Cortical normalization predicts stochastic choice in value-guided decision-making

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Introduction

- Valuation and preference should be independent of other available alternatives (independence of irrelevant alternatives, IIA)
- Animals and humans show significant context-dependence in preference and choice behavior
- Rational choice theories cannot explain context-dependent choice

What is the underlying neural basis for behavioral violations of rationality?

Background

Context-dependent valuation in area LIP

- Computing value in the presence of distractors
- Heeger 1992
- Iyengar et al. 2004
- Divisive normalization mediates relative value

Simulation results 1

Example IIA violation: distractor value

- IIA examined in trinary choice as a function of varying distractor V3
- Key measure: relative choice probability \( P(1) : P(2) \)
- Divisive normalization parameters fixed (\( \beta = 100, \theta = 0, \sigma^2_V = 0 \)) and noise parameters varied (\( \sigma^2_H = 10 \))

Example set size effect

- Paradox of choice examined as a function of distractor number \( N \)
- Key measure: relative choice probability \( P(1) : P(2) \)
- Divisive normalization parameters fixed and noise parameters varied

Simulation results 2

Effect of divisive gain control

- Mean firing rates (\( \mu \)) determined by divisive normalized value coding
- Noise implemented in two ways:
  1) variable noise: \( \epsilon \sim N(0, \sigma^2_H) \)
  2) fixed noise: \( \epsilon \sim N(0, \sigma^2_V) \)
- Simulated choices: \( n = 10^3 \) trials
- Additional pooling model with noise implemented as correlated variability

Pooling and correlation

- Context-dependence examined in populations of Poisson neurons
- Two key parameters: pool size, correlation
- Correlated spike counts generated using latent multivariate Gaussian
  (Macke et al. 2009)

Summary

1) Normalized value representations produce context-dependent choice
2) Neural variability is a critical element
3) Context-dependence persists in presence of gain control and pooling
4) Normalization and noise in neural value representations may drive behavioral context-dependent violations of rationality