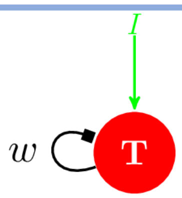
# Computational study summary

## Research question:

Is the model from Brunel and Lavigne (2009) sensitive to variations in parameter values & input-output relationships?

## 1D model:

$$\frac{dr_T}{dt} = -r_T + \Phi[(J_1 - J_I)\cdot r_T + I_{ext} + I_{sel}] = -r_T + \Phi[w \cdot r_T + I]$$




$T = Target;\ w = synaptic\ weight;\ I = external\ input\ current;\ r_T = population\ firing\ rate$

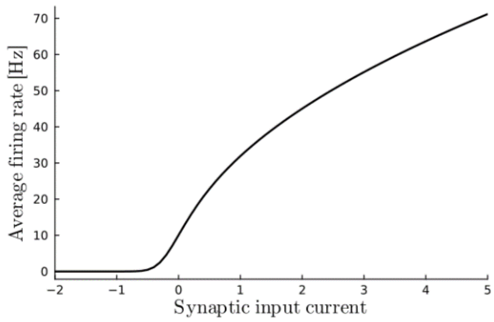
### Input-output relationship?

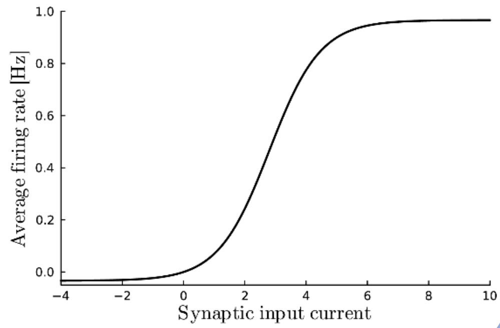
**Brunel and Lavigne (2009)** VS **Gjorgjieva *et al.* (2021)**

$$\Phi_1(x) = \frac{1}{\tau_m\sqrt{\pi}}\left[\int_{-\infty}^{+\infty}\exp\left(-xz^2-\frac{\sigma^4 z^6}{48}\right)dz\right]^{-1}$$

$$\Phi_2(x) = \frac{1}{1+\exp(-\alpha(x-\theta))} - \frac{1}{1+\exp(\alpha\theta)}$$

$\alpha$ tunes linear slope; $\theta$ tunes midpoint input




## Spontaneous activity:

Conditions on $w$ and $I$ to have a stable equilibrium at $r_T = r_{spont}$ in:

- A bistable regime:

$$w < \frac{1}{\Phi'\left(\Phi^{-1}(r_{spont})\right)} \quad \text{AND} \quad I_{SN,2}(w) < I_{ext} = \Phi^{-1}(r_{spont}) - w\cdot r_{spont} < I_{SN,1}(w)$$

- A monostable regime of a bistable system:

$$w < \frac{1}{\Phi'\left(\Phi^{-1}(r_{spont})\right)} \quad \text{AND} \quad I_{ext} < I_{SN,2}(w) \quad \text{OR} \quad I_{ext} > I_{SN,1}(w)$$

- A monostable system (i.e. any $r_{spont}$ is the only equilibrium in the system):

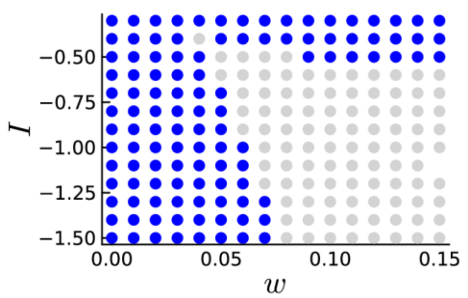
$$w < \frac{1}{\Phi'_{max}}$$

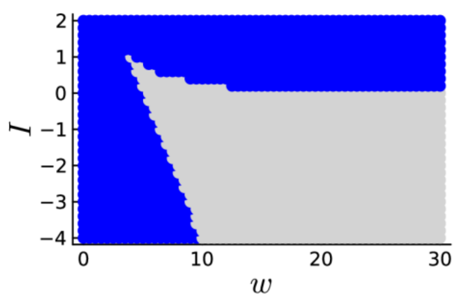
SN = Saddle-node; $\Phi'$ = transfer function derivative; $\Phi^{-1}$ = Inverse transfer function

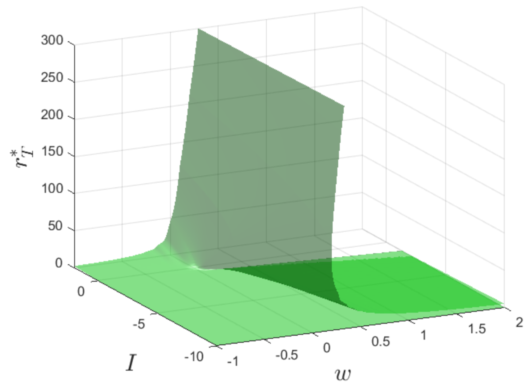
## Phase portrait & Bifurcation analyses:

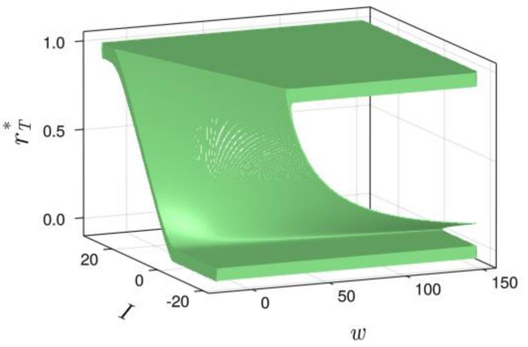
Brunel and Lavigne (2009) VS Gjorgjieva *et al.* (2021)

Blue area = monostable regime; Gray area = bistable regime




## Application to a pulse-shaped stimulus (similar to experimental stimuli in psychology experiments):

Example with Gjorgjieva *et al.* (2021)'s transfer function and a **bistable regime**:

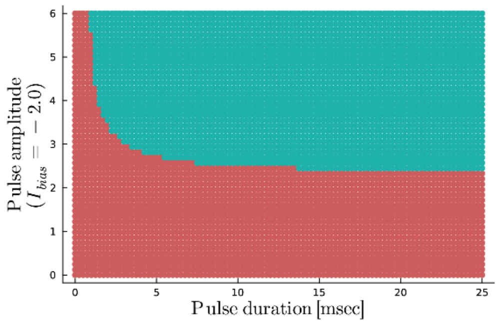
**When does the system jump to the high stable state associated to $I_{bias}$, and show persistent activity?**

Condition on pulse amplitude: $I_{app} > I_{SN,1} - I_{bias}$

Condition on pulse duration: $r_T(t = end\ pulse) > r^*_{T,unstable}$

($r^*_{T,unstable}$ associated to $I_{bias}$)

Red area = No jump; Green area = Jump




## Conclusions

- **Model from B&L (2009) is rather insensitive to variations in transfer function**: both transfer functions allow the system to display monostable and/or bistable behaviors. The only difference was the presence/absence of upper saturation.
- **Model from B&L (2009) is rather sensitive to other parameter variations**: varying one parameter requires others to vary to get back some properties (e.g. spontaneous activity).
- When using **pulse-shaped stimuli, both the pulse amplitude** and **the pulse duration determine** together the **final steady state** reached by the system, in particular when the latter is biased in a bistable regime.

## References


- Brunel, Nicolas and Frédéric Lavigne (Dec. 2009). “Semantic Priming in a Cortical Network Model”. In: Journal of Cognitive Neuroscience 21.12, pp. 2300–2319. issn: 0898-929X. DOI: 10.1162/jocn.2008.21156. eprint: https://direct.mit.edu/jocn/article-pdf/21/12/2300/1937667/jocn.2008.21156.pdf.
- Dejace, Caroline (2023). “Modeling and dynamical analysis of cortical network activity in semantic priming”. Available on https://matheo.uliege.be/
- Gjorgjieva, Julijana et al. (2021). “Tutorial 1: Neural Rate Models, Week 2, Day 4: Dynamic Networks”. URL: https://compneuro.neuromatch.io/tutorials/W2D4_DynamicNetworks/student/W2D4_Tutorial1.html (last accessed: 10.08.2023)