Firing Reliably with Unreliable Synapses

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Introduction

Stellate cells (SC) in V1 are considered to be the first stage of processing of visual information in cortex. 6% of a SC synapses are direct inputs from LGN and 80% synapses are from other cortical layers.

- **How can LGN effectively drive a SC cell on a large background of synaptic 'noise'?**

Cortical synapses are probabilistic and show complex history-dependent short term dynamics.

- **How can LGN reliably transmit information using unreliable synapses?**

We evaluate the contribution of
- LGN input correlations
- LGN spatial synaptic grouping
- LGN bursting

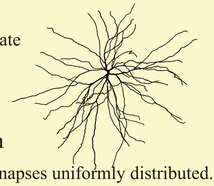
on the ability to make a SC cell fire reliably.

Methods

- Model and quantitative assumptions

Cell biophysics

- Reconstructed spiny stellate cell from cat visual cortex. Passive dendrites, active



Synaptic distribution

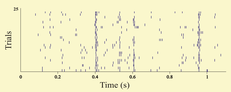
- 5000 Dynamic AMPA synapses uniformly distributed. 1 Hz Poisson.
- 1100 $GABA_A$ perisomatic synapses. 5 Hz Poisson.
- 300 Dynamic LGN synapses.

NEURON simulator

- Reliability

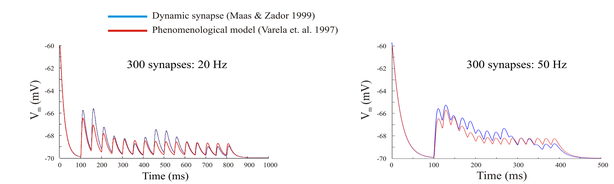
- Spike trains are convolved with a Gaussian kernel (width 2)
- Reliability is obtained as the average normalized dot-product ('cosine') of all pairs of trials.
- =3 ms, N=25-30 trials.

$$R_{corr} \quad \frac{2}{N(N\ \ 1)} \sum_{i\ 1}^{N} \sum_{j\ i\ 1}^{N} \frac{\vec{s}_i}{|\vec{s}_i|} \frac{\vec{s}_j}{|\vec{s}_j|}$$



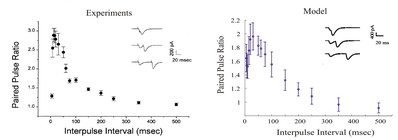
1.Dynamic Synapse

$$P_{release}(t)=1-e^{-F(t)D(t)}$$

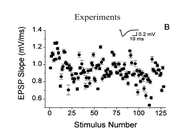


Model validation: The Dobrunz experiments

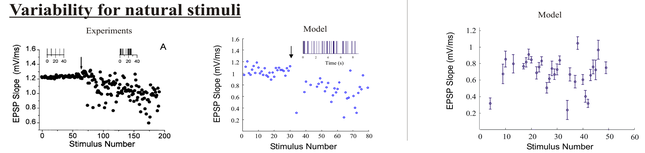
Paired-pulse facilitation



$P_{release}$ depends on history

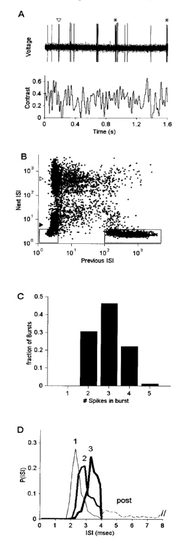


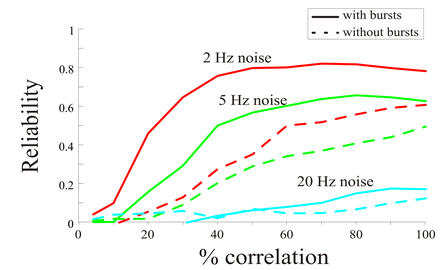
Variability for natural stimuli

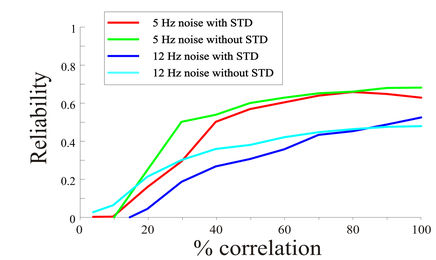


3.Bursts and Reliability

(Reinagel et. al. 1999)

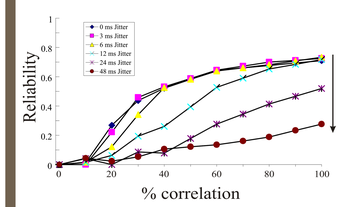




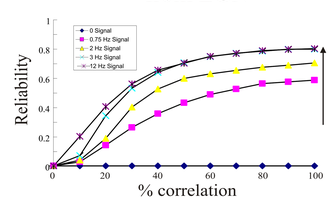


2.Correlation and Reliability

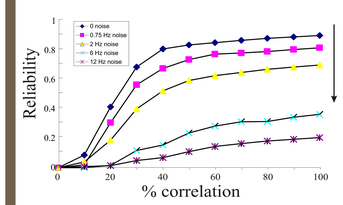
A. Jitter in signal arrival



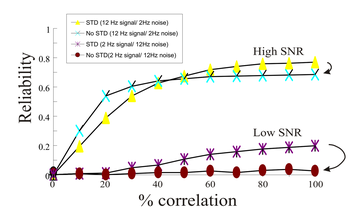
C. Variation in input signal from LGN



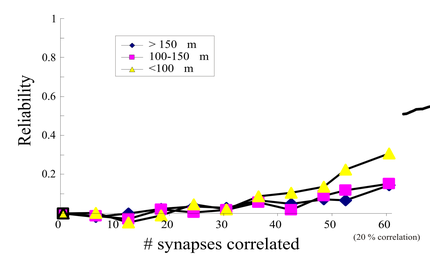
B. Variation in input noise

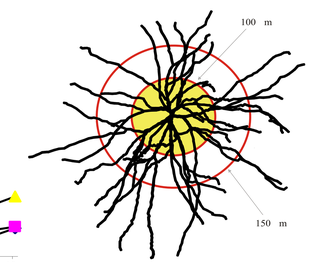


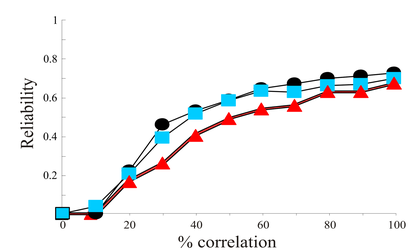
D. Influence of Short Term Dynamics

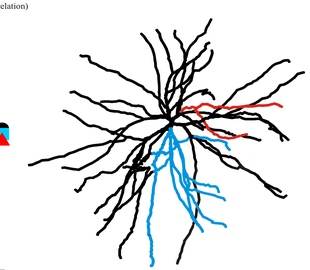


4.Spatial Grouping and Reliability









Conclusions

- A Stellate cell (SC) simulated under *in vivo* conditions tolerates up to 6 ms LGN jitter (single spike signals) before becoming unreliable.
- Short term synaptic dynamics (facilitation, depression) significantly improve SC reliability.
- LGN bursts improve SC reliability at low (< 10 Hz) LGN background firing rates.
- Spatial grouping of LGN synapses on restricted dendritic branches, or at large distances from the soma decrease SC reliability.

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Acknowledgments

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