Neural Wave Interference in Inhibition-Stabilized Networks

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Model

$$\begin{aligned}\tau_E \frac{dr_E(l)}{dt} &= -r_E(l) + g(\mathcal{W}_E) \\ \frac{dr_I(l)}{dt} &= -r_I(l) + g(\mathcal{W}_I),\end{aligned}$$

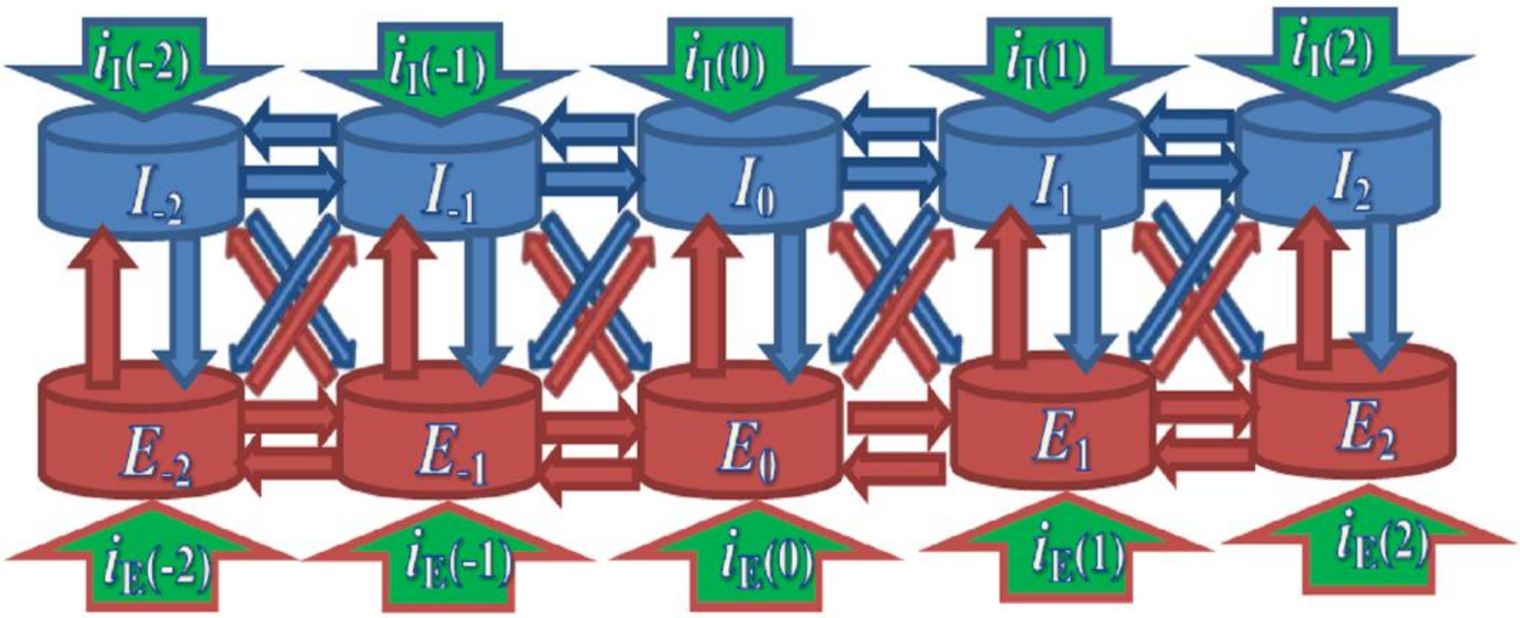
$$\mathcal{W}_E = w_{EE}r_E(l) + \tilde{w}_{EE}r_E(l+1) + \tilde{w}_{EE}r_E(l-1)$$
$$-w_{EI}r_I(l) - \tilde{w}_{EI}r_I(l+1) - \tilde{w}_{EI}r_I(l-1) + i_E(l),$$

$$\mathcal{W}_I = w_{IE}r_E(l) + \tilde{w}_{IE}r_E(l+1) + \tilde{w}_{IE}r_E(l-1)$$
$$-w_{II}r_I(l) - \tilde{w}_{II}r_I(l+1) - \tilde{w}_{II}r_I(l-1) + i_I(l),$$

Linearized equations

$$\tau_E \frac{dr_E(l)}{dt} = -r_E(l) + \mathcal{W}_E$$

$$\frac{dr_I(l)}{dt} = -r_I(l) + \mathcal{W}_I.$$



Main parameters

Responsible for spatial distribution of firing rates in network chain

$$\mathcal{K} = 4(\tilde{w}_{II}\tilde{w}_{EE} - \tilde{w}_{EI}\tilde{w}_{IE})$$

$$\mathcal{T} = (\tilde{w}_{EE}(w_{II}+1) + \tilde{w}_{II}(w_{EE}-1) - \tilde{w}_{EI}w_{IE} - \tilde{w}_{IE}w_{EI})/\mathcal{K}.$$

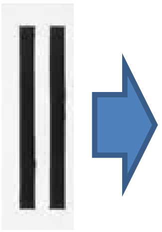
$$\mathcal{M} = (w_{II}+1)(1-w_{EE}) + w_{EI}w_{IE} + \mathcal{K}\mathcal{T}^2$$

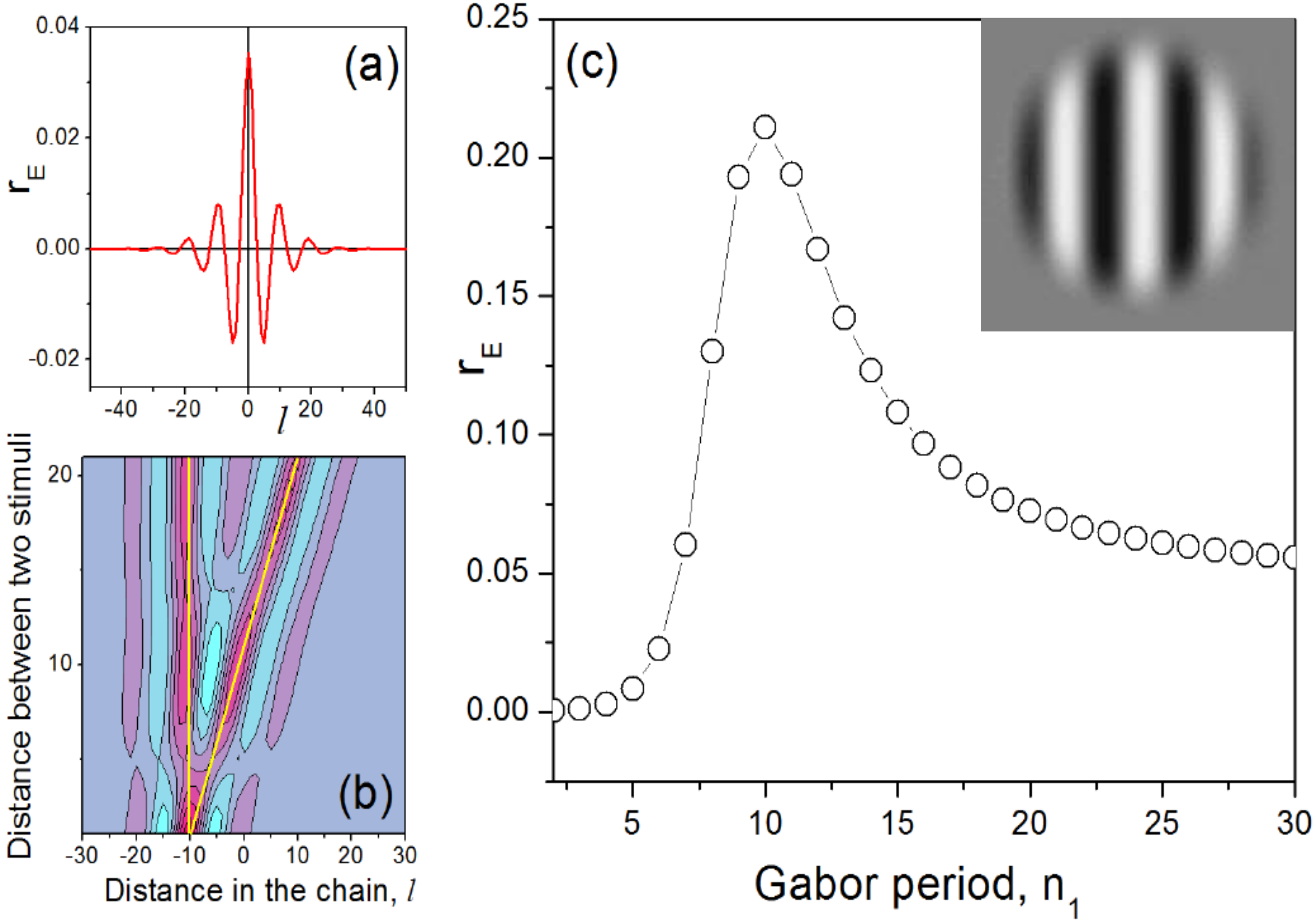
Responsible for temporal distribution of firing rates in network chain

$$\mathcal{R} = \tilde{w}_{EE} - \tau_E\tilde{w}_{II}$$

$$\mathcal{Q} = w_{EE} - 1 - \tau_E w_{II} - \tau_E + 2|\tilde{w}_{EE} - \tau_E\tilde{w}_{II}| < 0$$

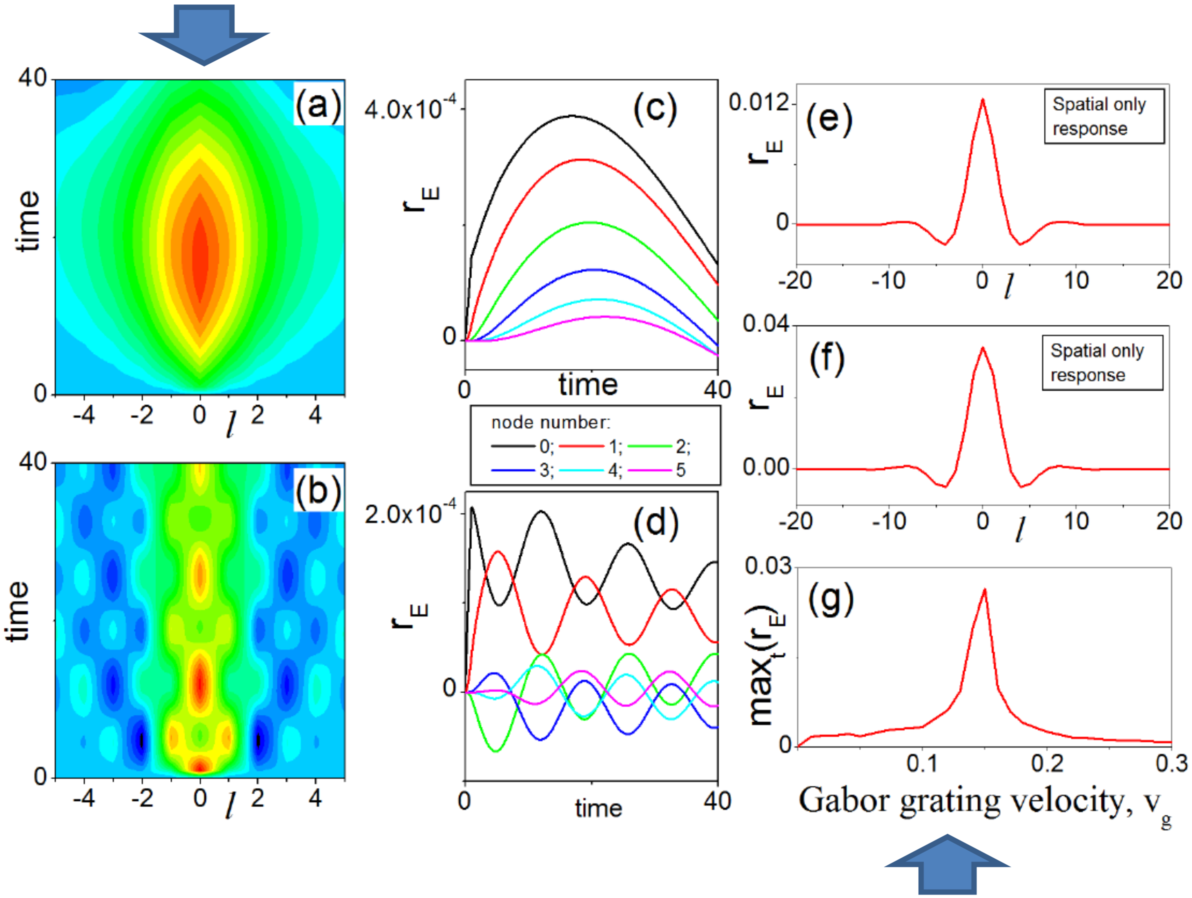
Spatial interference





Temporal interference

$$i_E(t < t_{\text{stim}}, l = 0) = \alpha j, i_I(t < t_{\text{stim}}, l = 0) = (1 - \alpha)j.$$



$$j(l) = j_0 \cos(2\pi(l - v_g t/n_1)) \exp(-l^2/n_0^2).$$

Conclusions

- We analysed interference of the neural waves propagating through an inhibitory-excitatory neural chain with nearest-neighbour coupling.
- We derived the combinations of parameters responsible for the shape of neural waves generated by static and short-lived stimuli.
- We found that the interference patterns generated in this network have three properties commonly observed in biological vision:

1) selectivity for to spatial and temporal frequencies of stimulus intensity modulation,

2)selectivity for stimulus velocity, and

3)``lateral interactions'' between spatially separate stimuli.

It is possible that neural wave interference is responsible for some of the basic visual phenomena that had been attributed to distinct and specialized neural mechanisms.