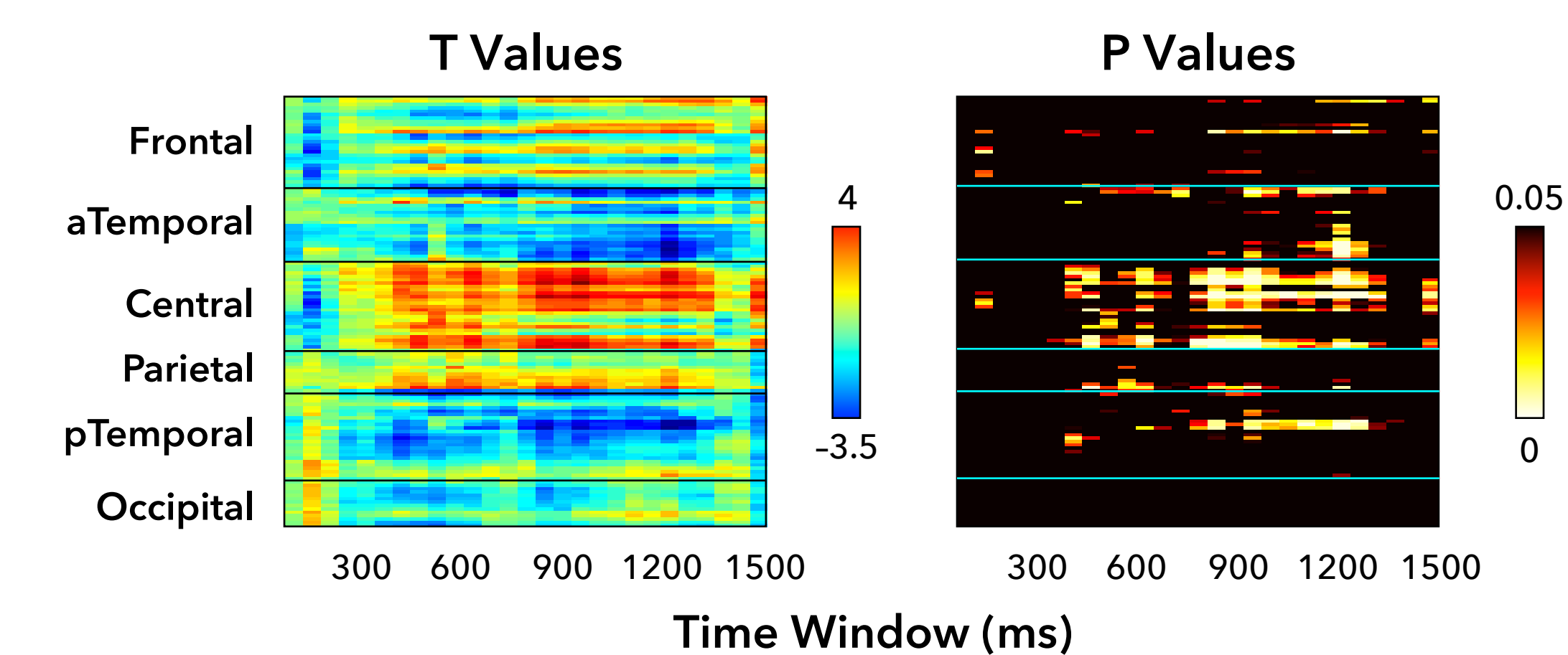
- "Rational" Bayesian DE = –0.55
- Average observed DE = 0.07 is significantly greater ($p < 10^{-26}$)
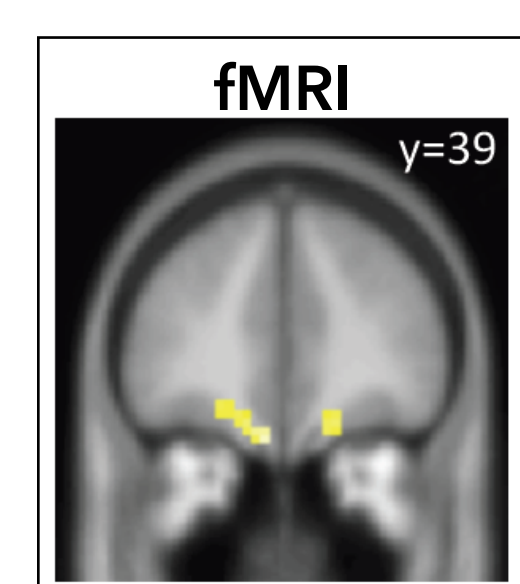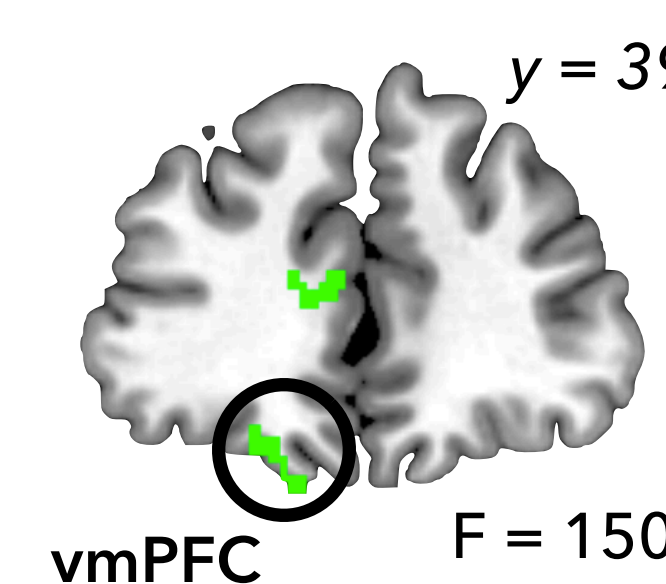 - Suboptimal decisions to sell gains and hold losses
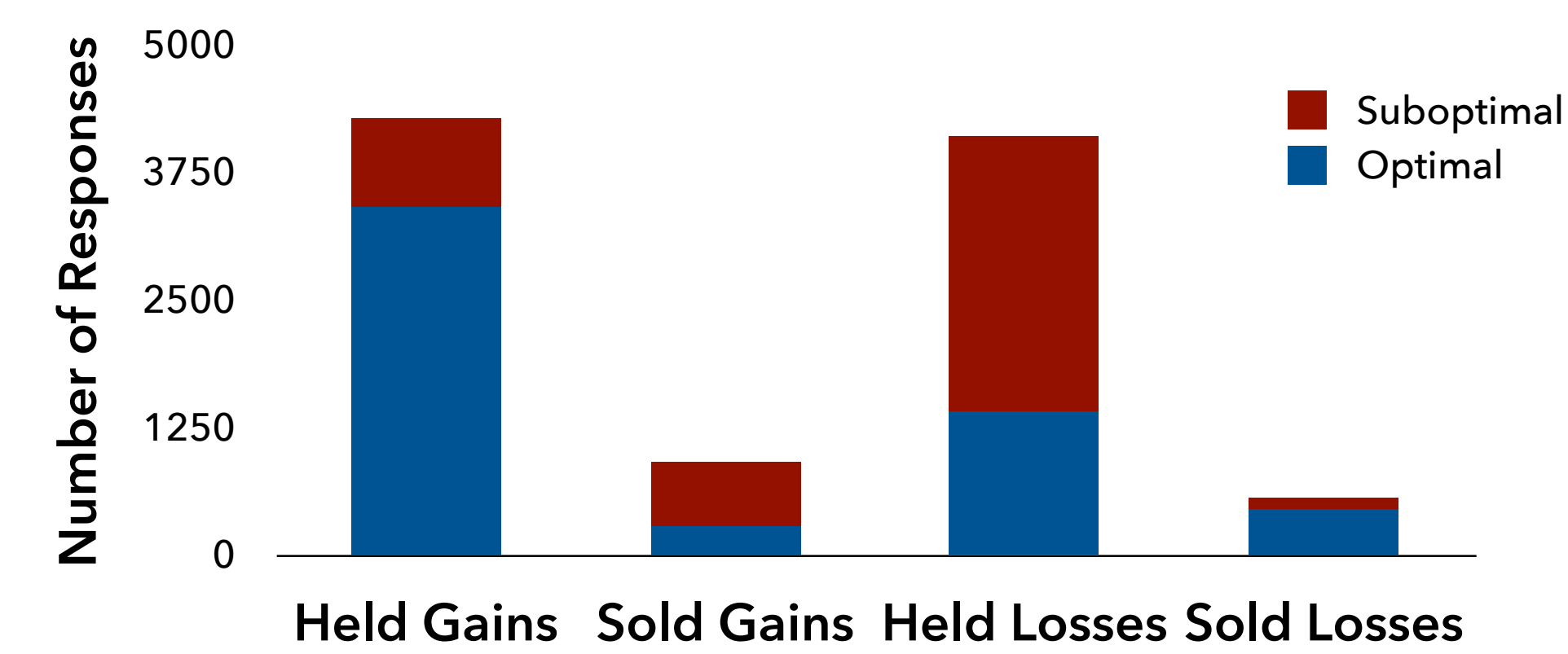
Results: Sensitivity to Capital Gain

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

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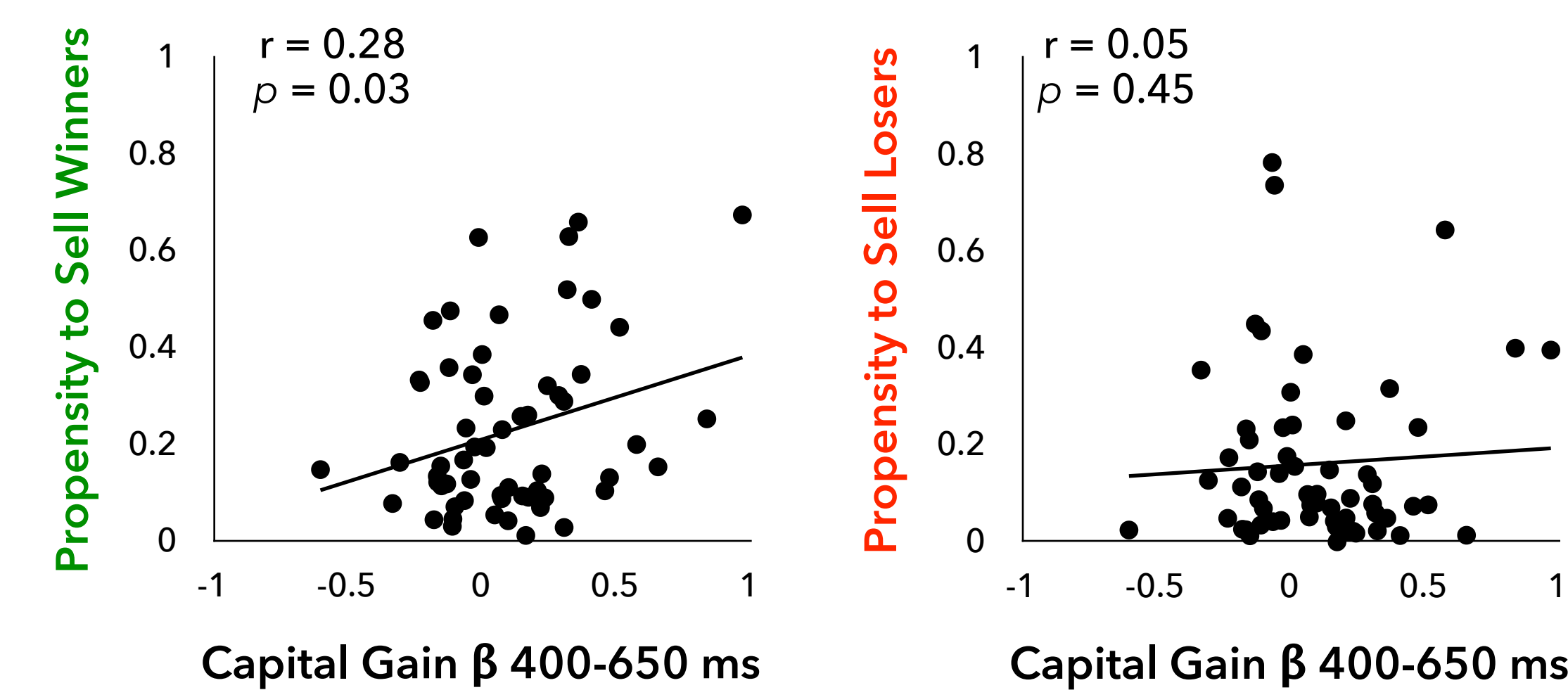

Central SOI, 400 to 650 ms post-stimulus

- Distributed source reconstruction in SPM8 (group inversion)

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

Correlating ERP with Selling Gains

- Neural CG β significantly correlated with selling "winners"
 - Significant for regression on gains only (r = 0.25, $p = 0.05$)

## Results: Sensitivity to Capital Loss

- Early CG response from 150 to 200 ms post-stimulus
  - Greatest response to smallest capital gain
  - Relation to frontal midline theta (FMθ)?

Frontal SOI, 150 to 200 ms post-stimulus
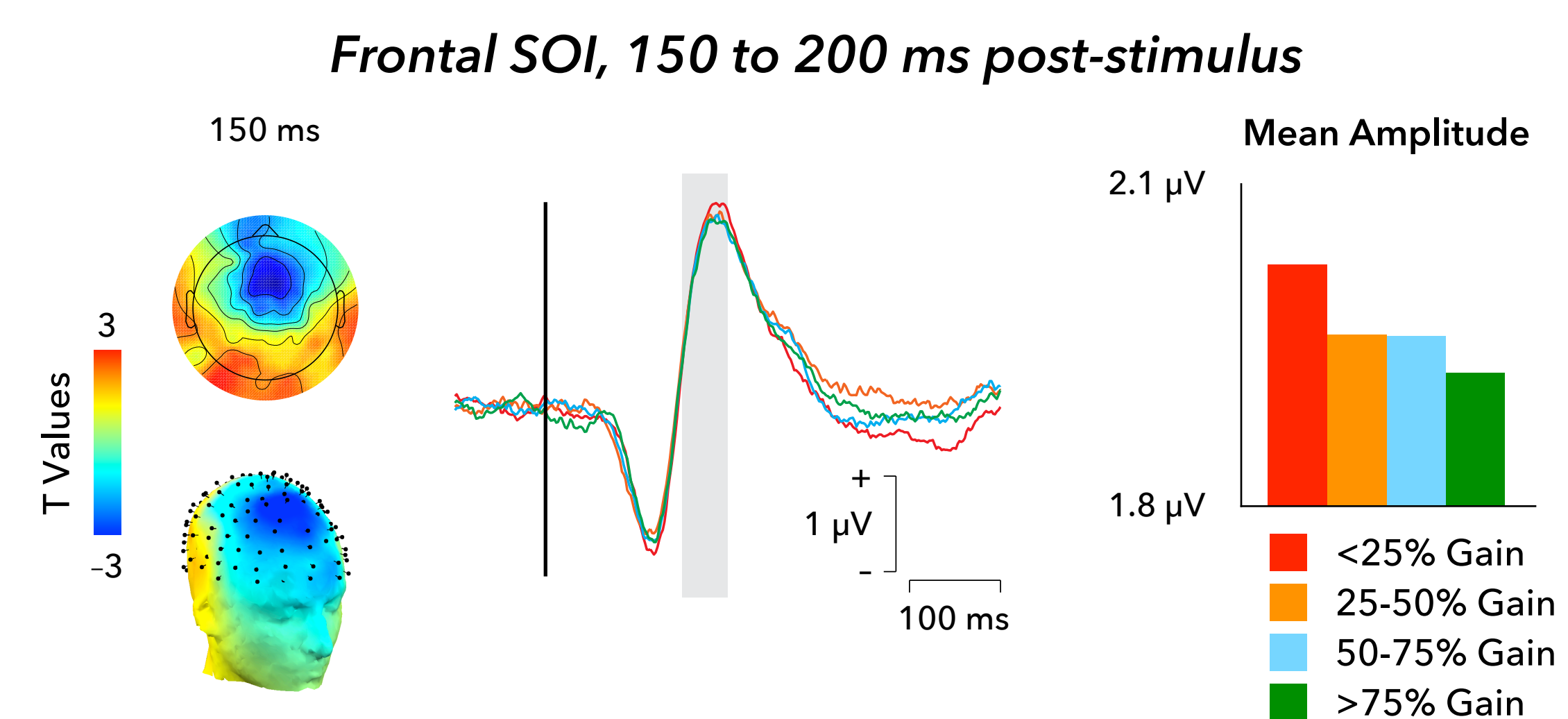
- Event-related spectral perturbation (ERSP)
  - Independent component clustering in EEGLAB (N = 58)
  - Highest vs. lowest CG quartiles (High vs. Low Gain)
  - Median split on DE (High vs. Low DE)

Component Loading, Frontal Midline Sensors


Gain x Group Interaction: $p < 0.05$
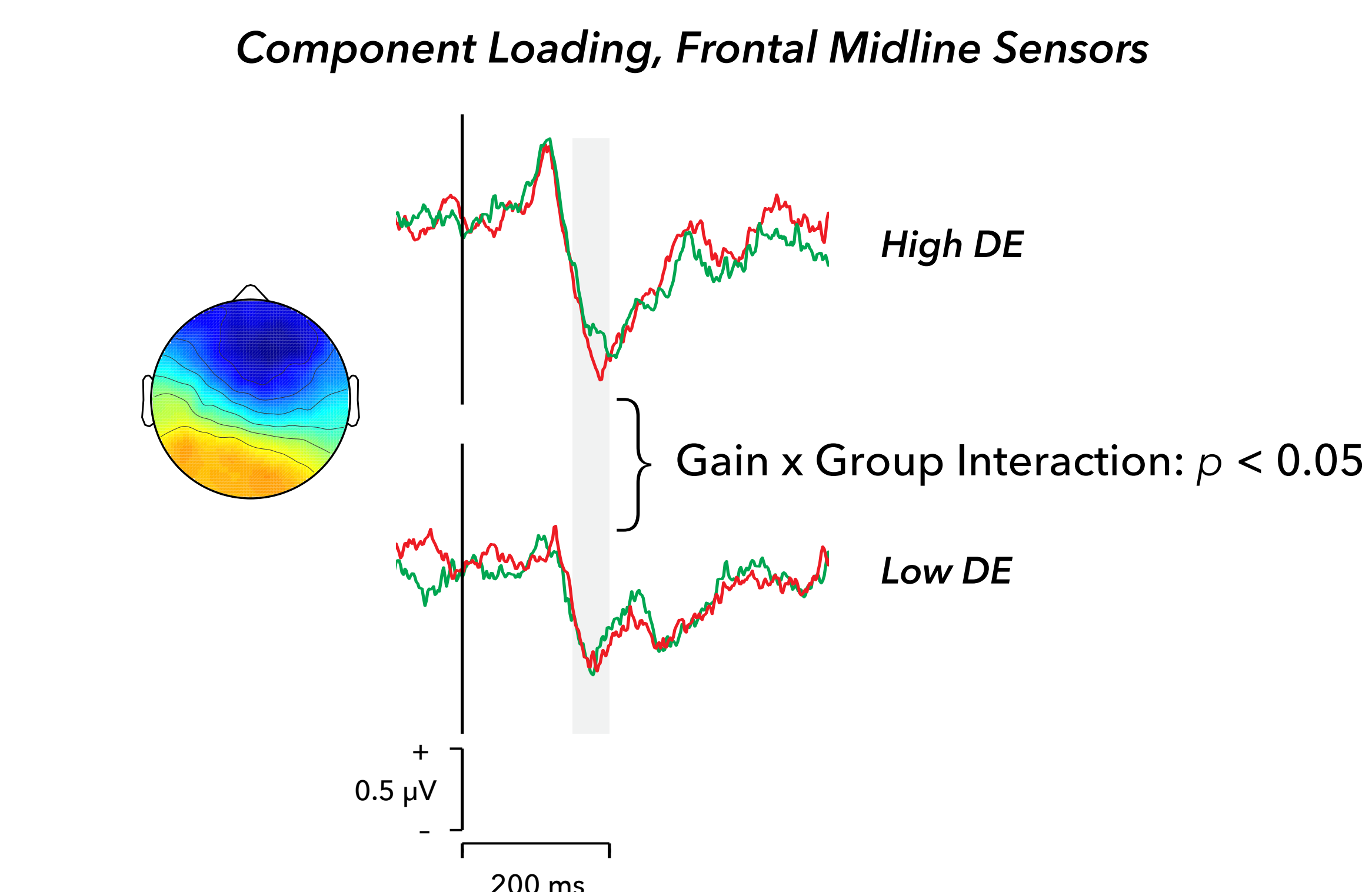
Time-Frequency: Gain vs. Loss
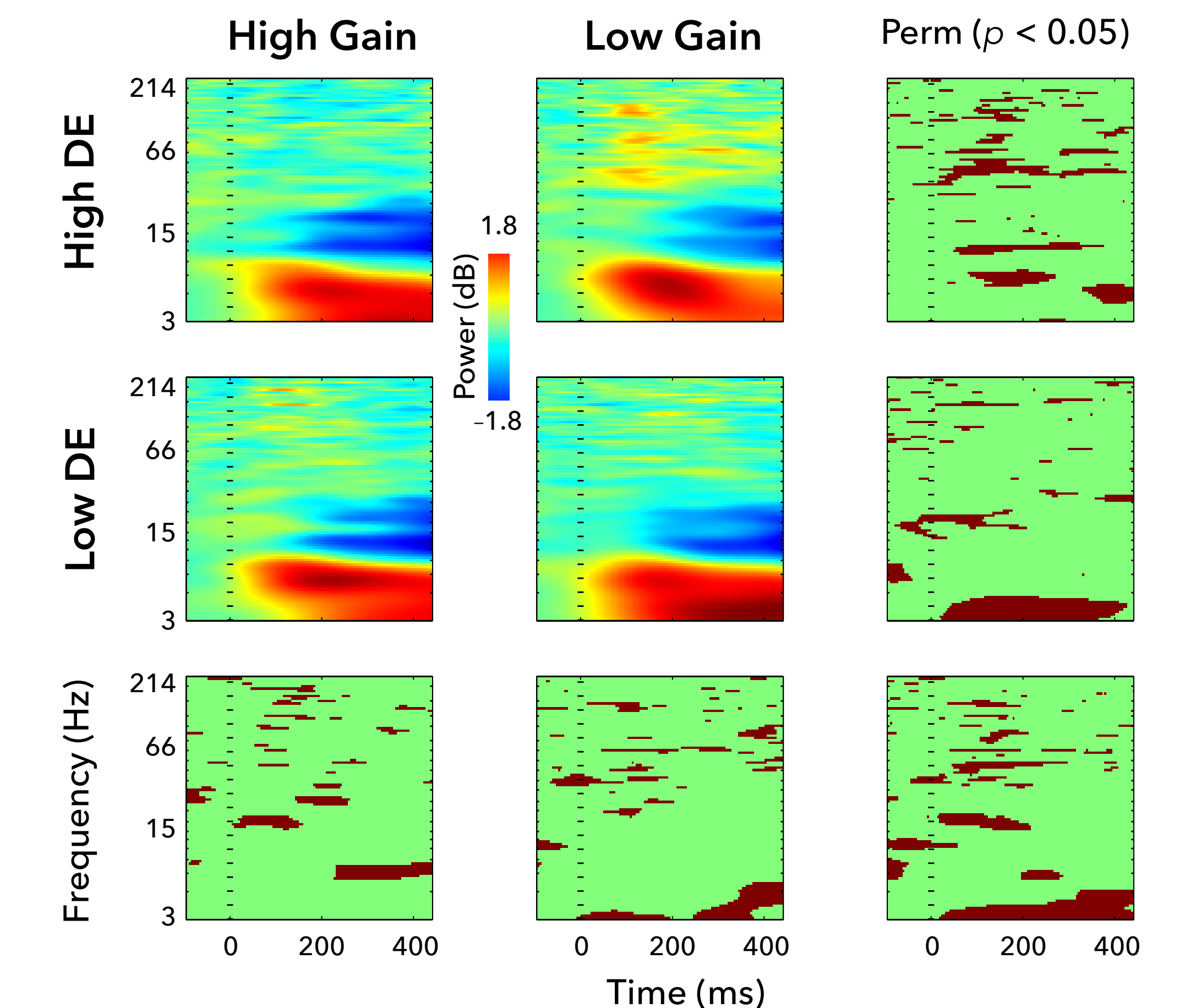
- Condition x Group interaction in theta and gamma range
  - Differences in early attention may affect optimal choice

Early Effects on Optimal Choice

- Paired t test on optimal vs. suboptimal choice, High v. Low DE
  - Optimal: Held gains and sold losses
- P1 response (~100 ms) known to be modulated by attention
  - Significant interaction of group x choice optimality

Average SOI, 100 to 150 ms post-stimulus
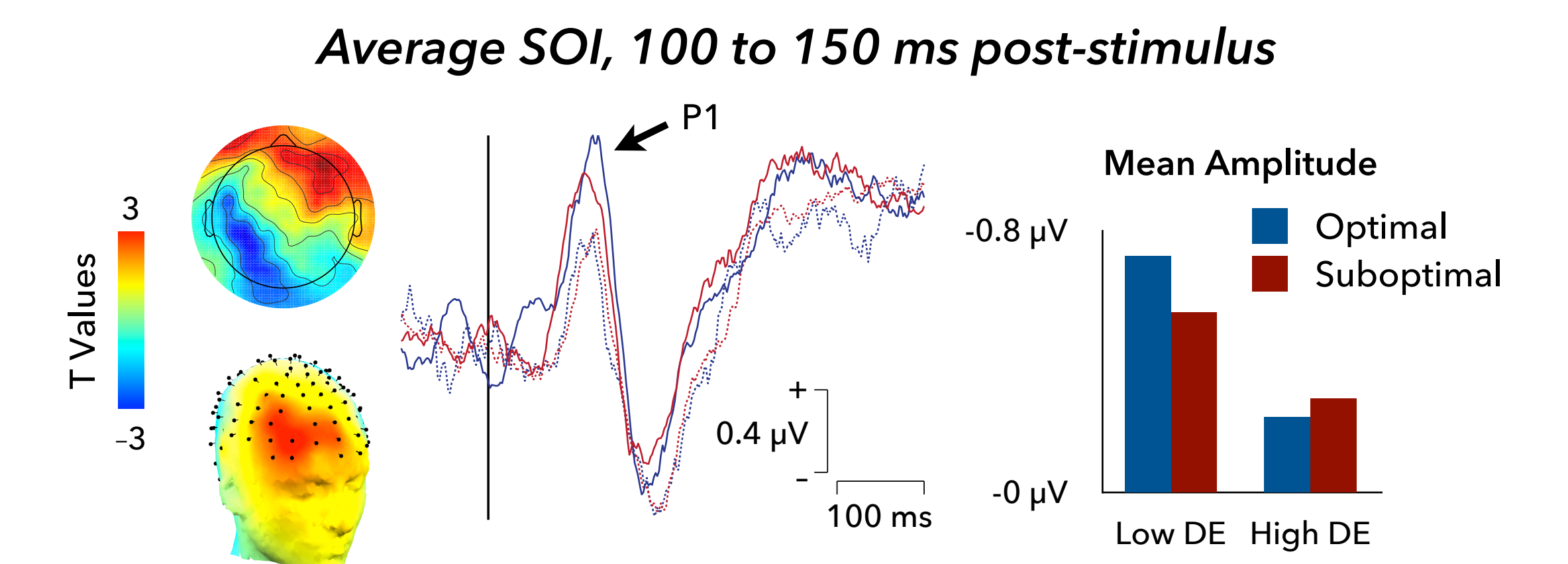
Conclusions

- **Neural correlates of sensitivity to capital gain**
  - Localized to vmPFC 400-650 ms after stimulus onset
  - Correlated with propensity to sell winning stocks
- **Neural correlates of sensitivity to capital loss**
  - Frontal midline sensors 150-200 ms post-stimulus
  - Increased gamma activity to loss in High DE group
  - May reflect attentional differences starting from ~100 ms

➡ ERP provides insight into time course of disposition effect
➡ Different neural mechanisms may underlie sensitivity to capital gain and capital loss in financial decision-making