We have developed a simple dynamic model of value-based divisive normalization. Recently, we have found that a canonical gain control computation (divisive normalization [1, 2]) implements a relative coding of value in monkey lateral intraparietal cortex (LIP) [3]. Here, we seek to link (1) the dynamics of decision activity to (2) steady-state normalized value coding using a dynamic model of divisive normalization.

**Question:** Can a single dynamic network model explain both circuit dynamics (mechanism) and circuit computation (function)?

**Model**

**Circuit differential equation model**

\[
\begin{align*}
\tau \frac{dR}{dt} & = -R + \frac{V}{1 + G_1} \\
\tau \frac{dG}{dt} & = -G + \sum_{j=1}^{N} \omega_{ij} R_j
\end{align*}
\]

- Value inputs to decision circuit
- Option: excitatory-inhibitory pair
- Divisive suppression signal sums over normalization pool

**Temporal dynamics of circuit behavior**

- Isoclines (dashed) define stable state for R, G units (A.U. for t, activity)
- Behavior determined by interacting dynamic system of equations

**Neurophysiology**

- Divisive normalization at equilibrium implements a relative value code
- Dynamic equilibrium explains initial transient dynamics of value-based divisive normalization.

**Dynamic model predictions**

1. **Step input generates characteristic value-dependent internal network dynamics**

   - Value context. LIP neurons implement relative value coding characterized at equilibrium by divisive normalization (data from [3]).

   - Model dynamics. Step value input: 1) transient dynamics, 2) initial and sustained value coding, and 3) time-varying value modulation.

2. **Divisive normalization at equilibrium implements a relative value code**

   - Static normalization model (fit to LIP data)
   - LIP response (n = 5)
   - Physiological timing of value modulation. Option value (RF target) and value context (extra-RF target) differ in time of influence.

3. **Differential timing of direct and contextual value information processing**

   - LIIP activity: differential reward motion-discrimination task
   - Figure and data from [4]

   - Timing of model value coding. Dynamic value coding produces earlier option value (V1) and later value context (V2) modulation.

**Future directions**

Comparison to other dynamic models

- Conductance-based
- Biophysical spiking network

**Longer timescales: adaptive value coding**

- Temporal context task

**Summary**

1. We have developed a simple dynamic model of value-based divisive normalization.
2. Dynamic normalization explains initial transient dynamics and equilibrium relative value coding.
3. The model predicts characteristic differences in timing between direct and contextual information.
4. Our results highlight the importance of a dynamic rather than static view of cortical computation.

**References**