Exploring the Chain Model

Matej Fandl Faculty of mathematics, physics and informatics, Comenius University, Bratislava

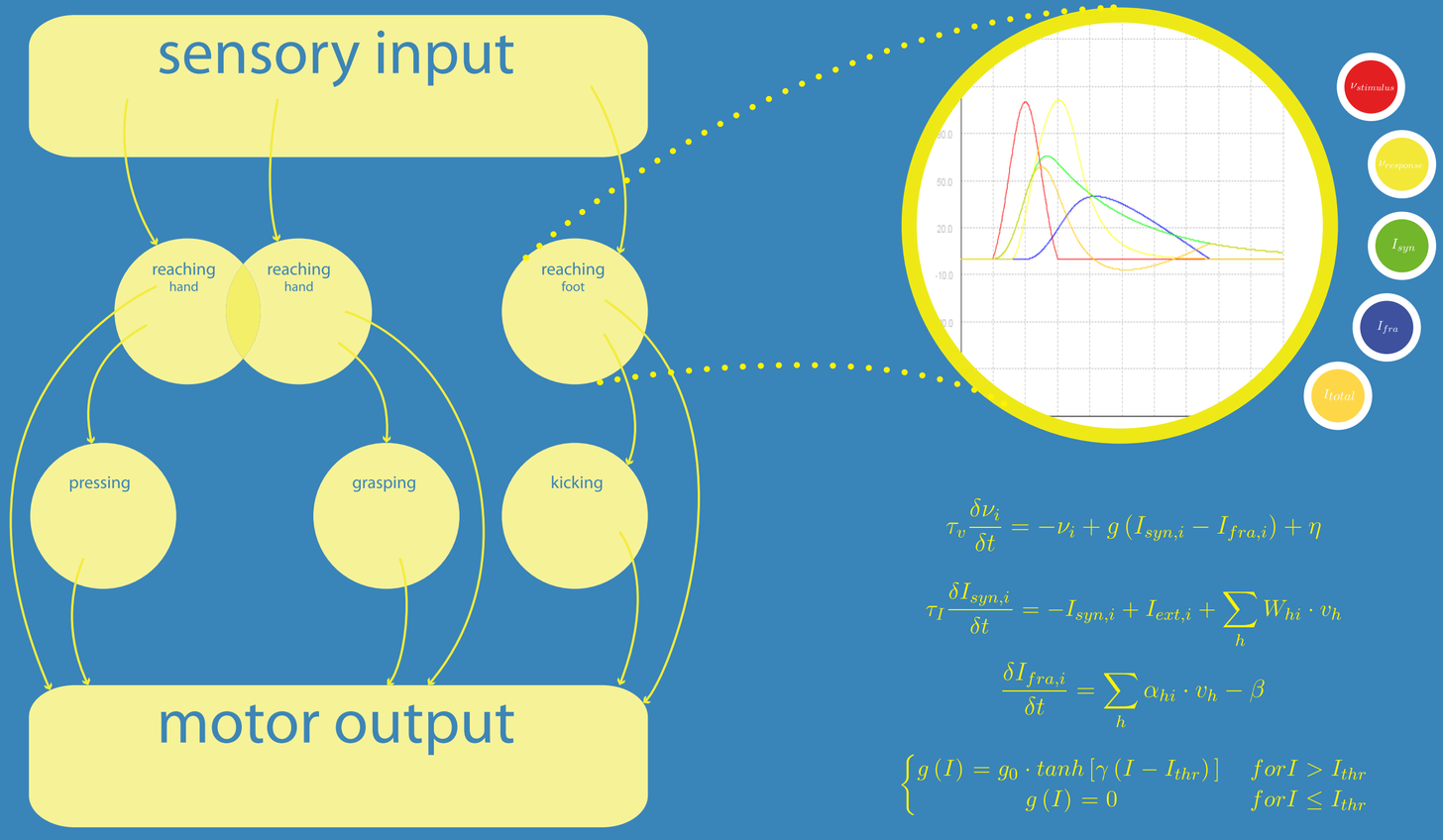
MEi:CogSci

Abstract

Empirical evidence shows, that motor areas of the brain are activated both during action execution and comprehension of action related verbs, or sentences [3]. Interestingly, there is a controversy in form of both facilitation [5], [6] and interference [4] appearing when motor action related sentence comprehension and related motor action execution take place shortly after one another. I replicated a computational chain model proposed by Chersi et al.[1], which attempts to explain this behavior.

The Chain Model

Δ different activation patterns of neurons encoding the same motor act according to the goal of sequence they are part of
Δ neuronal pools encode simple motor acts
Δ chains of these pools encode short habitual action sequences
Δ sentence comprehension or action execution correspond to action propagation within specific chains
Δ 6 pools, 3 chains
Δ pools encoding the same motor act using the same effector share a portion of their neurons



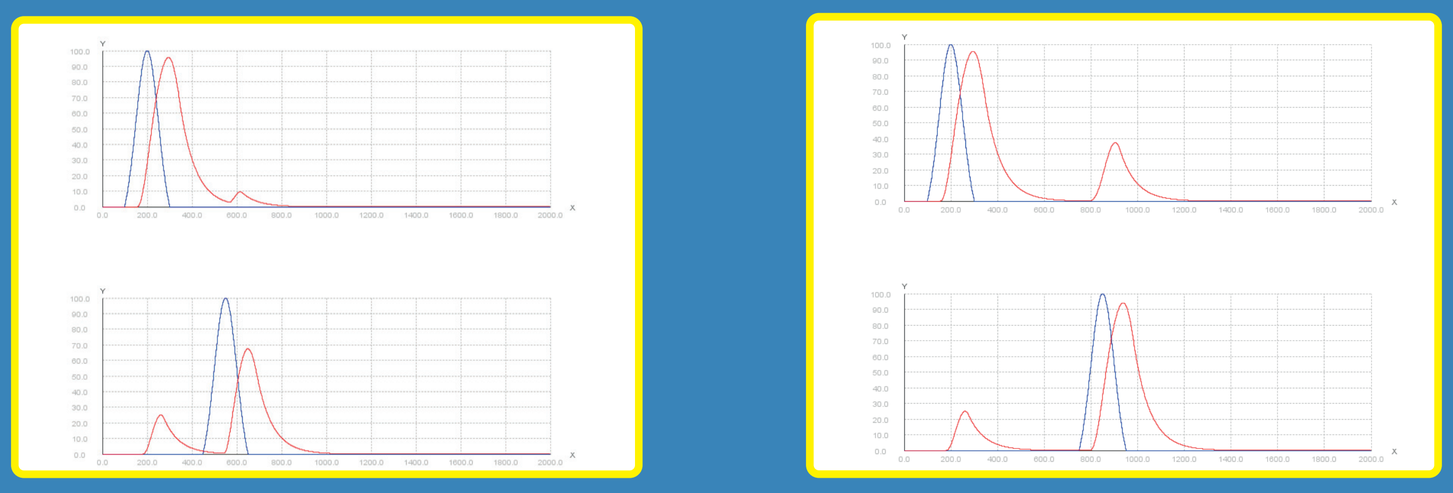
$$\tau_v \frac{\delta \nu_i}{\delta t} = -\nu_i + g\left(I_{syn,i} - I_{fra,i}\right) + \eta$$

$$\tau_I \frac{\delta I_{syn,i}}{\delta t} = -I_{syn,i} + I_{ext,i} + \sum_h W_{hi} \cdot v_h$$

$$\frac{\delta I_{fra,i}}{\delta t} = \sum_h \alpha_{hi} \cdot v_h - \beta$$

$$\begin{cases} g(I) = g_0 \cdot tanh\left[\gamma\left(I - I_{thr}\right)\right] & for I > I_{thr} \\ g(I) = 0 & for I \leq I_{thr} \end{cases}$$

The schema of the implemented model, graph with life cycle of important variables during stimulation of one neuronal pool and the corresponding equations. ν_i is mean firing rate of the i-th pool, τ_v is the corresponding time constant, **g()** is the reponse function, g_0 is the maximum firing rate, **γ** is the steepness of the response, I_{thr} is the firing threshold, $I_{syn,\,i}$ is the total synaptic current, **η** is the spontaneous activity - not modeled in my case, τ_I is the corresponding time constant, W_{hi} is the connection strength from unit h to unit i, $I_{ext,\,i}$ is the external input arriving from areas which are active during action execution or action related sentence comprehension, modelled as bell shaped activity peak lasting 200ms ($\nu_{stimulus}$ in graph), $I_{fra,\,i}$ is the firing rate adaptation current - proportional to firing rate through **α** and decaying with the rate of **β**



Responses of reaching neuronal pools (top - sentence, bottom - act) after early Go (left) and late Go (right) signal presentation.

Implementation

Δ each pool modeled as firing rate model [2] with time-dependent synaptic currents
Δ parameters set according to Chersi et al. [1] with small fitting procedure
Δ trying to reproduce the biological data as close as possible [1]

Experiment

Δ replicated experiment by Chersi et al. [1]
Δ subject: model
Δ two sentences:
  Δ *to grasp the apple* (*reaching with the hand + grapsing*)
  Δ *to kick the ball* (*reaching with the foot + hitting*)
Δ motor act to be executed after Go signal is presented (200 - 1200 ms after stimulus onset):
  Δ press a button (*reaching with the hand + pressing*)
Δ interest: the temporal relation of the go signal delay and facilitation/interference

Results

Δ both facilitation and interference in reaction time observed in action reaching pool after the *to grasp the apple* sentence was presented
  Δ facilitation factor of -14 ms
  Δ interference factor of 7 ms
Δ only interference in firing rate observed
Δ facilitation - Go later than 550ms after stimulus onset
Δ interference - Go earlier than 500ms after stimulus onset
Δ neurodynamical factors

Future prospects

This exploration was only the first step in my future plans in the field of cognitive robotics. I believe, that after further investigation, this kind of models can help entangle the wires connecting language and motor areas of the brain and immitation, which could take us another step closer to building robots able to communicate the human way.

Acknowledgements

In first place, I would like to thank Kristína Rebrová for leading me during this project and for her valuable feedback and patience with me. Also, I would like to thank Fabian Chersi for being kind and answering my questions about his model.

References

[1] F. Chersi, S. Thill, T. Ziemke, A. M. Borghi, "Sentence processing: linking language to motor chains", Front. Neurorobotics, vol. 4, no. 4, May 2010

[2] P. Dayan, L. F. Abbott, "Network Models," in Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, MIT Press, 2001, pp. 229-278

[3] F. Pulvermüller, "Brain mechanisms linking language and action", Nat. Rev. Neurosci, vol. 6, no. 7, pp. 576-582, July 2005

[4] G. Buccino et al., "Listening to action related sentences modulates the activity of the motor system: a combined TMS and behavioral study", Cogn. Brain. Res., vol. 24, pp. 355-363, 2005

[5] Pulvermüller et al., "Functional links between motor and language systems", Eur. J. Neurosci, vol. 21, pp. 793-797, 2005

[6] C. Scorolli, A. M. Borghi, "Sentence comprehension and action: effector specific modulation of the motor system", Brain Res., vol. 1130, pp. 119-124, Jan. 2007