Brain Rhythms: Recovery of Memories and Sleep

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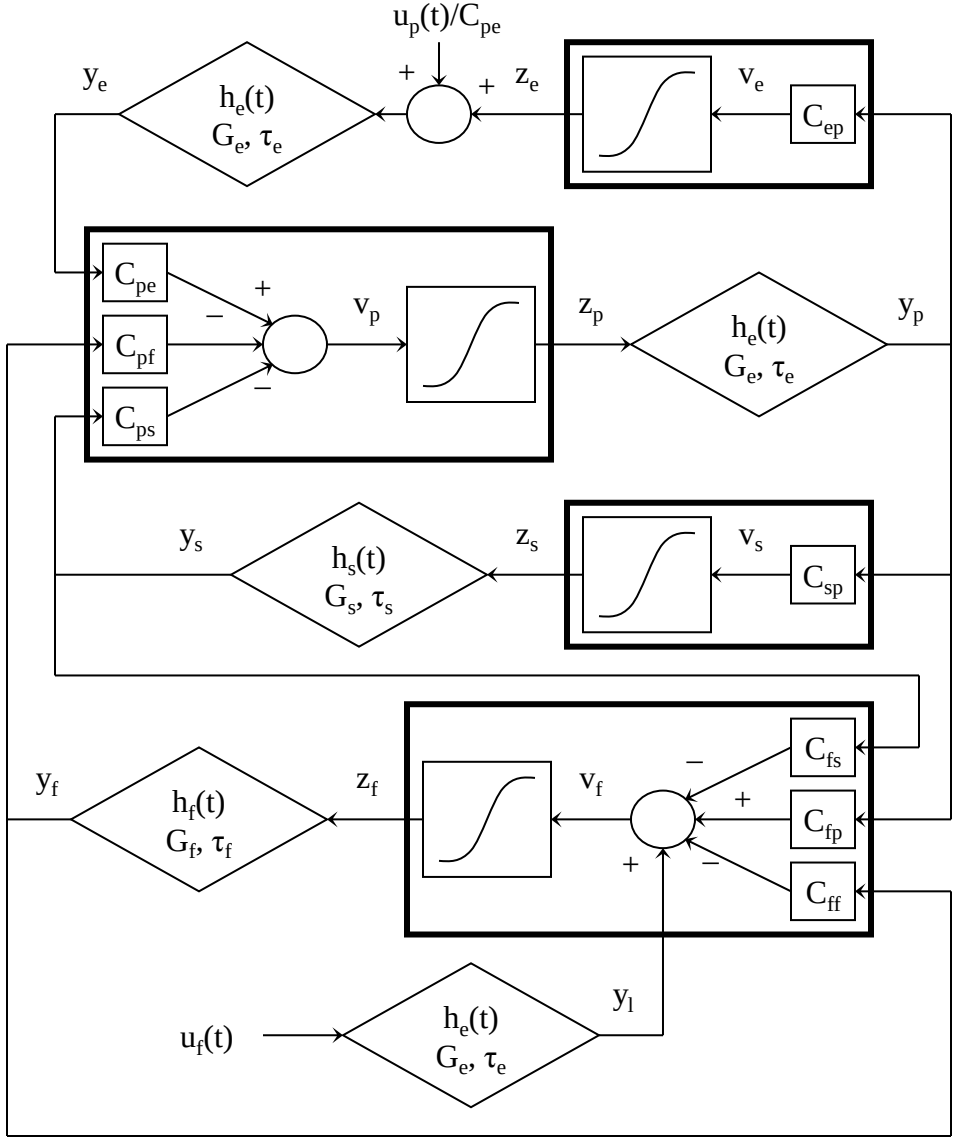
OUTLINE

- Brain rhythms
- Introduction to Neural Mass Models (NMM)
- The recovery of a sequence of events from memory
- Cortico-thalamic activity during sleep

BRAIN RHYHTMS

- δ: < 4 Hz. Characterizes slow wave sleep.
- ϑ: 4 Hz to 8 Hz. Is observed in drowsy subjects.
- α: 8 Hz to 12 Hz. Emerges with closing of the eyes and with relaxation.
- μ: 8 Hz to 12 Hz. α rhythm that emerges with hands or arms idle.
- β: 12 Hz to 25 Hz. Is closely linked to motor behavior, or associated with active, busy or anxious thinking and active concentration.
- γ: > 25 Hz. Is observed during the execution of higher cognitive tasks.

NEURAL MASS MODELS



$$v_p(t) = C_{pe}y_e(t) - C_{ps}y_s(t) - C_{pf}y_f(t) + E(t)$$
$$z_p(t) = \frac{2e_0}{1+e^{r(s_0-v_p)}}$$
$$\frac{dy_p(t)}{dt} = x_p(t)$$
$$\frac{dx_p(t)}{dt} = \frac{G_e}{\tau_e}z_p(t) - \frac{2}{\tau_e}x_p(t) - \frac{1}{\tau_e^2}y_p(t)$$
$$v_e(t) = C_{ep}y_p(t)$$
$$z_e(t) = \frac{2e_0}{1+e^{r(s_0-v_e)}}$$
$$\frac{dy_e(t)}{dt} = x_e(t)$$
$$\frac{dx_e(t)}{dt} = \frac{G_e}{\tau_e}\left(z_e(t) + \frac{u_p(t)}{C_{pe}}\right) - \frac{2}{\tau_e}x_e(t) - \frac{1}{\tau_e^2}y_e(t)$$
$$v_s(t) = C_{sp}y_p(t)$$
$$z_s(t) = \frac{2e_0}{1+e^{r(s_0-v_s)}}$$
$$\frac{dy_s(t)}{dt} = x_s(t)$$
$$\frac{dx_s(t)}{dt} = \frac{G_s}{\tau_s}z_s(t) - \frac{2}{\tau_s}x_s(t) - \frac{1}{\tau_s^2}y_s(t)$$
$$v_f(t) = C_{fp}y_p(t) - C_{fs}y_s(t) - C_{ff}y_f(t) + y_l(t)$$
$$z_f(t) = \frac{2e_0}{1+e^{r(s_0-v_f)}}$$
$$\frac{dy_f(t)}{dt} = x_f(t)$$
$$\frac{dx_f(t)}{dt} = \frac{G_f}{\tau_f}z_f(t) - \frac{2}{\tau_f}x_f(t) - \frac{1}{\tau_f^2}y_f(t)$$
$$\frac{dy_l(t)}{dt} = x_l(t)$$
$$\frac{dx_l(t)}{dt} = \frac{G_e}{\tau_e}u_f(t) - \frac{2}{\tau_e}x_l(t) - \frac{1}{\tau_e^2}y_l(t)$$

Ursino et al., 2010

NEURAL MASS MODELS

Approximation of groups of neurons with their mean activity

- Realistic activities and waveforms
- Computationally efficient
- Results immediately readable

Ursino et al., 2010

NEURAL ASSEMBLY

Ensemble of neurons that take part to the realization of a single cognitive task

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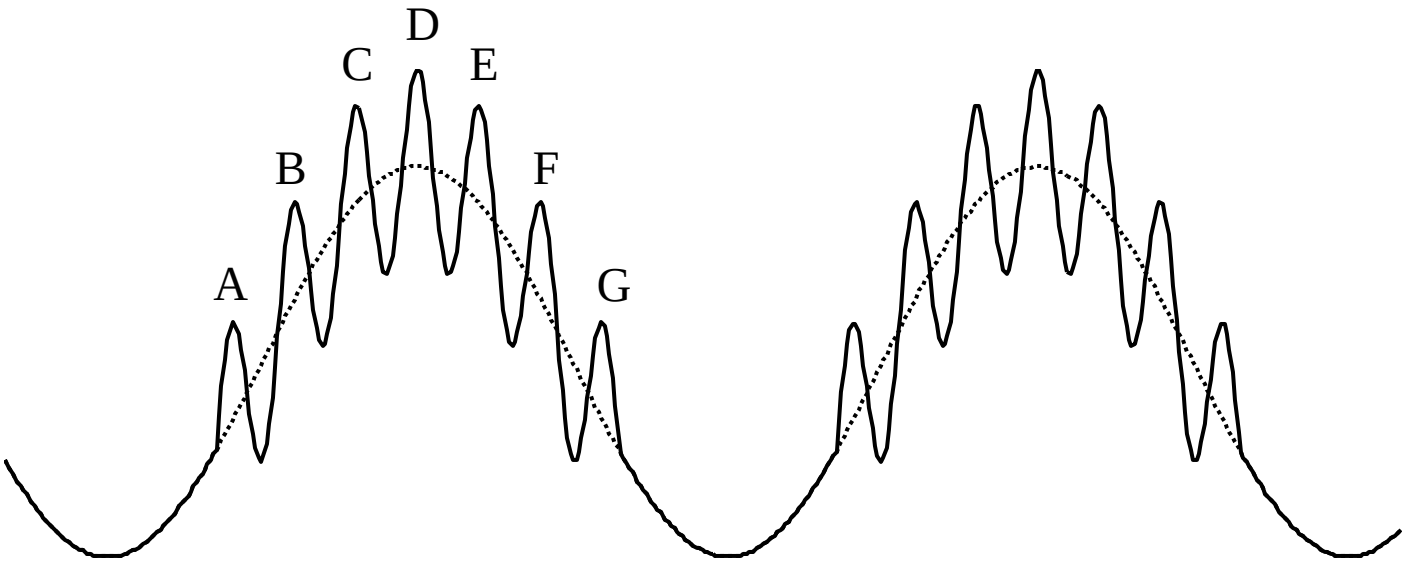
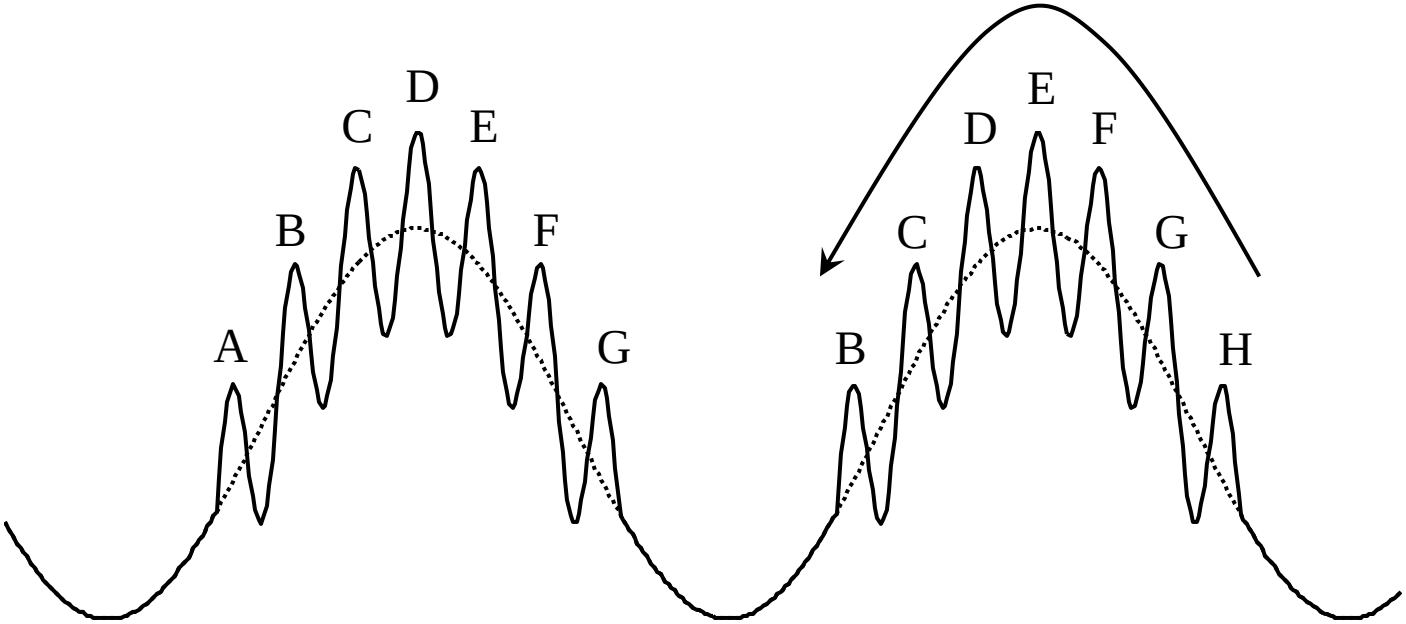


Binding and segmentation: gamma synchronization (>25 Hz) in theta phases (4-8 Hz)

Lisman and Idiart, 1995

NEURAL ASSEMBLY

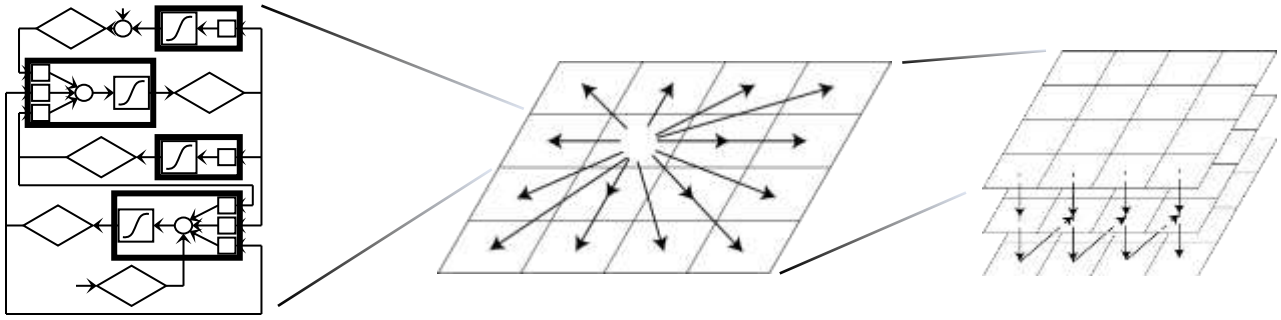
Ensemble of neurons that take part to the realization of a single cognitive task



Precession of the theta phase during task execution (e.g. rat travelling through maze)

Skaggs et al., 1996

A MULTI-SCALE PERSPECTIVE

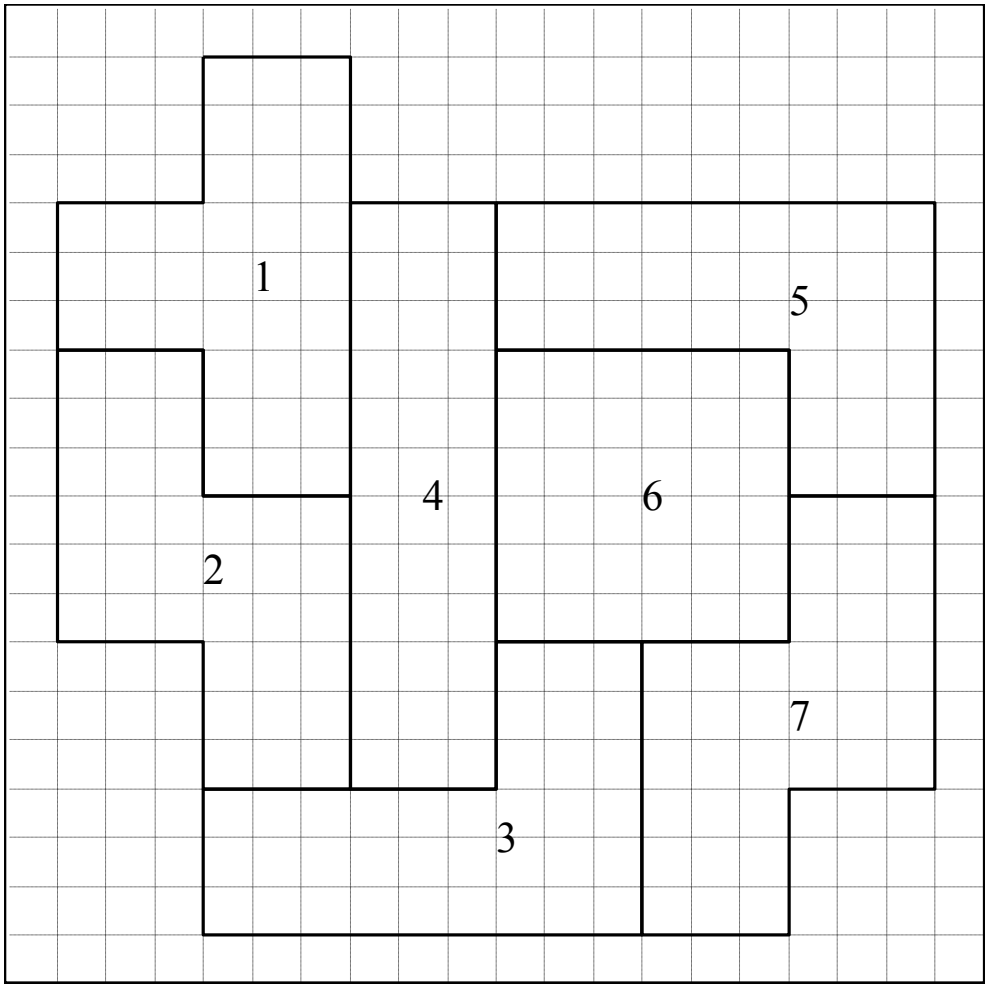


Cortical column

Neural layer

Neural network

THE OBJECTS

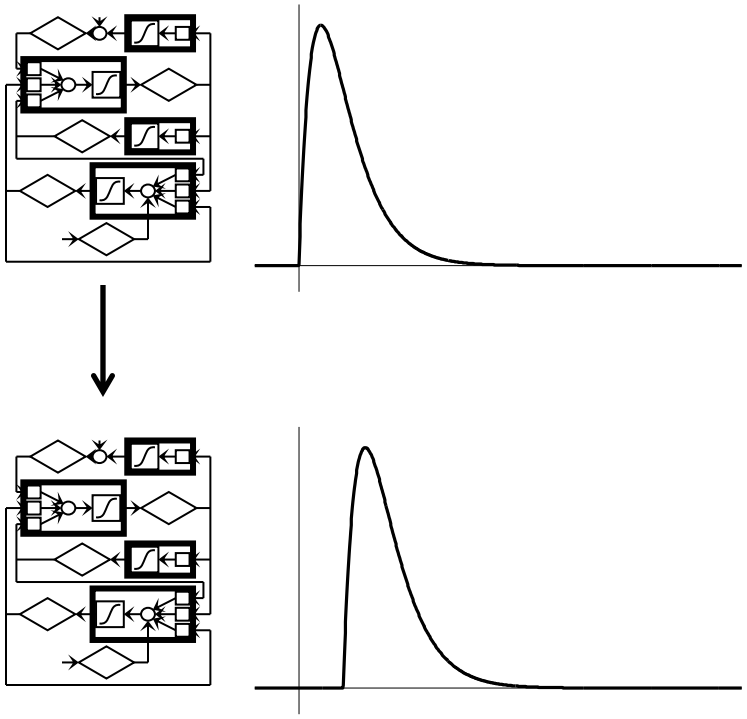


Miller, 1956

TRAINING RULES

Hebb rule

Coherent spikes
reinforce connections



TRAINING RULES

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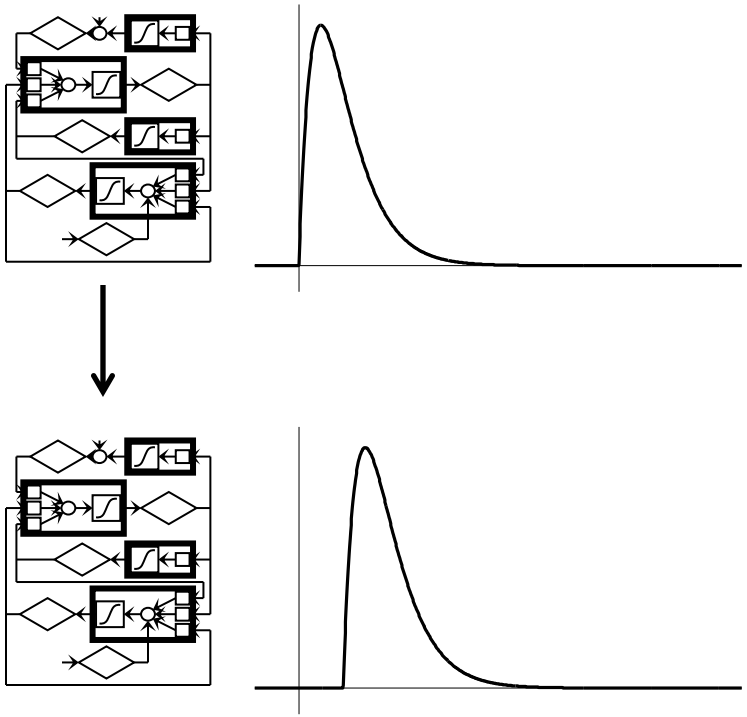
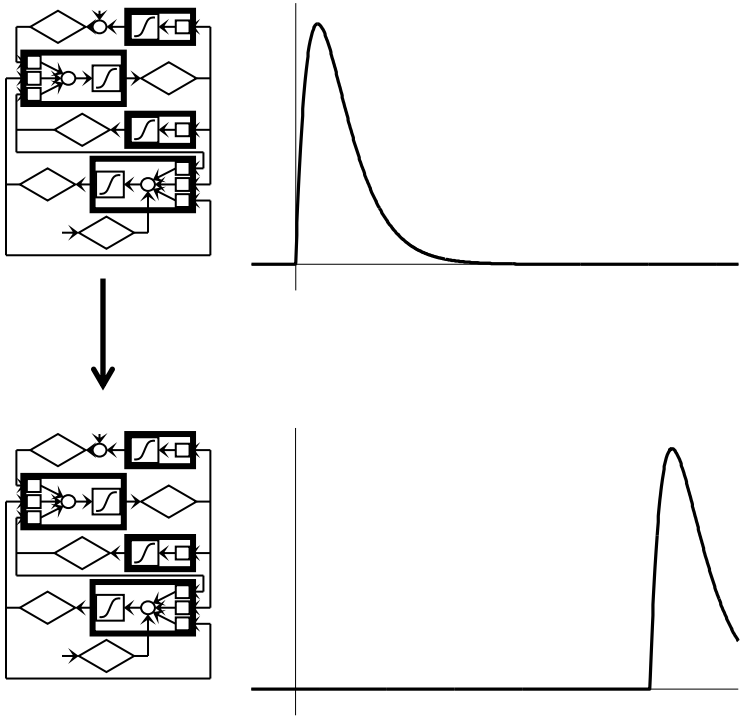
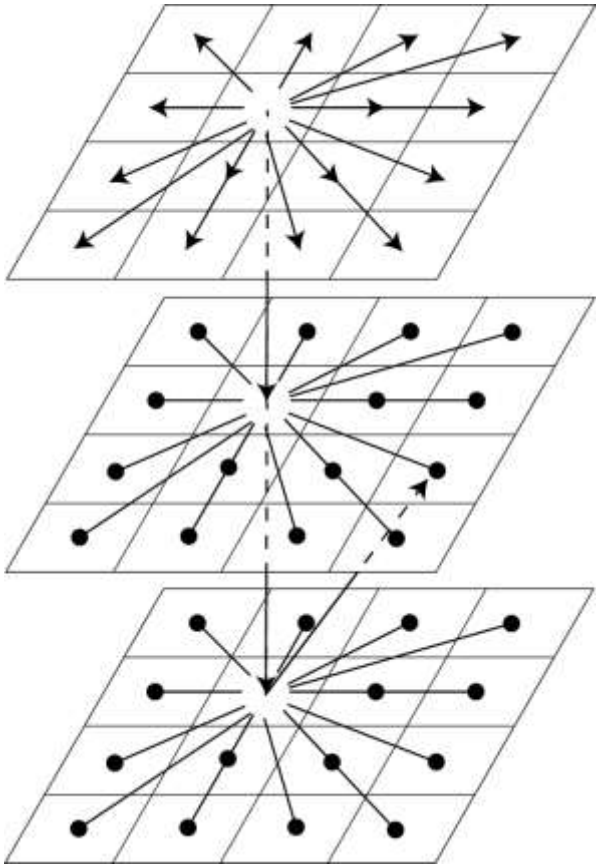


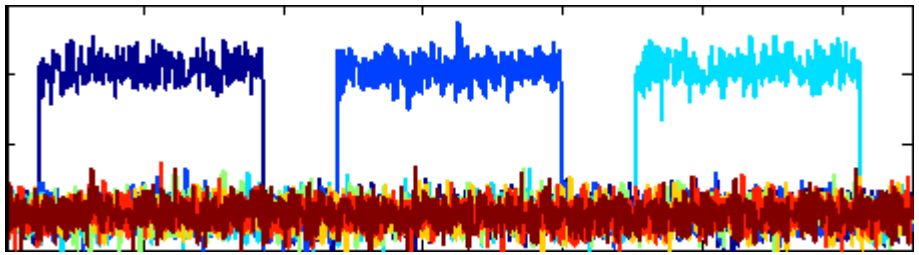
Anti-Hebb rule

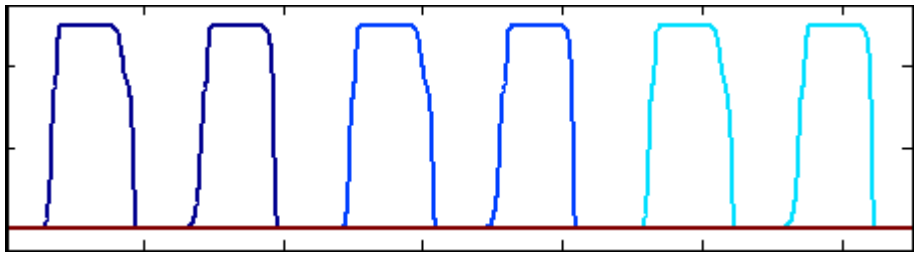
Incoherent spikes
reinforce connections

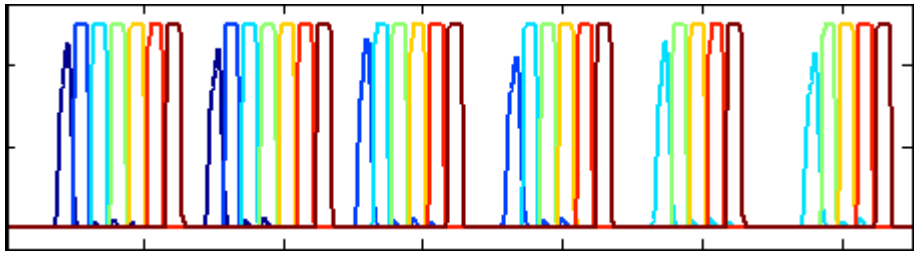


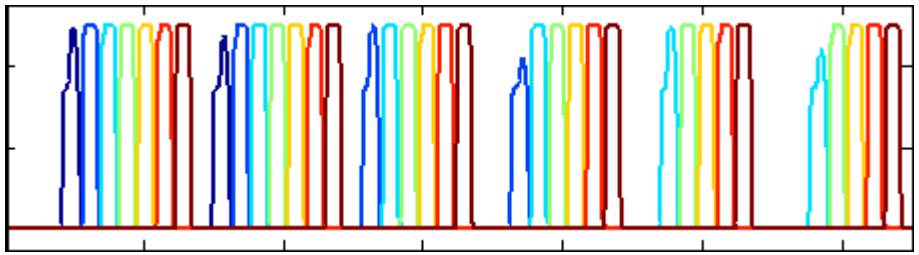
SEQUENCE AND PRECESSION

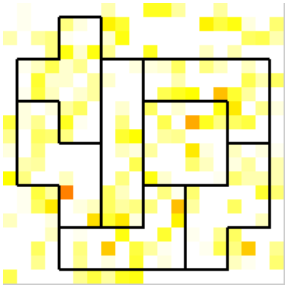


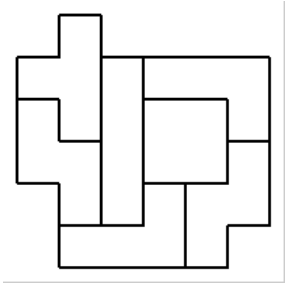


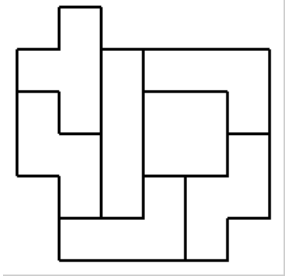


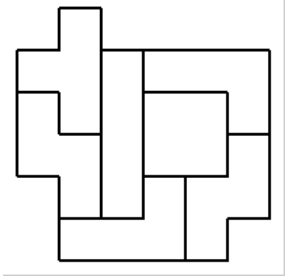




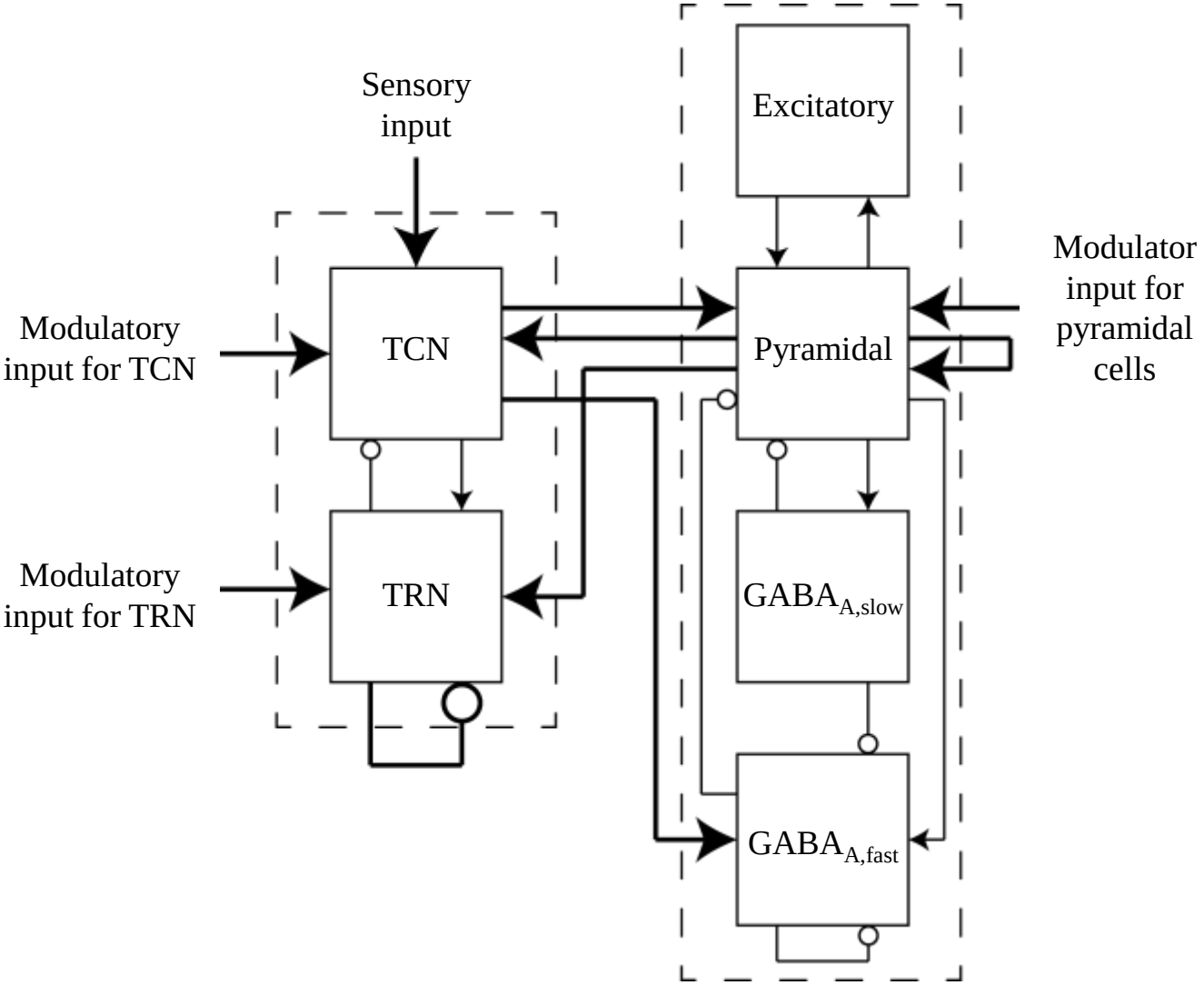




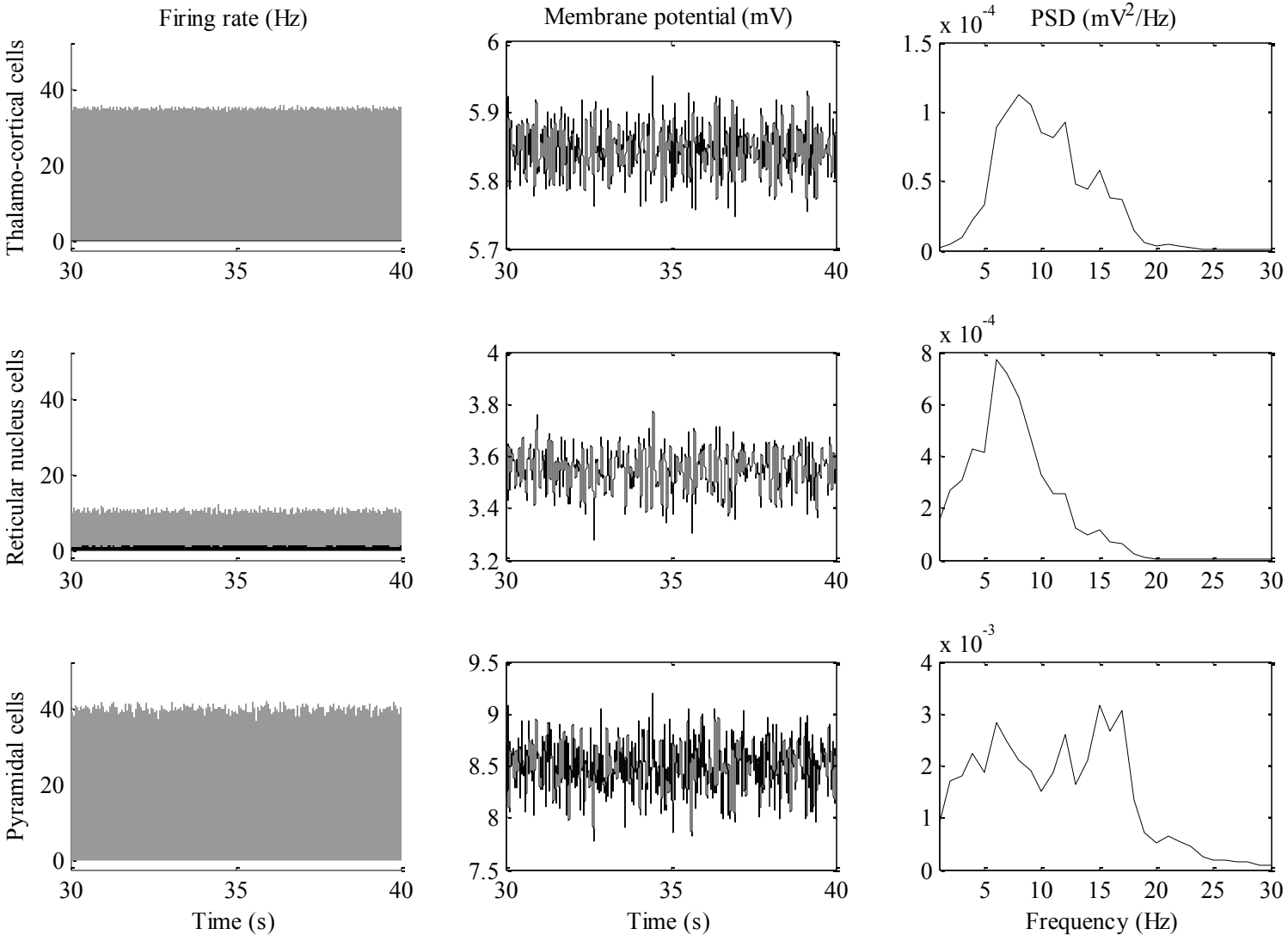




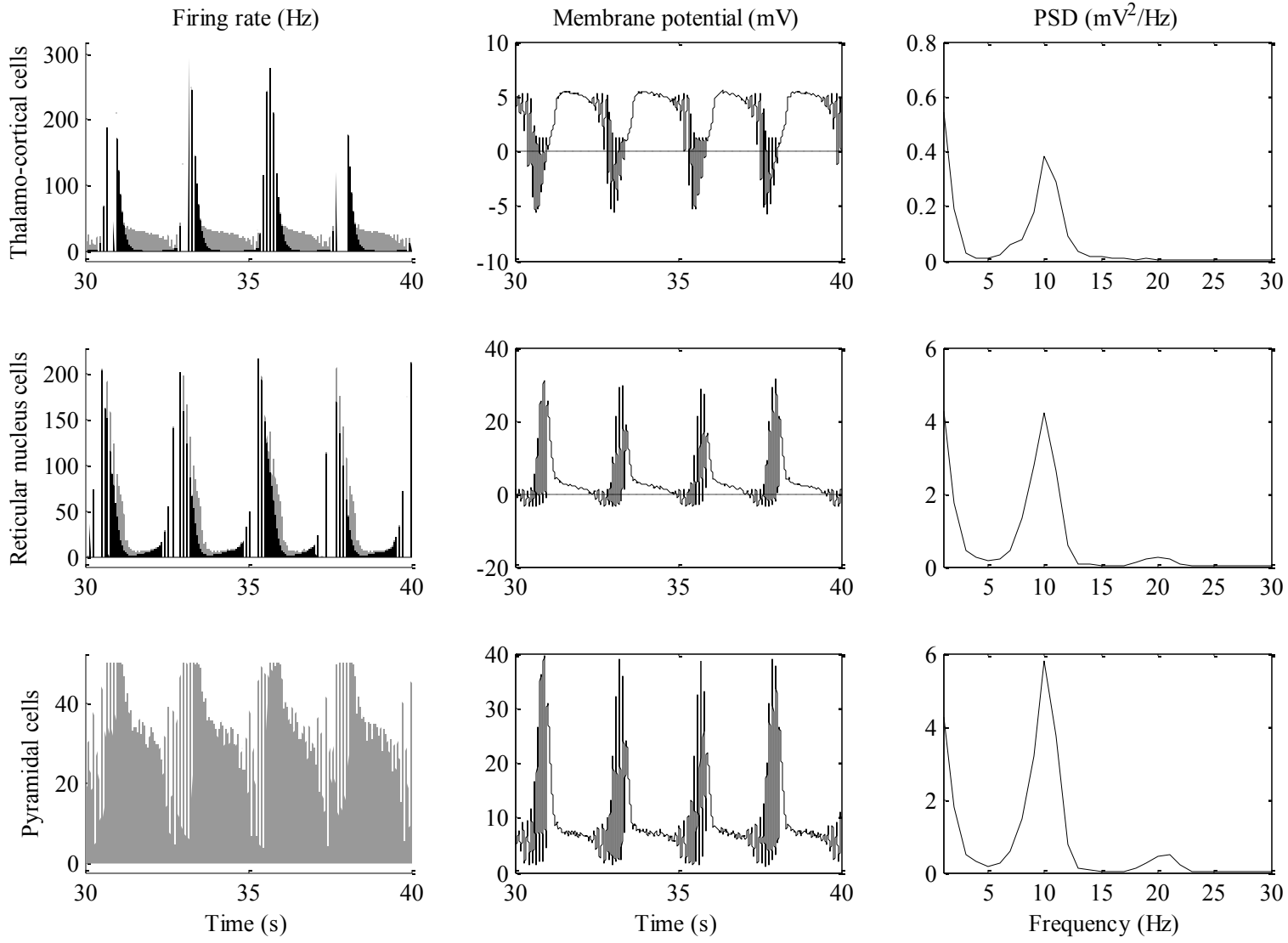
THALAMO-CORTICAL MODEL



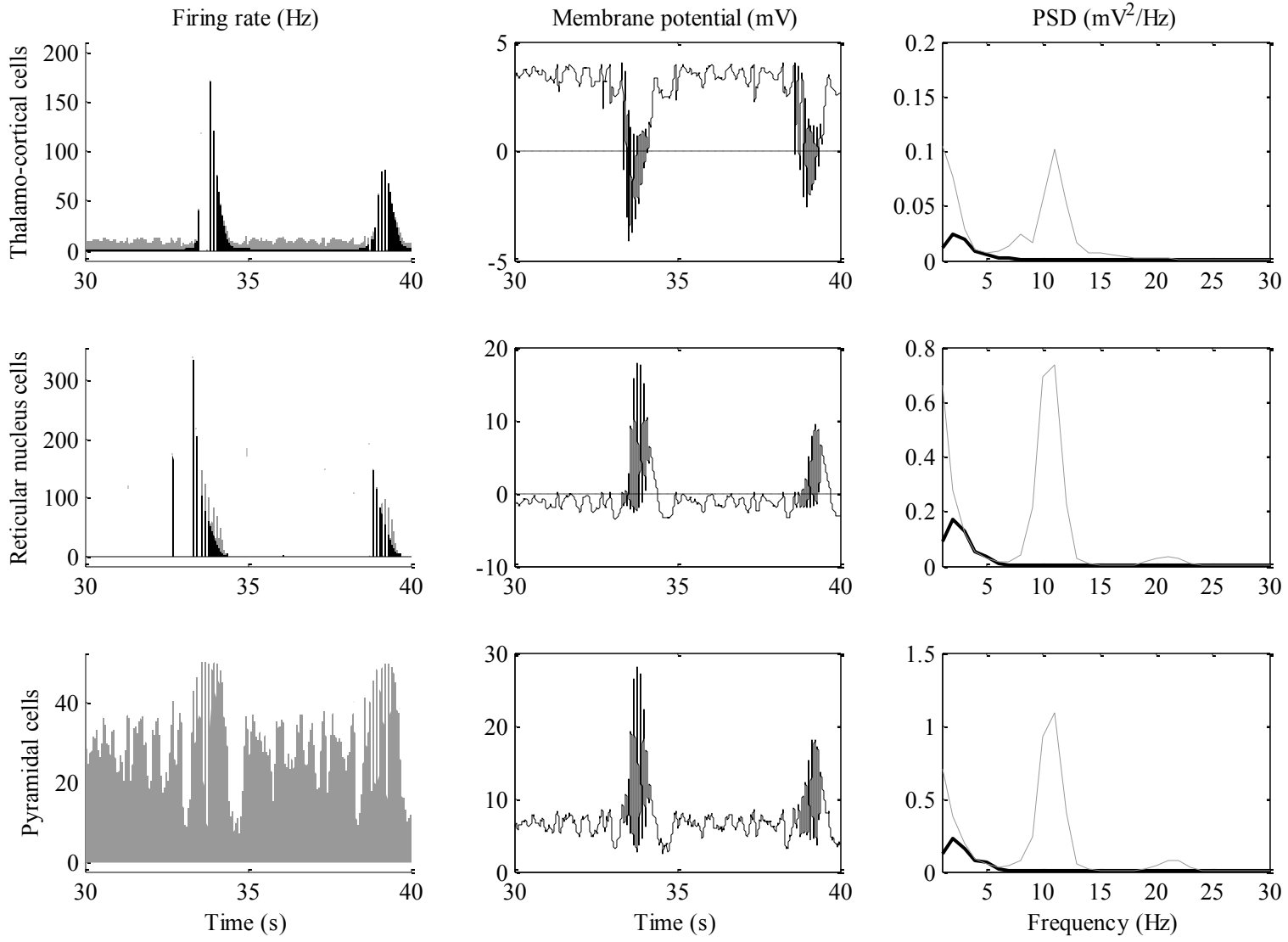
BETA ACTIVITY



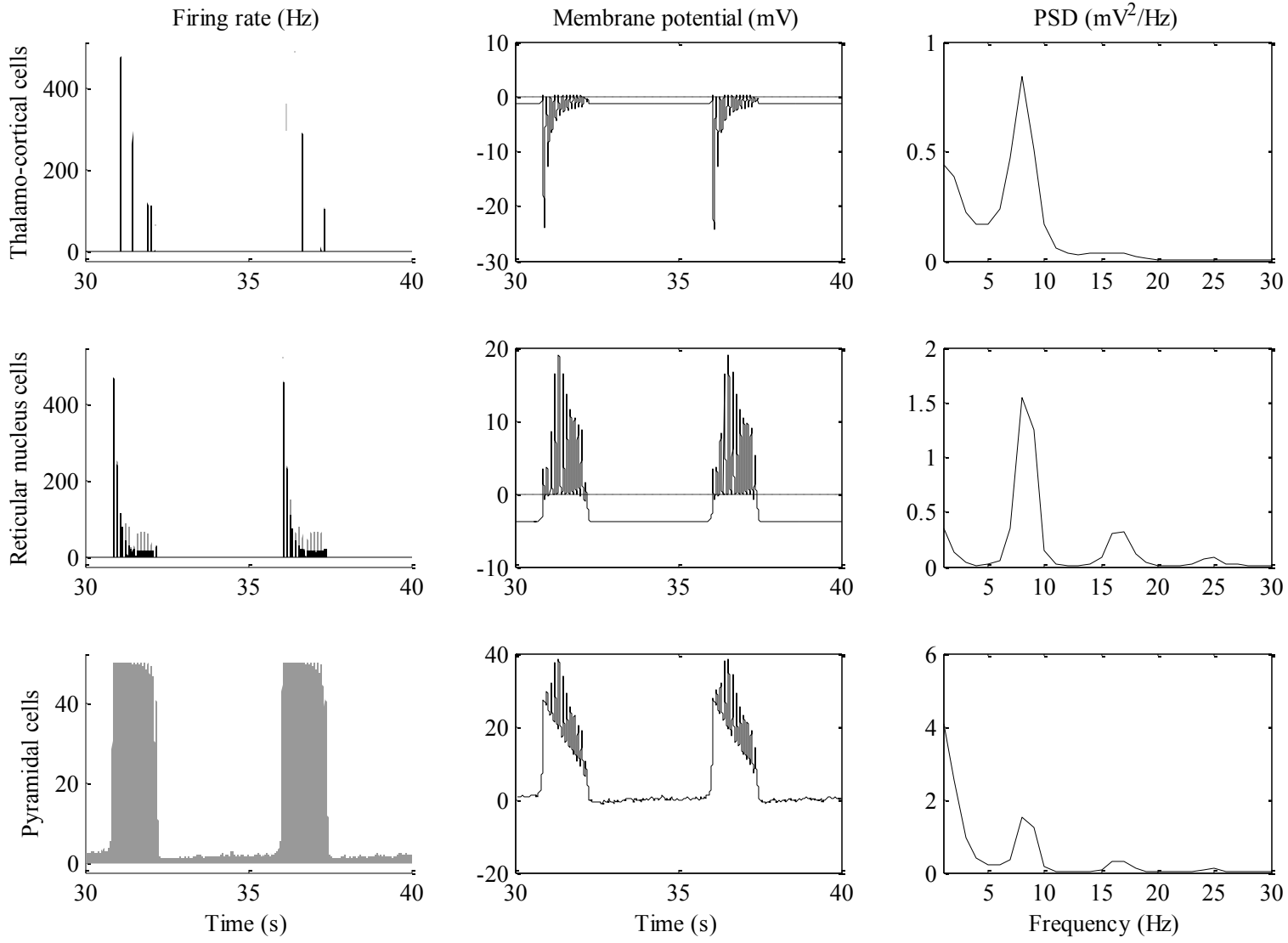
SPINDLES


Firing rate (Hz)
Membrane potential (mV)
PSD (mV^2/Hz)
Thalamo-cortical cells
Reticular nucleus cells
Pyramidal cells
Time (s)
Time (s)
Frequency (Hz)

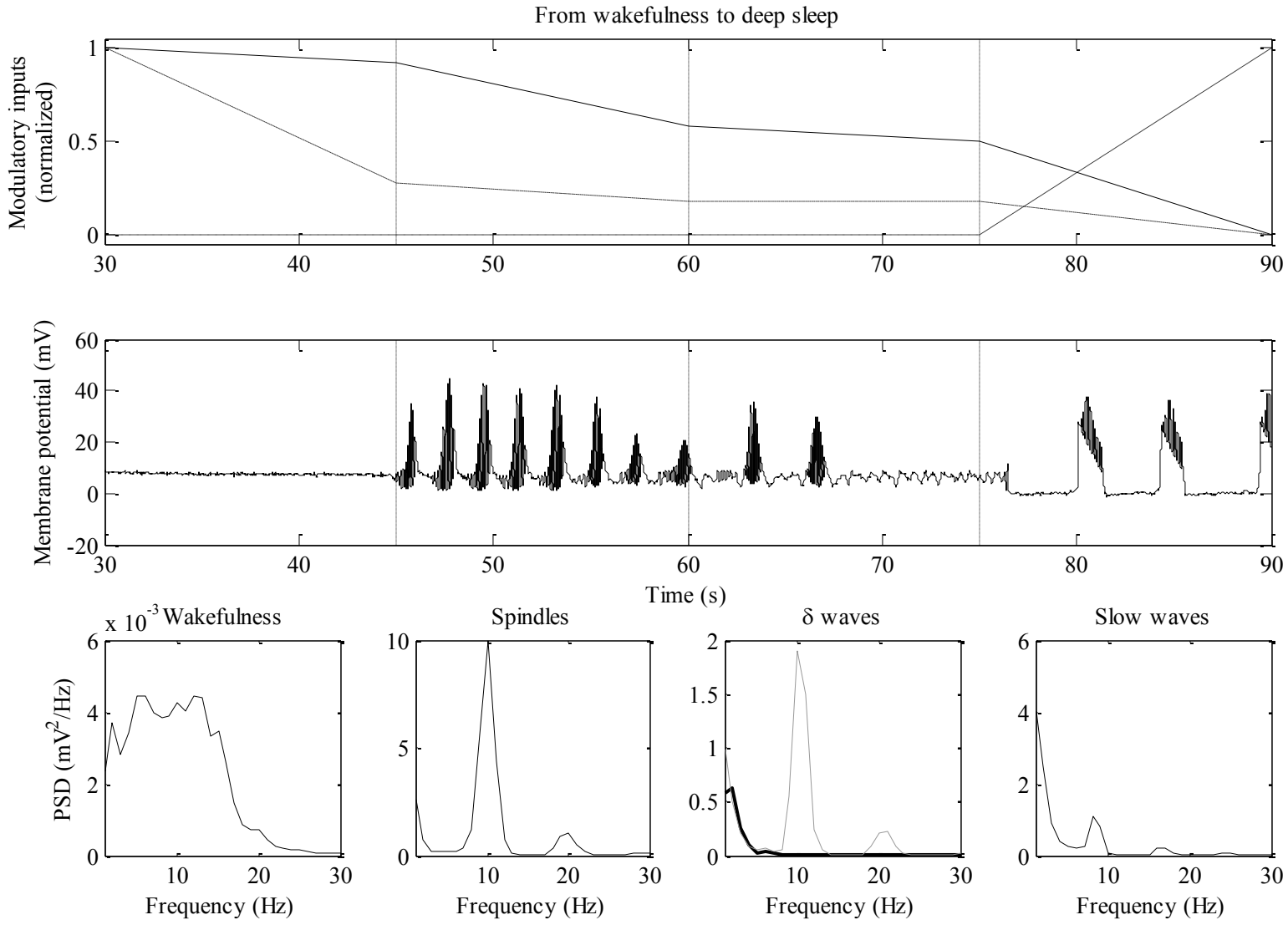
DELTA ACTIVITY



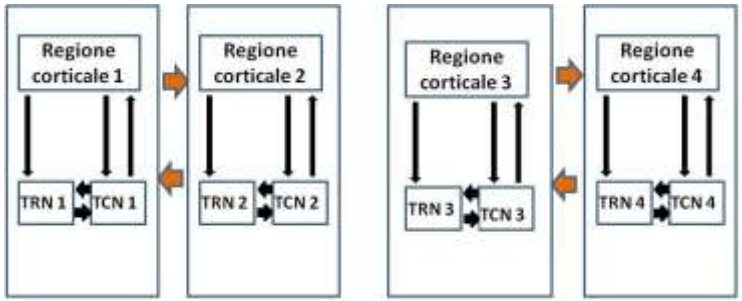
SLOW WAVE SLEEP

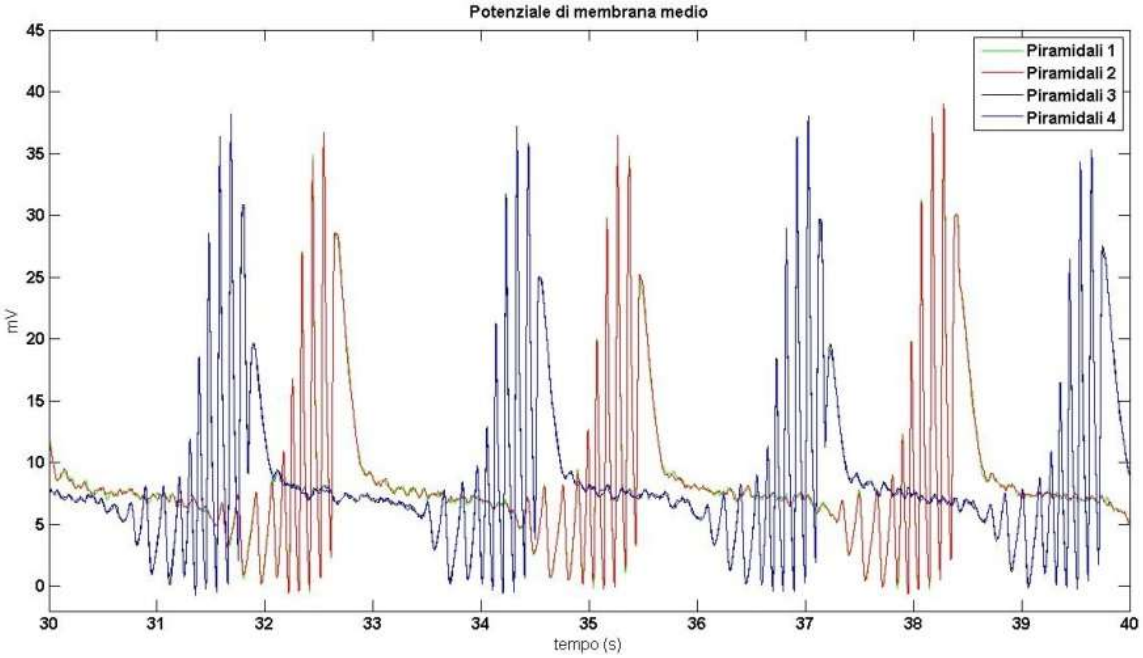


WAVE-SLEEP TRANSITION



REGIONS SYNCHRONIZATION





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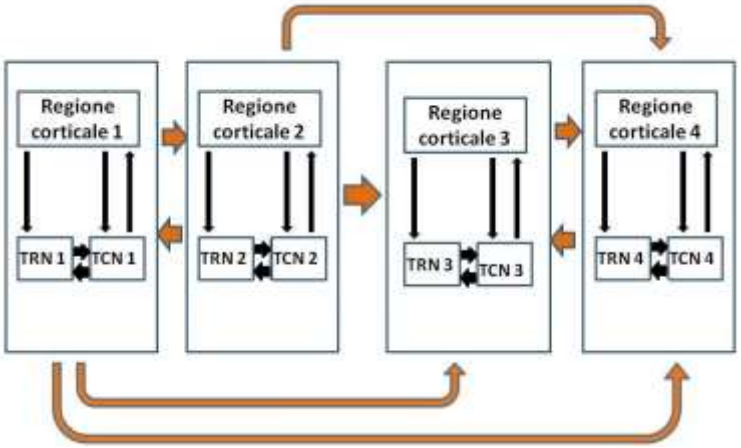

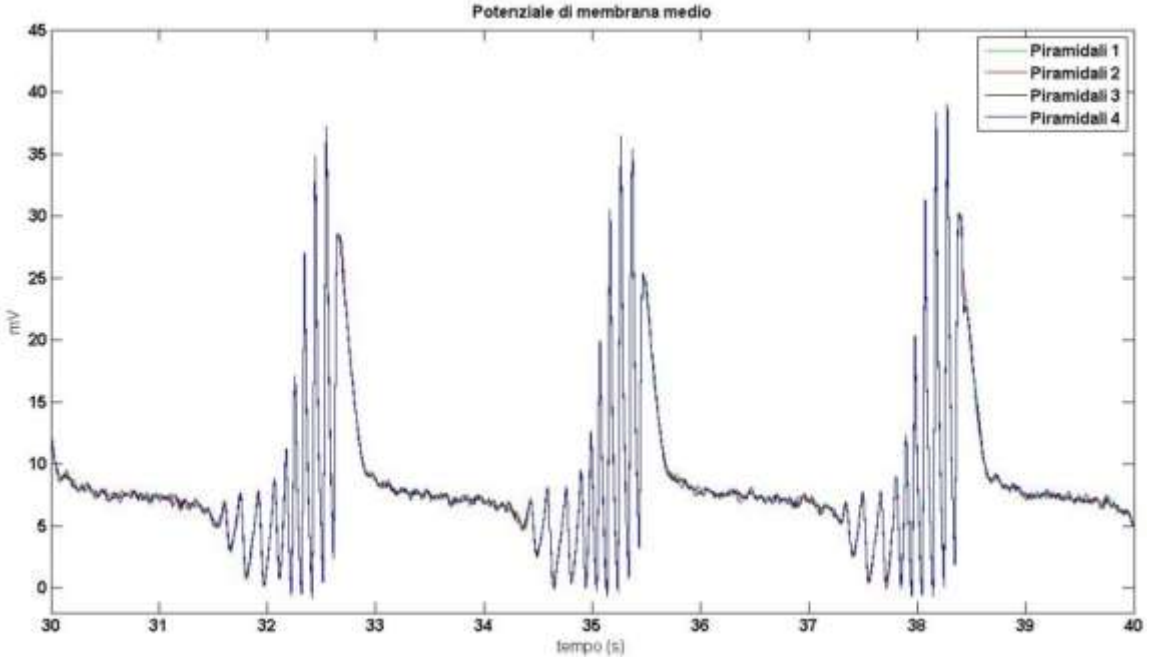

Thank you

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