MODELLING OF *glissando* PATTERNS IN THE SMALL NEURONAL CIRCUIT

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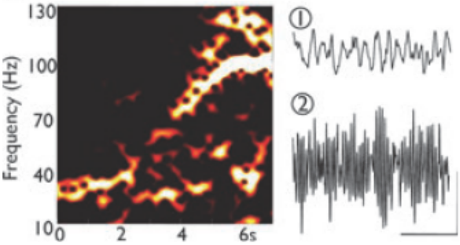
GLISSANDO: EXPERIMENTAL OBSERVATIONS

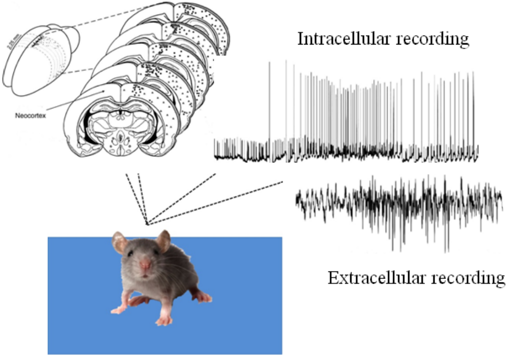
I. Medical investigations



- Glissando is observed in human (rat) neocortex
- Glissando activity occurs in preseizure state (prior to ictal onset) from 1 to 5 s
- It characterized by the oscillating regime with a continuously growing frequency
- It doesn't depend chemical (synaptic) coupling

Marc O. Cunnigham, A. Roopun, I. S. Schofild. Glissandi: transient fast electrocorticographic oscillations of steadily increasing frequency, explained by temporally increasing gap junction conductance.*Epilepsia* **53** (2012), 1205

II. *In vitro* experiments



Occurrence of very fast oscillations (VFO, from ~70 to ~200 Hz)

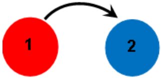
VFO is useful for identifying seizure-onset zones

VFO is normal cortical function pathologically enhanced in epilepsy

Controlled by electrical contacts between neurons

Traub, R.D., Duncan, R., Russell, A.J., Baldeweg, T., Tu, Y., Cunningham, M.O., Whittington, M.A. Spatiotemporal patterns of electrocorticographic very fast oscillations (> 80 Hz) consistent with a network model based on electrical coupling between principal neurons *Epilepsia* **51** (2010), 1587-1597.

NEURONAL MINI CIRCUIT



Rinzel system [Federation Proceedings, 1985]

$$\frac{dv_{1,2}}{dt} = I - g_{Na}(1-w_{1,2})(v_{1,2}-v_{Na})m_\infty(v_{1,2})^3 - \\ -g_K(w_{1,2}/S)^4(v_{1,2}-v_K) - g_l(v_{1,2}-v_l)$$

$$\frac{dw_{1,2}}{dt} = \varepsilon_{1,2}(w_\infty(v)-w)/\tau_{1,2}(v),$$

$$\begin{aligned} w_\infty(v) &= g\frac{S}{1+S^2}\left[n_\infty(v)+ +S(1-h_\infty(v))\right], \\ m_\infty(v) &= \frac{a_m(v)}{a_m(v)+b_m(v)}, \\ n_\infty(v) &= \frac{a_n(v)}{a_n(v)+b_n(v)}, \\ h_\infty(v) &= \frac{a_h(v)}{a_h(v)+b_h(v)}, \end{aligned}$$

$$\begin{aligned} a_m(v) &= 0.1(v+40)/\left(1-\exp(-(v+40)/10)\right), \\ b_m(v) &= 4\exp\left[-(v+65)/18\right], \\ a_h(v) &= 0.07\exp\left[-(v+65)/20\right], \\ b_h(v) &= 1/(1+\exp\left[-(v+35)/10\right)], \\ a_n(v) &= 0.01(v+55)/(1-\exp\left[-(v+55)/10\right]), \\ b_n(v) &= 0.125\exp\left[-(v+65)/80\right], \end{aligned}$$

Parametrical elecrical coupling

I.Relaxation time constant

$$\tau_{1,2}(v) = \left(5\exp\left[-(v+100)^2/55^2\right]+1\right)/c_{1,2}$$

II.Time scaling of each cell

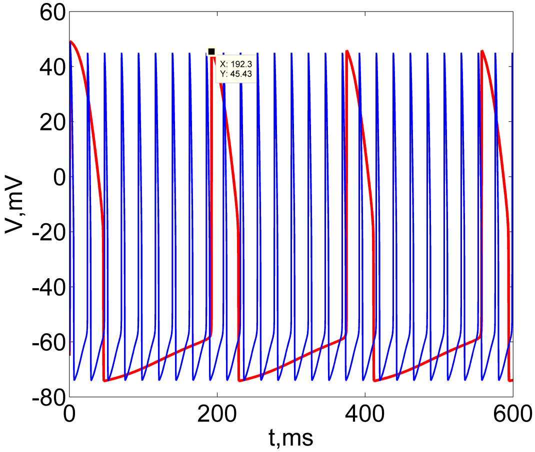
$c_1 = 30$ and $c_2 = 10$

III.Coupling between two oscillators

$$\varepsilon_2 = k_1/(1+\exp(-k_2(v_1+50))).$$

k_1 - scale factor
k_2 -coupling strength

Uncoupled system



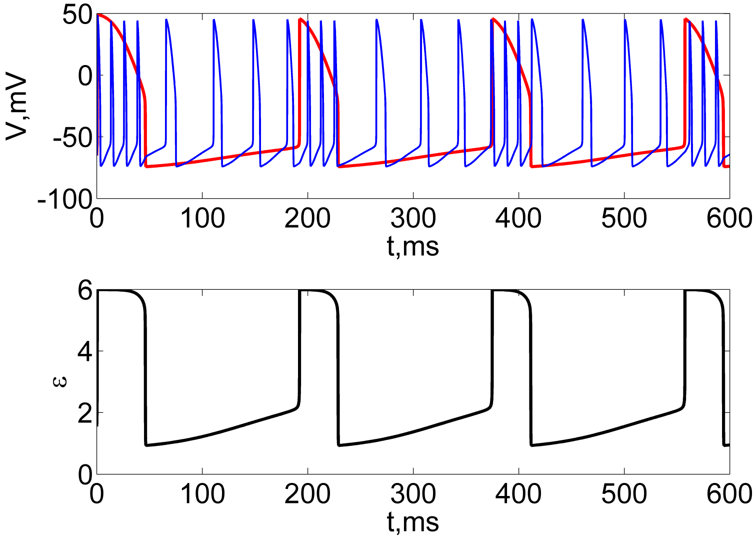
$k_1 = 6.0, k_2 = 0$

Rinzel's parameters

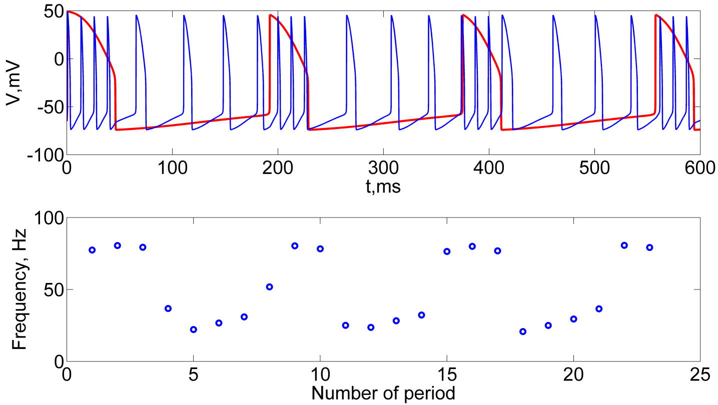
$v_{Na} = 50$ mV,
$v_K = -77$ mV,
$v_l = -54.4$ mV,
$g_{Na} = 120$ mS,
$g_K = 36$ mS, $g_l = 0.3$ mS,
$I = 20$ μA, $h_0 = 0.596$,
$n_0 = 0.317$

$\omega_1 \approx 5$ Hz, $\omega_2 \approx 45$ Hz

COUPLED SYSTEM: GLISSANDO



FREQUENCY DIAGRAM



Conclusions and outlook

- Glissando as a regime of continuous frequency growth could be realized in the minimal neuronal circuit, that consists only of the two cells unidirectionally connected
- This regime could be well reproduced in simple neuronal model (FHN system), Integrate-and-fire, as well as in Rinzel's or Hodgkin-Huxley models due to universality of new type of electrical coupling.
- The presented type of coupling mimics the dynamic of ion channels that allows to describe complex neuronal dynamics in absence of the chemical connections (synapses) in comparison with usual diffusion coupling (gap junction)