Phillip and Robinson's model

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Model

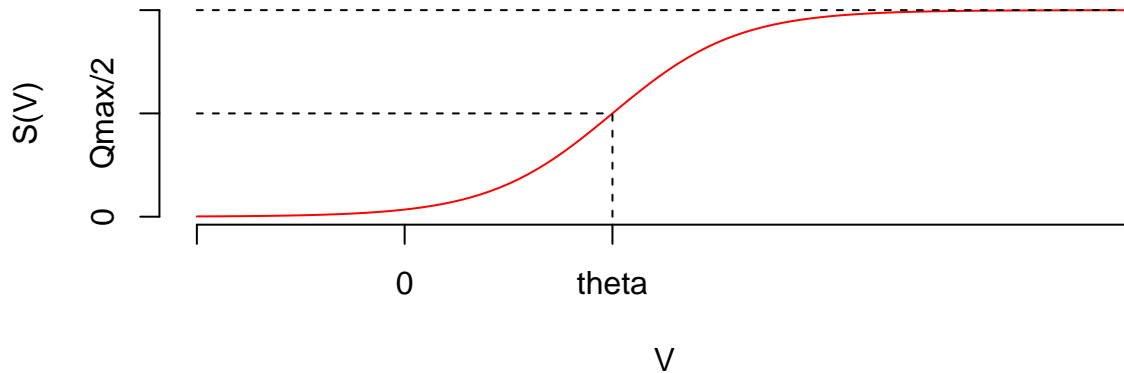The function `philrob` simulates Phillips and Robinson's model for sleep-wake dynamics.

Dynamics

The dynamics of the Phillips and Robinson model are given by the following system of ordinary differential equations:

$$
\begin{bmatrix} \tau_v \dot{V}_v + V_v \\ \tau_m \dot{V}_m + V_m \\ \chi \dot{H} + H \end{bmatrix} = \begin{bmatrix} 0 & -\nu_{vm} & \nu_{vh} \\ -\nu_{mv} & 0 & 0 \\ 0 & \mu & 0 \end{bmatrix} \begin{bmatrix} S(V_v) \\ S(V_m) \\ H \end{bmatrix} + \begin{bmatrix} -\nu_{vc} C(t) \\ \nu_{ma} S(V_{a0}) \\ 0 \end{bmatrix}
$$

where $S(V)$ is the saturation function:

$$
S(V) = \frac{Q_{max}}{1 + e^{-\frac{V-\theta}{\sigma}}}
$$

and the external forcing is typically given by $C(t)$:

$$
C(t) = \frac{1}{2} \left(1 + \cos(\omega t + \alpha)\right)
$$

Parameters

The default values for the parameters are listed in the table below:
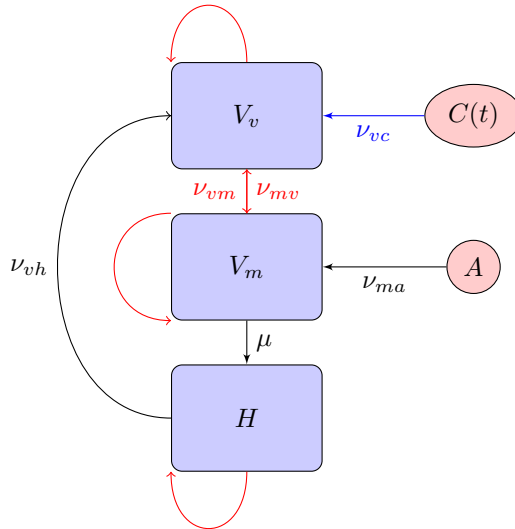
Symbol	Value	Units
τ_m	$10/3600$	h
τ_v	$10/3600$	h
χ	10.8	h
ν_{vm}	$1.9/3600$	$mV \cdot h$
ν_{mv}	$1.9/3600$	$mV \cdot h$
ν_{vh}	0.19	$mV \cdot nM^{-1}$
μ	10^{-3}	$nM \cdot h$
ν_{vc}	6.3	mV
$\nu_{ma}S(V_{a0})$	1	mV
Q_{max}	$100 \cdot 3600$	h^{-1}
θ	10	mV
σ	3	mV
ω	$2\pi/24$	h^{-1}
α	0	1

State variables

The state variables are defined as:

State variable	Units	Physiological interpetation	Informal interpretation
V_v	mV	Activity of the VLPO	Stay asleep system
V_m	mV	Activity of the MA	Stay awake system
H	1	Homeostatic pressure	Somnogen level

Diagram

Schematic summary of the dynamics. The blue nodes represent the system's states (V_v the activity of the

ventrolateral preoptic area, V_m the activity of the mono aminergic group and H the homeostatic pressure). The red nodes represent the external sources ($C(t)$, the astronomical light/dark forcing, and A, the acetylcholine group constant influence). The positive effects are coded as black arrows. Negative ones as red arrows. Blue arrows represent oscillating effects.

Reference

Phillips AJK, Robinson PA. A Quantitative Model of Sleep-Wake Dynamics Based on the Physiology of the Brainstem Ascending Arousal System. J Biol Rhythms. 2007 Apr 29;22(2):167–79. Available from: http://journals.sagepub.com/doi/10.1177/0748730406297512

Examples of usage

Getting the time series

With default parameters:

```
## Problem setting
y0 <- c(Vv = -13, Vm = 1, H = 10) # Initial conditions

nDays <- 5
ts <- seq(0, nDays*24, length.out=nDays*24*20) # Times to simulate

# Simulate
sol <- philrob(ts, y0)
```

With custom parameters:

```
## Problem setting
y0 <- c(Vv = -13, Vm = 1, H = 10) # Initial conditions

nDays <- 3
ts <- seq(0, nDays*24, length.out=nDays*24*20) # Times to simulate

parms <- philrob_default_parms() # Load default parameters...
parms['vvc'] <- 6 # .. and modify one

# Simulate
sol <- philrob(ts, y0, parms)
```

With custom forcing:

```
## Problem setting
y0 <- c(Vv = -13, Vm = 1, H = 10) # Initial conditions

nDays <- 3
ts <- seq(0, nDays*24, length.out=nDays*24*20) # Times to simulate

C <- function(t) { 0 }

# Simulate
sol <- philrob(ts, y0, parms = philrob_default_parms(), forcing = C)
```

With stabilization run of three days:

```
## Problem setting
y0 <- c(Vv = -13, Vm = 1, H = 10) # Initial conditions

nDays <- 5
ts <- seq(0, nDays*24, length.out=nDays*24*20) # Times to simulate

# Simulate
sol <- philrob(ts, y0, tStabil = 3*24)
```

The output looks like:

time	Vv	Vm	H	asleep

time	Vv	Vm	H	asleep
0.0000000	-12.63976	0.8997572	12.57292	FALSE
0.0500208	-12.63566	0.8996213	12.59124	FALSE
0.1000417	-12.63099	0.8994660	12.60948	FALSE
0.1500625	-12.62574	0.8992910	12.62762	FALSE
0.2000834	-12.61991	0.8990963	12.64568	FALSE

where:

- `time`: the time (in h),
- `Vv`: activity of the ventrolateral preoptic area (in mV)
- `Vm`: activity of the monoaminergic group (in mV)
- `H`: homeostatic pressure / somnogen
- `asleep`: the asleep/awake status (`TRUE` if asleep, `FALSE` if awake)

Plotting results

Raster / somnogram plot

```
philrobPlot(sol)
rasterPlot(sol)
```