

# COMPUTATIONAL STUDY SUMMARY

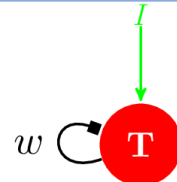
## RESEARCH QUESTION:

IS THE MODEL FROM BRUNEL AND LAVIGNE (2009) SENSITIVE TO VARIATIONS  
IN PARAMETER VALUES & INPUT-OUTPUT RELATIONSHIPS?

## 1D MODEL:

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

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



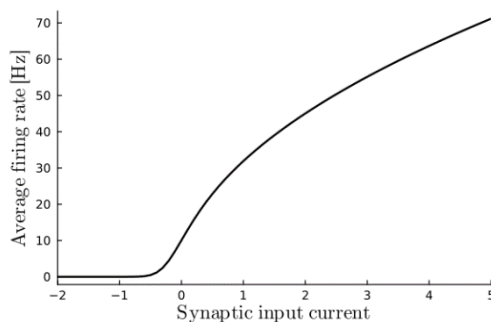
## INPUT-OUTPUT RELATIONSHIP?

BRUNEL AND LAVIGNE (2009)

VS

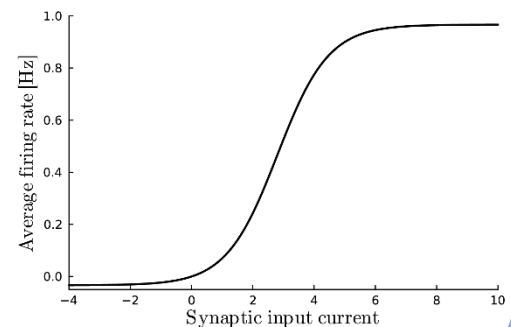
GJORGJIEVA *et al.* (2021)

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



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

$\alpha$  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:  
 $w < \frac{1}{\Phi'(\Phi^{-1}(r_{spont}))}$  AND  $I_{SN,2}(w) < I_{ext} = \Phi^{-1}(r_{spont}) - w \cdot r_{spont} < I_{SN,1}(w)$
- A MONOSTABLE REGIME OF A BISTABLE SYSTEM:  
 $w < \frac{1}{\Phi'(\Phi^{-1}(r_{spont}))}$  AND  $I_{ext} < I_{SN,2}(w)$  OR  $I_{ext} > I_{SN,1}(w)$
- 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

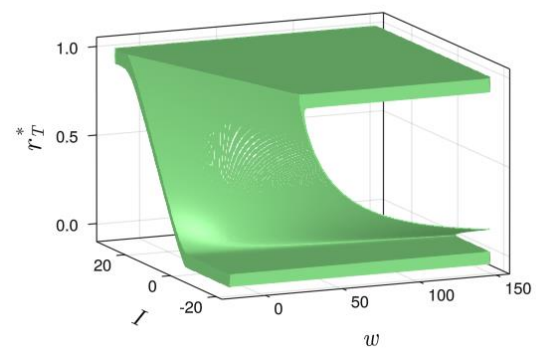
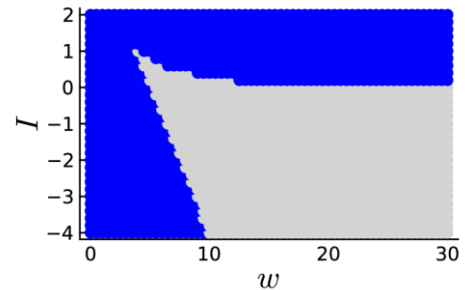
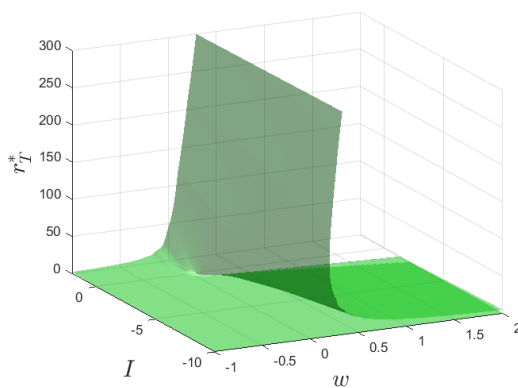
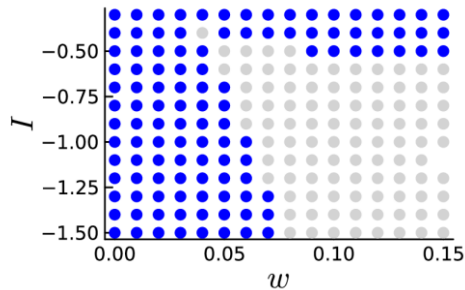
## PHASE PORTRAIT & BIFURCATION ANALYSES:

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):

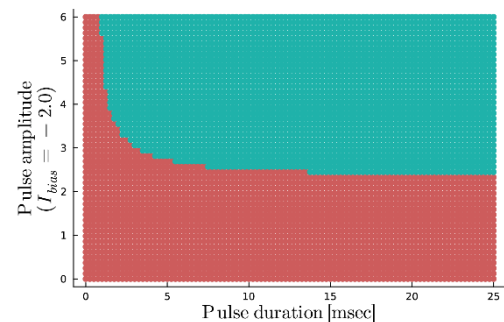
EXAMPLE WITH GJORGJIEVA *et al.* (2021)'S TRANSFER FUNCTION AND A BISTABLE REGIME:

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:  $r_T(t = \text{end pulse}) > r_{T,unstable}^*$   
( $r_{T,unstable}^*$  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](https://doi.org/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](https://compneuro.neuromatch.io/tutorials/W2D4_DynamicNetworks/student/W2D4_Tutorial1.html) (last accessed: 10.08.2023)