

Intermittency model description and examples

This livescript contains the following information:

- Descriptions of model parameters
- Descriptions of model equations
- Examples of how to run the model and plot results

Additional description and contextualization of the model can be found in:

- Tilsen, S. *Phrasal rhythmicity and the sources of temporal intermittency in speech*
- Tilsen, S. (2019) *Syntax with oscillators and energy levels*. Language Science Press.

Please note that this model is a work-in-progress, and a number of future improvements are planned.

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Model parameters

Below are described the parameters used in `intermittency_model.m`. The defaults are defined in the function `model_default_params.m`, but can be replaced by passing them as fields in an input structure (see [how to run the model below](#)). The variable names, default values, and short descriptions are provided for each parameter. The effects of their values can be better understood by examining the [model equations](#). Note the following abbreviations:

- C,c : concept system
- S,s : syntactic system
- F : feedback system
- E : excitation potential levels
- A : annealer
- M : excitation monitoring system

```
addpath('.\helpers');
P = model_default_params;
dp = @(ptype)disp_pars(P,ptype);
```

Simulation parameters:

```
dp('simulation');
```

name	val	desc
"T"	5	"maximal run time"
"stop_on_completion"	0.001	"stop if the sequence is completed"
"dt"	0.001	"time step"

Systems parameters:

```
p = dp('systems');
```

name	val	desc
"Nc"	{[100]}	"number of c-systems"
"Ns"	{[3]}	"number of s-systems"
"Sx0"	{[0.5000 0.3000 0.1000]}	"initial syntactic system activation"
"S_S"	{3x3 double }	"s-to-s coupling matrix"
"C_S_prop"	{[0.3333]}	"proportion of systems coupled to verbal S-system"
"Ne"	{[5]}	"number of initial energy levels (usually Ns + 2 extra for ground and
"f"	{[8]}	"oscillator intrinsic frequency (Hz)"

This is the syntactic system-to-syntactic system coupling matrix for an SVO utterance, where the rows/cols correspond to N+ (S), V, and N- (O) s-systems:

```
disp(p.val{p.name=='S_S'})
```

```
0    1    0
1    0   -1
0   -1    0
```

For further detail, see Tilsen (2019). *Syntax with oscillators and energy levels*.

Noise amplitudes:

```
dp('noise amplitude');
```

name	val	desc
"eta_Cp"	0.1	"c-system phase noise"
"eta_Cx"	0.1	"c-system activation noise"
"eta_Sp"	0.1	"s-system phase noise"
"eta_Sx"	0.5	"s-system activation noise"
"eta_Sx0"	0.1	"s-system activation reset noise"

Activation coupling strength parameters. Currently the default model includes only c-to-s activation coupling.

```
dp('activation coupling strength');
```

name	val	desc
"chi_SC"	0	"s-to-c coupling"
"chi_SS"	0	"s-to-s coupling"

"chi_CC"	0	"c-to-c coupling"
"chi_CS"	4	"c-to-s coupling"

Phase coupling strength parameters:

```
dp('phase coupling strength');
```

name	val	desc
"psi_SC"	10	"s-to-c coupling"
"psi_SS"	10	"s-to-s coupling"
"psi_CC"	0	"c-to-c coupling"
"psi_CS"	0.05	"c-to-s coupling"

Global excitation potential parameters:

```
dp('global excitation potential');
```

name	val	desc
"gw_ub"	1.1	"upper limit"
"gw_lb"	0	"lower limit"
"gain_gw"	0.1	"gain"

Syntactic-system excitation potential parameters:

```
dp('s-system excitation potential');
```

name	val	desc
"sigma_VE"	0.05	"width of force regions"
"gain_VE"	1	"strength of excitation potential"

Annealing parameters:

```
dp('annealer');
```

name	val	desc
"gain_Ai"	1.2	"gain of annealer in initial organization phase"
"gain_Ar"	6	"gain of annealer after initial organization phase"

Excitation monitor parameters:

```
dp('excitation monitor');
```

name	val	desc
"Me_unocc_cost"	15	"cost of unoccupied level"

"Me_multiocc_cost"	15	"cost of multiply occupied level"
"Me_decay"	10	"decay rate"
"sigme_VMe"	0.05	"width of excitation monitor potential"
"reset_Me"	0.5	"threshold for Monitor-induced reset"
"reorg_Me"	-0.5	"threshold for Monitor-induced reorganization"
"eps_Sx"	0.01	"supression value for syntactic systems"
"eps_Cx"	0.01	"degeneracy reset factor for concept systems"

Feedback parameters:

```
dp('feedback');
```

name	val	desc
"tau_Fx_dem"	{[0.5000 0.5000 0.5000]}	"feedback threshold for syntactic systems"
"tau_Sx_sel"	{[1]}	"threshold for syntactic system feedback growth"

Model equations

The model is implemented with a simple numerical method (first-order Euler). At each time step every dynamical variable is updated with an equation of the form:

$$x(t) = x(t-1) + \frac{\Delta x}{\Delta t} \cdot \delta t$$

with time indices $t = 1, 2, \dots, (T/\delta t)$

For convenience in presenting the equations below, \dot{x} is substituted for $\frac{\Delta x}{\Delta t}$, hence:

$$x(t) = x(t-1) + \dot{x}(t) \cdot \delta t$$

The specific update equations in the model are the following:

$$\theta_i^C(t) = \theta_i^C(t-1) + \dot{\theta}_i^C \cdot \delta t \quad \text{phase for concept system } i$$

$$\theta_m^S(t) = \theta_m^S(t-1) + \dot{\theta}_m^S \cdot \delta t \quad \text{phase for syntactic system } m$$

$$x_i^C(t) = x_i^C(t-1) + \dot{x}_i^C \cdot \delta t \quad \text{activation for concept system } i$$

$$x_m^S(t) = x_m^S(t-1) + \dot{x}_m^S \cdot \delta t \quad \text{activation for syntactic system } m$$

$$x_m^F(t) = x_m^F(t-1) + \dot{x}_m^F \cdot \delta t \quad \text{feedback for syntactic system } m$$

$$E_l(t) = E_l(t-1) + \dot{E}_l \cdot \delta t \quad \text{value of excitation level } l$$

$$A(t) = A(t-1) + \dot{A} \cdot \delta t \quad \text{annealer state}$$

$$M(t) = M(t-1) + \dot{M} \cdot \delta t \quad \text{excitation monitor}$$

For phase variables, 2π -periodicity is imposed by taking the updated value modulo 2π :

$$\theta_i^C(t) = \theta_i^C(t) \pmod{2\pi}$$

$$\theta_m^S(t) = \theta_m^S(t) \pmod{2\pi}$$

Note the following:

- Concept systems are indexed by i and j
- Syntactic systems are indexed by m and n . For convenience, the indices correspond to the order in which syntactic systems are selected.
- Excitation potential levels are indexed by l
- U is a random number from a uniform distribution on the interval (0,1)
- η parameters are the noise terms described above.

Concept system phase:

$$\dot{\theta}_i^C = \eta^{C\theta} \cdot U + \omega + \psi_{SC} \cdot \sum_m (-\sin(\phi_{mi}^{SC}) \cdot w_{mi}^{SC}) + \psi_{CC} \cdot \sum_j (-\sin(\phi_{ij}^{CC}) \cdot w_{ij}^{CC})$$

where:

$\omega = 2\pi f$ is the intrinsic oscillator frequency in radians per second

$\phi_{mi}^{SC} = \theta_i^C - \theta_m^S$ is the phase difference between the concept system i and syntactic system m

w_{mi}^{SC} is the syntactic-conceptual system coupling matrix

$\phi_{ij}^{CC} = \theta_i^C - \theta_j^C$ is the phase difference between the concept system i and concept system j

w_{ij}^{CC} is the conceptual-conceptual system coupling matrix

Syntactic system phase:

$$\dot{\theta}_m^S = \eta^{S\theta} \cdot U + \omega + \psi_{SS} \cdot \sum_n (-\sin(\phi_{mn}^{SS}) \cdot w_{mn}^{SS}) + \psi_{CS} \cdot \sum_i (-\sin(\phi_{im}^{CS}) \cdot w_{im}^{CS})$$

where:

$\phi_{mn}^{SS} = \theta_n^S - \theta_m^S$ is the phase difference between the syntactic system m and syntactic system n

w_{mn}^{SS} is the syntactic-syntactic system coupling matrix

$\phi_{im}^{CS} = \theta_m^S - \theta_i^C$ is the phase difference between the syntactic system m and concept system i

w_{im}^{CS} is the concept-syntactic system coupling matrix

Concept system activation:

$$\dot{x}_i^C = -\left(x_i^C - \left(\mathcal{E}_i + \eta^{Cx} \cdot U\right)\right)$$

where:

\mathcal{E}_i is the driving force from the environment on concept system i

Syntactic system activation:

$$\dot{x}_m^S = \eta^{Sx} \cdot U + V_m^S + W(x_m^S) + \chi_{CS} \cdot \sum_i w_{im}^{CS} \cdot (F_m^{Sx})$$

where:

$V_m^E = \alpha_{Ve} \cdot \frac{A}{\delta t} \cdot \sum_l V(x_m^S, E_l)$ is the force on syntactic system m associated with excitation potential forces

α_{Ve} is the gain of the excitation potential forces

A is the current state of the annealing system

$V(x_m^S, E_l) = -(x_m^S - E_l) \cdot e^{-\frac{(x_m^S - E_l)^2}{2\sigma_{VE}^2}}$ is the excitation potential force between level l and syntactic system m .

$W(x_m^S) = \alpha_W \cdot (W^{\text{lower}}(x_m^S) + W^{\text{upper}}(x_m^S))$ is the global activation potential

$W^{\text{lower}}(x_m^S) = \frac{1}{x_m^S - W_{\text{lower}}}$ is the lower bound component of the global activation potential

$W^{\text{upper}}(x_m^S) = \frac{-1}{W_{\text{upper}} - x_m^S}$ is the upper bound component of the global activation potential

$F_m^{Sx} = \begin{cases} 1, & \text{if } F_m^x < \tau_{dem} \\ 0, & \text{if } F_m^x \geq \tau_{dem} \end{cases}$ This factor enforces the condition that demoted syntactic systems are no longer coupled to concepts.

Syntactic system feedback:

$$\dot{F}_m^x = \begin{cases} 1, & \text{if } x_m^S > \tau_{sel} \\ 0, & \text{if } x_m^S \leq \tau_{sel} \end{cases}$$

This states that feedback for syntactic system m increases when system m is selected.

Excitation levels:

$\dot{E}_l = 0$ Excitation level values are constant in this version of the model, although note that the number of above-ground levels changes upon reorganization (see below).

Excitation monitoring system:

$$\dot{M} = M^{unocc} \cdot \mathcal{E}^{unocc} + M^{multiocc} \cdot \mathcal{E}^{multiocc} + M^{decay} \cdot (-1 - M)$$

where:

$\mathcal{E}^{multiocc} = \sum_{m,n,m \neq n} x_m^S x_n^S \cdot V^M(x_m^S, x_n^S)$ is the cost associated with multiply-occupied levels, where:

$$V^M(x_m^S, x_n^S) = e^{\frac{-(x_m^S - x_n^S)}{2\sigma_{VM}^2}}$$

$\mathcal{E}^{unocc} = \sum_l E_l \cdot \min_m \sqrt{(E_l - x_m^S)^2}$ is the cost associated with unoccupied levels

Annealing system:

$$\dot{A} = \begin{cases} \begin{cases} A^{init}, & \text{before any selection, or after degeneracy} \\ A^{reorg}, & \text{otherwise} \end{cases}, & A < 1 \\ 0, & A \geq 1 \end{cases}$$

This posits that the cooling rate is A^{init} before any systems have been selected and A^{reorg} after systems have been selected, and that the annealer state stops increases when $A \geq 1$.

Excitation operations:

After the above updates, excitation operations are applied, based on various conditions described below. Note that the following logical values are calculated each time step:

$sel_m = x_m^S > 1$: indicates whether syntactic system m is currently selected

$dem_m = sel_m \wedge F_m^x \geq \tau_{dem}$: flag syntactic system m for demotion if it is selected and if feedback for system m is greater than or equal to the demotion threshold

$sup_m = \neg sel_m \wedge F_m^x \geq \tau_{dem}$: indices whether syntactic m is currently suppressed (i.e., it is not selected but is has feedback state $\geq \tau_{dem}$)

Condition: degeneracy before any selection

$$M(t) > M^{reset} \wedge \forall_m \neg sup_m :$$

$A \rightarrow 0$ the annealer is reset to 0

$M \rightarrow 0$ the excitation monitoring system is reset to 0

$x_m^S \rightarrow x_0^S + \eta^{Sx0} \cdot U$ syntactic systems are reset to their initial values with a random perturbation

$C \rightarrow \epsilon_{Cx} \cdot C$ concept system values are diminished

Condition: degeneracy after any system has been selected and suppressed

$$M(t) > M^{reset} \wedge \exists_m sup_m :$$

$A \rightarrow 0$ the annealer is reset to 0

$M \rightarrow 0$ the excitation monitoring system is reset to 0

$$x_m^S \rightarrow \begin{cases} \eta^{Sx0} \cdot U + \frac{m}{N_{unsel}}, & \neg sup_m \\ \epsilon_{Sx}, & sup_m \end{cases}$$

The above states that the activations of syntactic systems that have not been suppressed are reset to evenly spaced values on the interval $\left[\frac{1}{N_{unsel}}, 1\right]$, where N_{unsel} is the number of systems that have not yet been selected, with a random perturbation $\eta^{Sx0} \cdot U$. The activations of syntactic systems that have been suppressed are set to ϵ_{Sx} . Note that this formulation of the operation requires that syntactic systems be indexed in the order in which they are canonically selected.

$C \rightarrow \epsilon_{Cx} \cdot C$ concept system values are diminished by the factor ϵ_{Cx}

Condition: initial coherence

$M(t) < M^{reorg} \wedge \forall_m \neg sel_m$: when the monitor reaches a coherence threshold and not any syntactic systems have yet been selected:

$A \rightarrow 0$ the annealer is reset to 0

$M \rightarrow 0$ the excitation monitoring system is reset to 0

$E \rightarrow r^C(E)$ the canonical reorganization operation is applied to the excitation potential levels. This operation eliminates the lowest non-ground level from the potential, reflecting the hypothesis that the potential itself emerges from the excitation of conceptual-syntactic systems.

$x_m^{Sx} \rightarrow \epsilon_{Sx}$, if dem_m the activations of demoted syntactic systems are set to ϵ_{Sx}

Condition: within sequence coherence

$\exists m \ dem_m$: when a syntactic system reaches the demotion state

$A \rightarrow 0$ the annealer is reset to 0

$M \rightarrow 0$ the excitation monitoring system is reset to 0

$E \rightarrow r^C(E)$ the canonical reorganization operation is applied to the excitation potential levels. This operation eliminates the lowest non-ground level.

$x_m^{Sx} \rightarrow \epsilon_{Sx}$, if dem_m the activations of demoted syntactic systems are set to ϵ_{Sx}

Examples

How to run the model and plot the results

```
sim = intermittency_model;
```

All of the dynamical variables and parameters are in the output structure (here named `sim`):

```
sim
sim = struct with fields:
    An: [5000x1 double]
    C_C: [100x100 double]
    C_S: [3x100 logical]
    C_S_prop: 0.3333
    Cp: [5000x100 double]
    Cx: [5000x100 double]
    Cx_eq: [0.0402 0.0261 0.0222 0.0051 0.0040 0.0780 0.0630 1.0588 0.0166 0.0407 0.0527 0.0746 0.0963
    EV: {6x2 cell}
    Ex: [5000x5 double]
    Fx: [5000x3 double]
    Me: [5000x1 double]
    Me_decay: 10
    Me_multiocc_cost: 15
    Me_unocc_cost: 15
    N_ixs: [1 2 3 4 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 24 25 26 27 28 30 31 32 33 34 35 36 39
    Nc: 100
    Ne: 5
    Ns: 3
    P: [42x4 table]
    PHI_CC: [100x100 double]
    PHI_CS: [100x3 double]
    PHI_SC: [3x100 double]
```

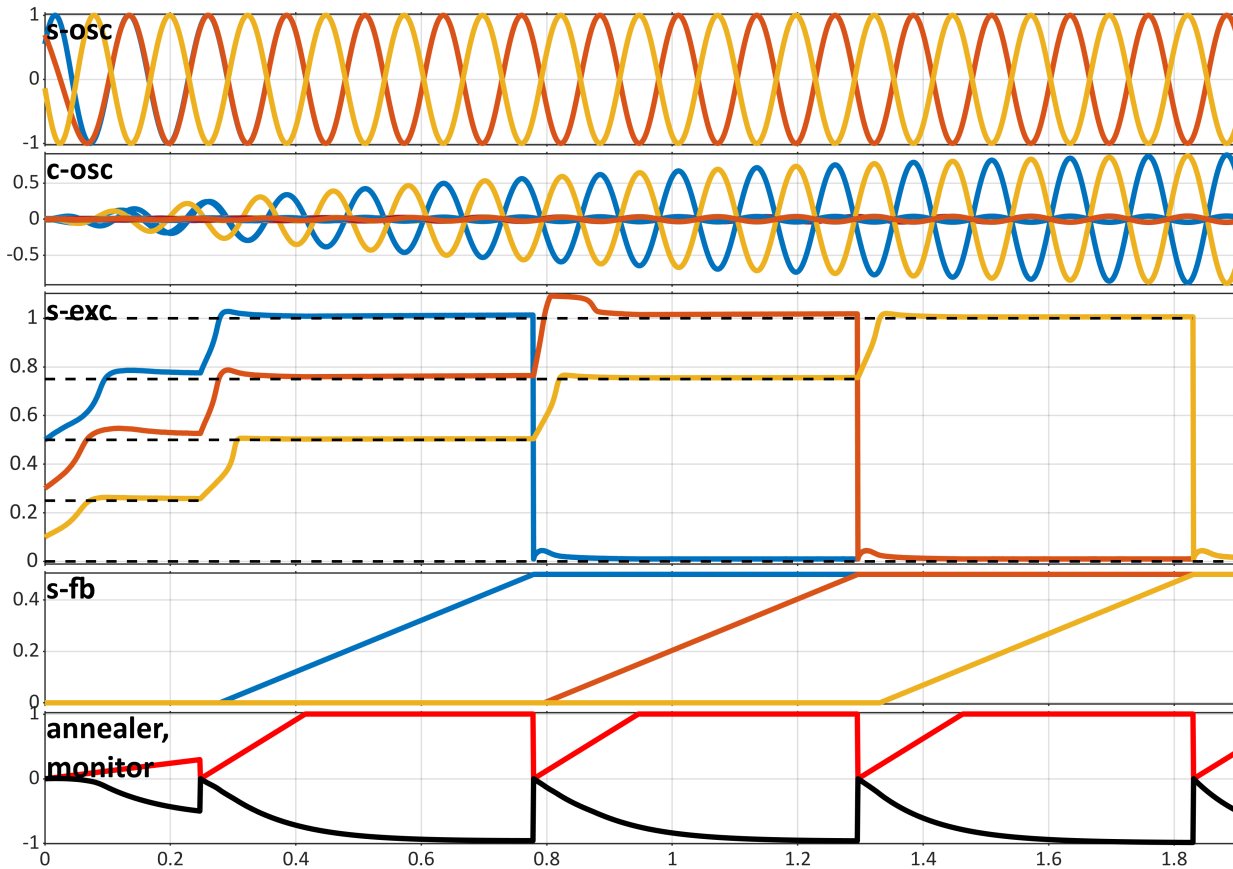
```

PHI_SS: [3×3 double]
S_S: [3×3 double]
Sp: [5000×3 double]
Sx: [5000×3 double]
Sx0: [0.5000 0.3000 0.1000]
T: 5
VE_S: [-6.4267 -6.4247 -6.4822]
V_E: @(x,c)-(x-c).*(exp(-((x-c).^2)./(2*sigma_VE^2)))
V_Me: @(x)exp(-(x.^2)./(2*sigme_VMe^2))
V_ixs: [5 19 23 29 37 38 47 48 56 65 72 78 79 80 91 96 97 98 100]
c_coup: [0 0 0]
chi_CC: 0
chi_CS: 4
chi_SC: 0
chi_SS: 0
dAn: 6
dCp: [50.3289 50.3471 50.3613 50.2713 50.3335 50.3344 50.3443 50.2921 50.3250 50.3442 50.3564 50.3686 50.3808 50.3930 50.4052 50.4174 50.4296 50.4418 50.4540 50.4662 50.4784 50.4906 50.5028 50.5150 50.5272 50.5394 50.5516 50.5638 50.5760 50.5882 50.6004 50.6126 50.6248 50.6370 50.6492 50.6614 50.6736 50.6858 50.6980 50.7102 50.7224 50.7346 50.7468 50.7590 50.7712 50.7834 50.7956 50.8078 50.8200 50.8322 50.8444 50.8566 50.8688 50.8810 50.8932 50.9054 50.9176 50.9298 50.9420 50.9542 50.9664 50.9786 50.9908 51.0030 51.0152 51.0274 51.0396 51.0518 51.0640 51.0762 51.0884 51.1006 51.1128 51.1250 51.1372 51.1494 51.1616 51.1738 51.1860 51.1982 51.2104 51.2226 51.2348 51.2470 51.2592 51.2714 51.2836 51.2958 51.3080 51.3202 51.3324 51.3446 51.3568 51.3690 51.3812 51.3934 51.4056 51.4178 51.4300 51.4422 51.4544 51.4666 51.4788 51.4910 51.5032 51.5154 51.5276 51.5398 51.5520 51.5642 51.5764 51.5886 51.6008 51.6130 51.6252 51.6374 51.6496 51.6618 51.6740 51.6862 51.6984 51.7106 51.7228 51.7350 51.7472 51.7594 51.7716 51.7838 51.7960 51.8082 51.8204 51.8326 51.8448 51.8570 51.8692 51.8814 51.8936 51.9058 51.9180 51.9302 51.9424 51.9546 51.9668 51.9790 51.9912 52.0034 52.0156 52.0278 52.0400 52.0522 52.0644 52.0766 52.0888 52.1010 52.1132 52.1254 52.1376 52.1498 52.1620 52.1742 52.1864 52.1986 52.2108 52.2230 52.2352 52.2474 52.2596 52.2718 52.2840 52.2962 52.3084 52.3206 52.3328 52.3450 52.3572 52.3694 52.3816 52.3938 52.4060 52.4182 52.4304 52.4426 52.4548 52.4670 52.4792 52.4914 52.5036 52.5158 52.5280 52.5402 52.5524 52.5646 52.5768 52.5890 52.6012 52.6134 52.6256 52.6378 52.6500 52.6622 52.6744 52.6866 52.6988 52.7110 52.7232 52.7354 52.7476 52.7598 52.7720 52.7842 52.7964 52.8086 52.8208 52.8330 52.8452 52.8574 52.8696 52.8818 52.8940 52.9062 52.9184 52.9306 52.9428 52.9550 52.9672 52.9794 52.9916 53.0038 53.0160 53.0282 53.0404 53.0526 53.0648 53.0770 53.0892 53.1014 53.1136 53.1258 53.1380 53.1502 53.1624 53.1746 53.1868 53.1990 53.2112 53.2234 53.2356 53.2478 53.2600 53.2722 53.2844 53.2966 53.3088 53.3210 53.3332 53.3454 53.3576 53.3698 53.3820 53.3942 53.4064 53.4186 53.4308 53.4430 53.4552 53.4674 53.4796 53.4918 53.5040 53.5162 53.5284 53.5406 53.5528 53.5650 53.5772 53.5894 53.6016 53.6138 53.6260 53.6382 53.6504 53.6626 53.6748 53.6870 53.6992 53.7114 53.7236 53.7358 53.7480 53.7602 53.7724 53.7846 53.7968 53.8090 53.8212 53.8334 53.8456 53.8578 53.8700 53.8822 53.8944 53.9066 53.9188 53.9310 53.9432 53.9554 53.9676 53.9798 53.9920 54.0042 54.0164 54.0286 54.0408 54.0530 54.0652 54.0774 54.0896 54.1018 54.1140 54.1262 54.1384 54.1506 54.1628 54.1750 54.1872 54.1994 54.2116 54.2238 54.2360 54.2482 54.2604 54.2726 54.2848 54.2970 54.3092 54.3214 54.3336 54.3458 54.3580 54.3702 54.3824 54.3946 54.4068 54.4190 54.4312 54.4434 54.4556 54.4678 54.4800 54.4922 54.5044 54.5166 54.5288 54.5410 54.5532 54.5654 54.5776 54.5898 54.6020 54.6142 54.6264 54.6386 54.6508 54.6630 54.6752 54.6874 54.6996 54.7118 54.7240 54.7362 54.7484 54.7606 54.7728 54.7850 54.7972 54.8094 54.8216 54.8338 54.8460 54.8582 54.8704 54.8826 54.8948 54.9070 54.9192 54.9314 54.9436 54.9558 54.9680 54.9802 54.9924 55.0046 55.0168 55.0290 55.0412 55.0534 55.0656 55.0778 55.0900 55.1022 55.1144 55.1266 55.1388 55.1510 55.1632 55.1754 55.1876 55.1998 55.2120 55.2242 55.2364 55.2486 55.2608 55.2730 55.2852 55.2974 55.3096 55.3218 55.3340 55.3462 55.3584 55.3706 55.3828 55.3950 55.4072 55.4194 55.4316 55.4438 55.4560 55.4682 55.4804 55.4926 55.5048 55.5170 55.5292 55.5414 55.5536 55.5658 55.5780 55.5902 55.6024 55.6146 55.6268 55.6390 55.6512 55.6634 55.6756 55.6878 55.6999 55.7121 55.7243 55.7365 55.7487 55.7609 55.7731 55.7853 55.7975 55.8097 55.8219 55.8341 55.8463 55.8585 55.8707 55.8829 55.8951 55.9073 55.9195 55.9317 55.9439 55.9561 55.9683 55.9805 55.9927 56.0049 56.0171 56.0293 56.0415 56.0537 56.0659 56.0781 56.0903 56.1025 56.1147 56.1269 56.1391 56.1513 56.1635 56.1757 56.1879 56.1999 56.2121 56.2243 56.2365 56.2487 56.2609 56.2731 56.2853 56.2975 56.3097 56.3219 56.3341 56.3463 56.3585 56.3707 56.3829 56.3951 56.4073 56.4195 56.4317 56.4439 56.4561 56.4683 56.4805 56.4927 56.5049 56.5171 56.5293 56.5415 56.5537 56.5659 56.5781 56.5903 56.6025 56.6147 56.6269 56.6391 56.6513 56.6635 56.6757 56.6879 56.6999 56.7121 56.7243 56.7365 56.7487 56.7609 56.7731 56.7853 56.7975 56.8097 56.8219 56.8341 56.8463 56.8585 56.8707 56.8829 56.8951 56.9073 56.9195 56.9317 56.9439 56.9561 56.9683 56.9805 56.9927 57.0049 57.0171 57.0293 57.0415 57.0537 57.0659 57.0781 57.0903 57.1025 57.1147 57.1269 57.1391 57.1513 57.1635 57.1757 57.1879 57.1999 57.2121 57.2243 57.2365 57.2487 57.2609 57.2731 57.2853 57.2975 57.3097 57.3219 57.3341 57.3463 57.3585 57.3707 57.3829 57.3951 57.4073 57.4195 57.4317 57.4439 57.4561 57.4683 57.4805 57.4927 57.5049 57.5171 57.5293 57.5415 57.5537 57.5659 57.5781 57.5903 57.6025 57.6147 57.6269 57.6391 57.6513 57.6635 57.6757 57.6879 57.6999 57.7121 57.7243 57.7365 57.7487 57.7609 57.7731 57.7853 57.7975 57.8097 57.8219 57.8341 57.8463 57.8585 57.8707 57.8829 57.8951 57.9073 57.9195 57.9317 57.9439 57.9561 57.9683 57.9805 57.9927 58.0049 58.0171 58.0293 58.0415 58.0537 58.0659 58.0781 58.0903 58.1025 58.1147 58.1269 58.1391 58.1513 58.1635 58.1757 58.1879 58.1999 58.2121 58.2243 58.2365 58.2487 58.2609 58.2731 58.2853 58.2975 58.3097 58.3219 58.3341 58.3463 58.3585 58.3707 58.3829 58.3951 58.4073 58.4195 58.4317 58.4439 58.4561 58.4683 58.4805 58.4927 58.5049 58.5171 58.5293 58.5415 58.5537 58.5659 58.5781 58.5903 58.6025 58.6147 58.6269 58.6391 58.6513 58.6635 58.6757 58.6879 58.6999 58.7121 58.7243 58.7365 58.7487 58.7609 58.7731 58.7853 58.7975 58.8097 58.8219 58.8341 58.8463 58.8585 58.8707 58.8829 58.8951 58.9073 58.9195 58.9317 58.9439 58.9561 58.9683 58.9805 58.9927 59.0049 59.0171 59.0293 59.0415 59.0537 59.0659 59.0781 59.0903 59.1025 59.1147 59.1269 59.1391 59.1513 59.1635 59.1757 59.1879 59.1999 59.2121 59.2243 59.2365 59.2487 59.2609 59.2731 59.2853 59.2975 59.3097 59.3219 59.3341 59.3463 59.3585 59.3707 59.3829 59.3951 59.4073 59.4195 59.4317 59.4439 59.4561 59.4683 59.4805 59.4927 59.5049 59.5171 59.5293 59.5415 59.5537 59.5659 59.5781 59.5903 59.6025 59.6147 59.6269 59.6391 59.6513 59.6635 59.6757 59.6879 59.6999 59.7121 59.7243 59.7365 59.7487 59.7609 59.7731 59.7853 59.7975 59.8097 59.8219 59.8341 59.8463 59.8585 59.8707 59.8829 59.8951 59.9073 59.9195 59.9317 59.9439 59.9561 59.9683 59.9805 59.9927 60.0049 60.0171 60.0293 60.0415 60.0537 60.0659 60.0781 60.0903 60.1025 60.1147 60.1269 60.1391 60.1513 60.1635 60.1757 60.1879 60.1999 60.2121 60.2243 60.2365 60.2487 60.2609 60.2731 60.2853 60.2975 60.3097 60.3219 60.3341 60.3463 60.3585 60.3707 60.3829 60.3951 60.4073 60.4195 60.4317 60.4439 60.4561 60.4683 60.4805 60.4927 60.5049 60.5171 60.5293 60.5415 60.5537 60.5659 60.5781 60.5903 60.6025 60.6147 60.6269 60.6391 60.6513 60.6635 60.6757 60.6879 60.6999 60.7121 60.7243 60.7365 60.7487 60.7609 60.7731 60.7853 60.7975 60.8097 60.8219 60.8341 60.8463 60.8585 60.8707 60.8829 60.8951 60.9073 60.9195 60.9317 60.9439 60.9561 60.9683 60.9805 60.9927 61.0049 61.0171 61.0293 61.0415 61.0537 61.0659 61.0781 61.0903 61.1025 61.1147 61.1269 61.1391 61.1513 61.1635 61.1757 61.1879 61.1999 61.2121 61.2243 61.2365 61.2487 61.2609 61.2731 61.2853 61.2975 61.3097 61.3219 61.3341 61.3463 61.3585 61.3707 61.3829 61.3951 61.4073 61.4195 61.4317 61.4439 61.4561 61.4683 61.4805 61.4927 61.5049 61.5171 61.5293 61.5415 61.5537 61.5659 61.5781 61.5903 61.6025 61.6147 61.6269 61.6391 61.6513 61.6635 61.6757 61.6879 61.6999 61.7121 61.7243 61.7365 61.7487 61.7609 61.7731 61.7853 61.7975 61.8097 61.8219 61.8341 61.8463 61.8585 61.8707 61.8829 61.8951 61.9073 61.9195 61.9317 61.9439 61.9561 61.9683 61.9805 61.9927 62.0049 62.0171 62.0293 62.0415 62.0537 62.0659 62.0781 62.0903 62.1025 62.1147 62.1269 62.1391 62.1513 62.1635 62.1757 62.1879 62.1999 62.2121 62.2243 62.2365 62.2487 62.2609 62.2731 62.2853 62.2975 62.3097 62.3219 62.3341 62.3463 62.3585 62.3707 62.3829 62.3951 62.4073 62.4195 62.4317 62.4439 62.4561 62.4683 62.4805 62.4927 62.5049 62.5171 62.5293 62.5415 62.5537 62.5659 62.5781 62.5903 62.6025 62.6147 62.6269 62.6391 62.6513 62.6635 62.6757 62.6879 62.6999 62.7121 62.7243 62.7365 62.7487 62.7609 62.7731 62.7853 62.7975 62.8097 62.8219 62.8341 62.8463 62.8585 62.8707 62.8829 62.8951 62.9073 62.9195 62.9317 62.9439 62.9561 62.9683 62.9805 62.9927 63.0049 63.0171 63.0293 63.0415 63.0537 63.0659 63.0781 63.0903 63.1025 63.1147 63.1269 63.1391 63.1513 63.1635 63.1757 63.1879 63.1999 63.2121 63.2243 63.2365 63.2487 63.2609 63.2731 63.2853 63.2975 63.3097 63.3219 63.3341 63.3463 63.3585 63.3707 63.3829 63.3951 63.4073 63.4195 63.4317 63.4439 63.4561 63.4683 63.4805 63.4927 63.5049 63.5171 63.5293 63.5415 63.5537 63.5659 63.5781 63.5903 63.6025 63.6147 63.6269 63.6391 63.6513 63.6635 63.6757 63.6879 63.6999 63.7121 63.7243 63.7365 63.7487 63.7609 63.7731 63.7853 63.7975 63.8097 63.8219 63.8341 63.8463 63.8585 63.8707 63.8829 63.8951 63.9073 63.9195 63.9317 63.9439 63.9561 63.9683 63.9805 63.9927 64.0049 64.0171 64.0293 64.0415 64.0537 64.0659 64.0781 64.0903 64.1025 64.1147 64.1269 64.1391 64.1513 64.1635 64.1757 64.1879 64.1999 64.2121 64.2243 64.2365 64.2487 64.2609 64.2731 64.2853 64.2975 64.3097 64.3219 64.3341 64.3463 64.3585 64.3707 64.3829 64.3951 64.4073 64.4195 64.4317 64.4439 64.4561 64.4683 64.4805 64.4927 64.5049 64.5171 64.5293 64.5415 64.5537 64.5659 64.5781 64.5903 64.6025 64.6147 64.6269 64.6391 64.6513 64.6635 64.6757 64.6879 64.6999 64.7121 64.7243 64.7365 64.7487 64.7609 64.7731 64.7853 64.7975 64.8097 64.8219 64.8341 64.8463 64.8585 64.8707 64.8829 64.8951 64.9073 64.9195 64.9317 64.9439 64.9561 64.9683 64.9805 64.9927 65.0049 65.0171 65.0293 65.0415 65.0537 65.0659 65.0781 65.0903 65.1025 65.1147 65.1269 65.1391 65.1513 65.1635 65.1757 65.1879 65.1999 65.2121 65.2243 65.2365 65.2487 65.2609 65.2731 65.2853 65.2975 65.3097 65.3219 65.3341 65.3463 65.3585 65.3707 65.3829 65.3951 65.4073 65.4195 65.4317 65.4439 65.4561 65.4683 65.4805 65.4927 65.5049 65.5171 65.5293 65.5415 65.5537 65.5659 65.5781 65.5903 65.6025 65.6147 65.6269 65.6391 65.6513 65.6635 65.6757 65.6879 65.6999 65.7121 65.7243 65.7365 65.7487 65.7609 65.7731 65.7853 65.7975 65.8097 65.8219 65.8341 65.8463 65.8585 65.8707 65.8829 65.8951 65.9073 65.9195 65.9317 65.9439 65.9561 65.9683 65.9805 65.9927 66.0049 66.0171 66.0293 66.0415 66.0537 66.0659 66.0781 66.0903 66.1025 66.1147 66.1269 66.1391 66.1513 66.1635 66.1757 66.1879 66.1999 66.2121 66.2243 66.2365 66.2487 66.2609 66.2731 66.2853 66.2975 66.3097 66.3219 66.3341 66.3463 66.3585 66.3707 66.3829 66.3951 66.4073 66.4195 66.4317 66.4439 66.4561 66.4683 66.4805 66.4927 66.5049 66.5171 66.5293 66.5415 66.5537 66.5659 66.5781 66.5903 66.6025 66.6147 66.6269 66.6391 66.6513 66.6635 66.6757 66.6879 66.6999 66.7121 66.7243 66.7365 66.7487 66.7609 66.7731 66.7853 66.7975 66.8097 66.8219 66.8341 66.8463 66.8585 66.8707 66.8829 66.8951 66.9073 66.9195 66.9317 66.9439 66.9561 66.9683 66.9805 66.9927 67.0049 67.0171 67.0293 67.0415 67.0537 67.0659 67.0781 67.0903 67.1025 67.1147 67.1269 67.1391 67.1513 67.1635 67.1757 67.1879 67.1999 67.2121 67.2243 67.2365 67.2487 67.2609 67.2731 67.2853 67.2975 67.3097 67.3219 67.3341 67.3463 67.3585 67.3707 67.3829 67.3951 67.4073 67.4195 67.4317 67.4439 67.4561 67.4683 67.4805 67.4927 67.5049 67.5171 67.5293 67.5415 67.5537 67.5659 67.5781 67.5903 67.6025 67.6147 67.6269 67.6391 67.6513 67.6635 67.6757 67.6879 67.6999 67.7121 67.7243 67.7365 67.7487 67.7609 67.7731 67.7853 67.7975 67.8097 67.8219 67.8341 67.8463 67.8585 67.8707 67.8829 67.8951 67.9073 67.9195 67.9317 67.9439 67.9561 67.9683 67.9805 67.9927 68.0049 68.0171 68.0293 68.0415 68.0537 68.0659 68.0781 68.0903 68.1025 68.1147 68.1269 68.1391 68.1513 68.1635 68.1757 68.1879 68.1999 68.2121 68.2243 68.2365 68.2487 68.2609 68.2731 68.2853 68.2975 68.3097 68.3219 68.3341 68.3463 68.3585 68.3707 68.3829 68.3951 68.4073 68.4195 68.4317 68.4439 68.4561 68.4683 68.4805 68.4927 68.5049 68.5171 68.5293 68.5415 68.5537 68.5659 68.5781 68.5903 68.6025 68.6147 68.6269 68.6391 68.6513 6
```

```
tau_Fx_dem: [0.5000 0.5000 0.5000]
tau_Sx_sel: 1
wC_S: [100×3 double]
wS_C: [3×100 double]
```

Passing the output structure to the function `plot_sim` will plot some of the variables. Other variables can be plotted by accessing the output structure above.

```
plot_sim(sim)
```



Changing parameters

Recall that the default parameters are specified in:

```
P = model_default_params;
head(P)
```

name	val	type	desc
{'T' }	{[5]}	{'simulation'}	{'maximal run time'}
{'stop_on_completion'}	{[1.0000e-03]}	{'simulation'}	{'stop if the sequence is completed'}
{'dt' }	{[1.0000e-03]}	{'simulation'}	{'time step'}
{'Nc' }	{[100]}	{'systems' }	{'number of c-systems'}
{'Ns' }	{[3]}	{'systems' }	{'number of s-systems'}
{'Sx0' }	{[0.5000 0.3000 0.1000]}	{'systems' }	{'initial syntactic system activation'}

```

{'S_S'          } {3x3 double      } {'systems' } {'s-to-s coupling matrix'
{'C_S_prop'     } {[              0.3333]} {'systems' } {'proportion of systems coupled to verbal'

```

All of the parameters can be overwritten by providing them as fields of a single input structure. For example, if we wanted to (i) prevent the simulation from stopping upon completion of the sequence, (ii) decrease the maximal run time to 3 s, and (iii) increase the noise amplitude for syntactic system activation, we would do the following:

```

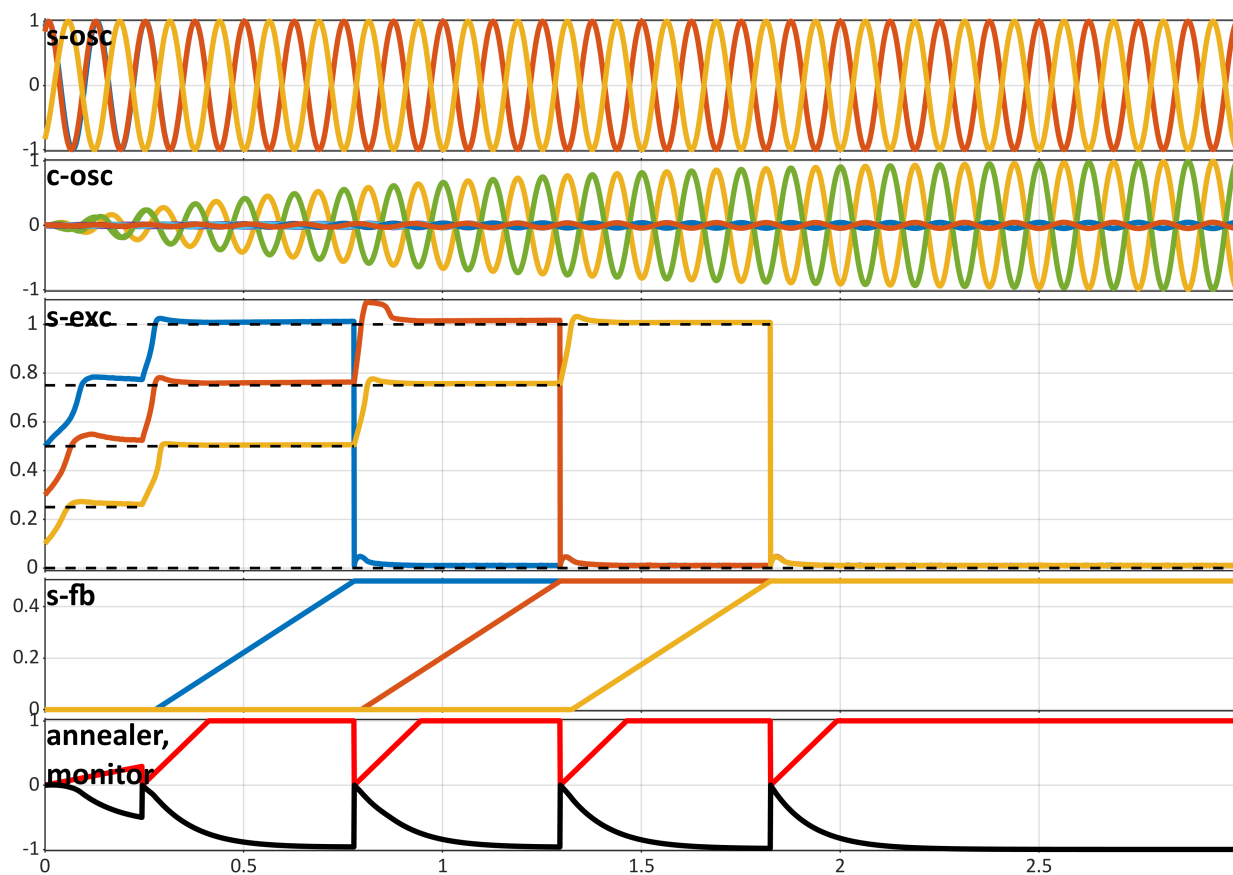
par.stop_on_completion = false;  %(i)
par.T = 3;                      %(ii)
par.eta_Sx = 1;                  %(iii)

```

```

sim = intermittency_model(par);
plot_sim(sim)

```



Helper functions for this livescript:

```

function [P] = disp_pars(P,ptype)
P = P(ismember(P.type,ptype),{'name' 'val' 'desc'});
P.name = string(P.name);
P.desc = string(P.desc);
try
    P.val=cell2mat(P.val);
catch

```

```
end  
disp(P);  
end
```