A neural model of the development of expertise

Travis DeWolf {tdewolf@uwaterloo.ca}
Chris Eliasmith {celiasmith@uwaterloo.ca}

Centre for Theoretical Neuroscience, University of Waterloo

Introduction

A hallmark of biological systems is the ability to develop expertise through practice. At first, system performance is poor and reliant on constant corrective feedback signals. Through practice proficiency develops, reflected in an increased volume of the associated cortical area (Pascual-Leone, 1995).

(Ashby et al, 2007) proposed that expertise develops through two pathways: A fast loop through direct cortico-cortico connections, and a slower subcortical loop through the basal ganglia. The slow loop uses feedback to converge on a solution and trains the fast loop to respond correctly automatically.

Goal

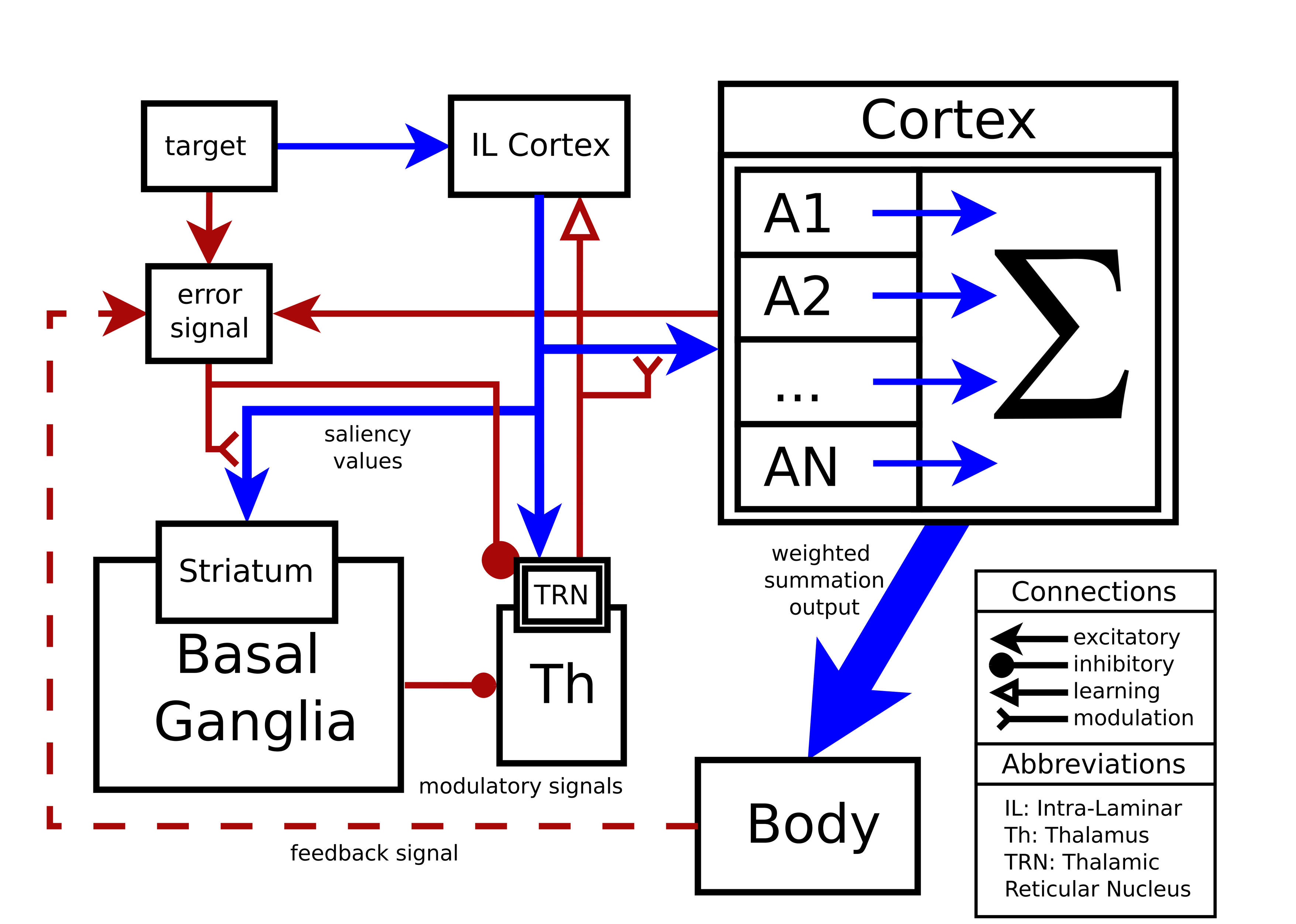
To build a biologically plausible spiking neuron model of the development of expertise that matches experimental data from single-cell recordings to behavior.

Model description

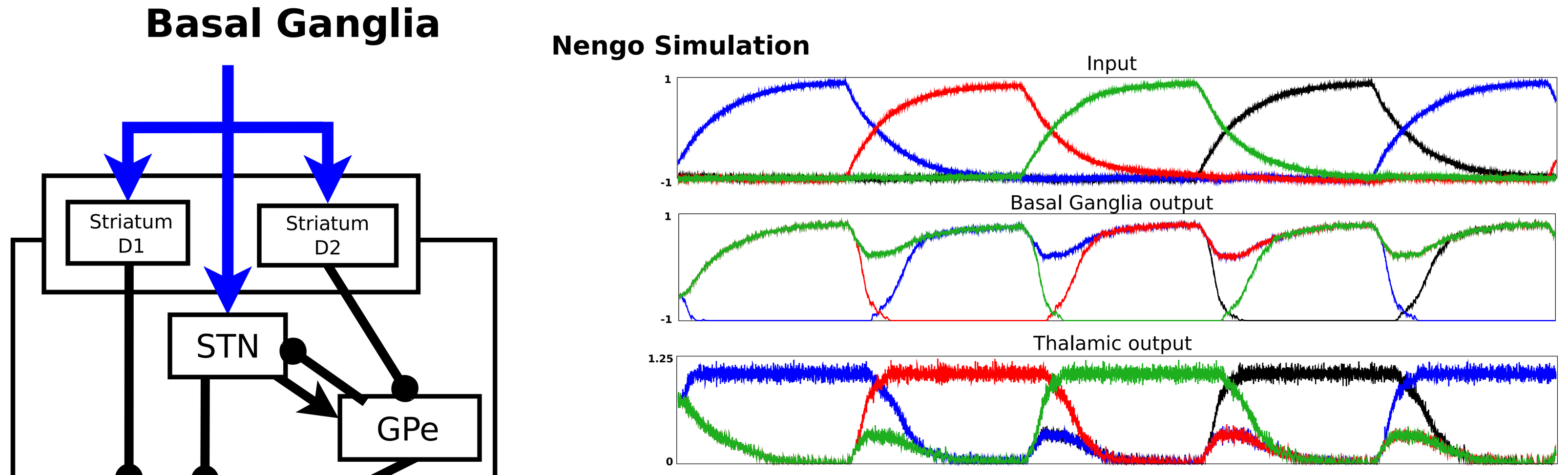
- The infra-limbic cortex stores learned control signals. Presented with a target it projects modulatory weights (blue lines) to the action set.
- The basal ganglia evaluates system output using feedback signals and modulates contribution to the output signal (red lines).
- With repetition the infra-limbic cortex learns to generate the correct action automatically whenever the target signal is presented.
- This transference allows the system to phase out the subcortical loop, and more quickly and consistently execute the task, showing development of expertise.

The model was built and simulated in Nengo (http://www.nengo.ca).

The model

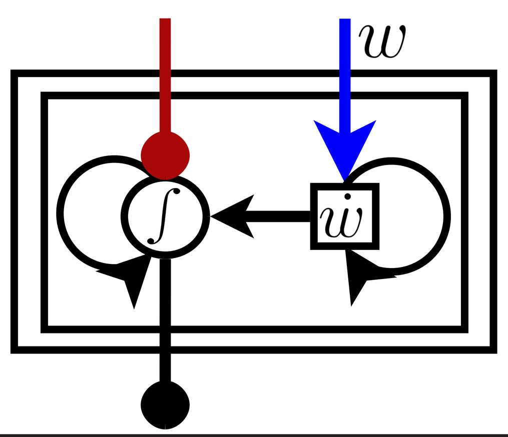


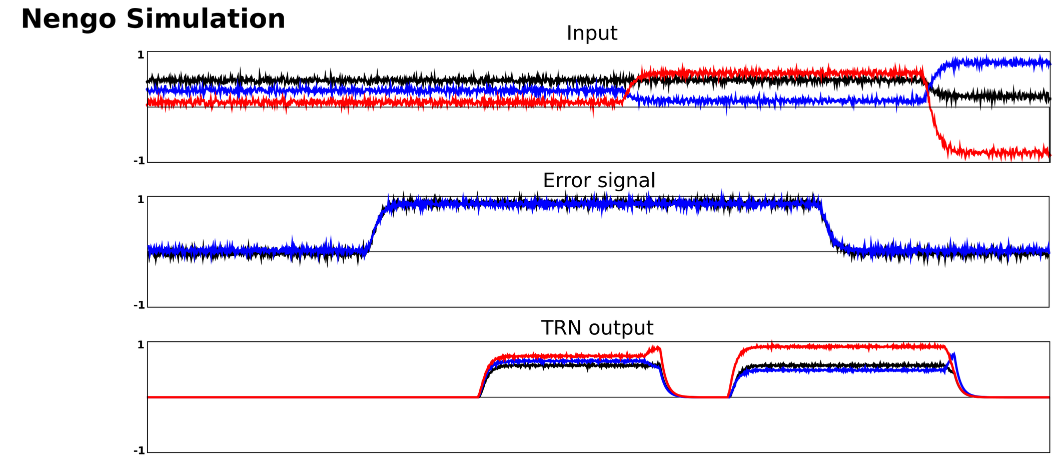
Basal Ganglia



The basal ganglia model used here is based off of the model presented in (Gurney, Prescott, & Redgrave, 2001). A multi-dimensional signal is projected in, and the system performs a soft winner-take-all computation. The output is then inverted in the thalamus and sent back to the cortex.

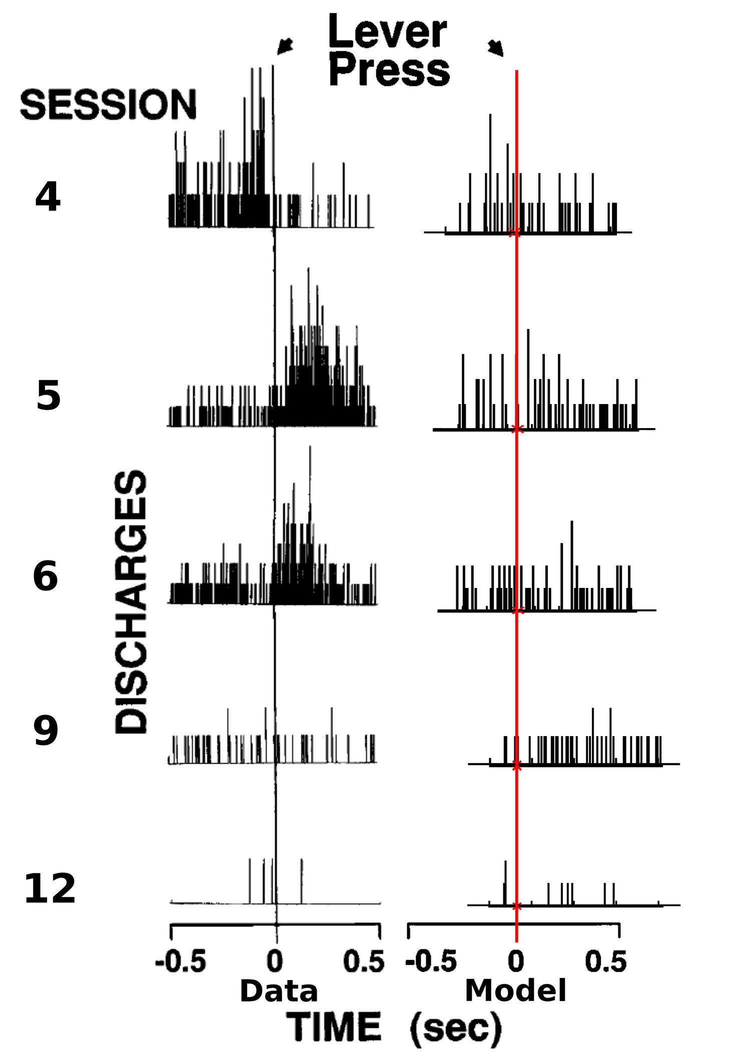
Thalamic Reticular Nucleus



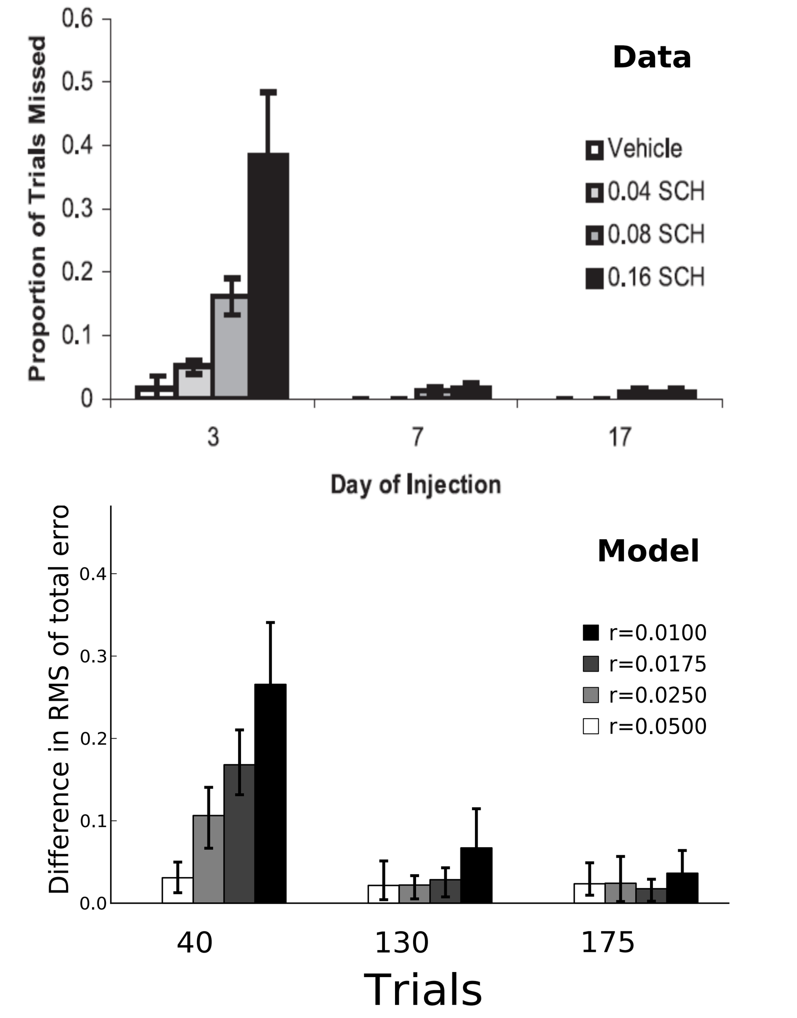


The thalamic reticular nucleus (TRN) supresses subcortical output in this model. When there is a change in cortical input, the TRN inhibits output from the thalamus. This inhibition stops only if an outside error signal is present, indicating that subcortical modulation is required.

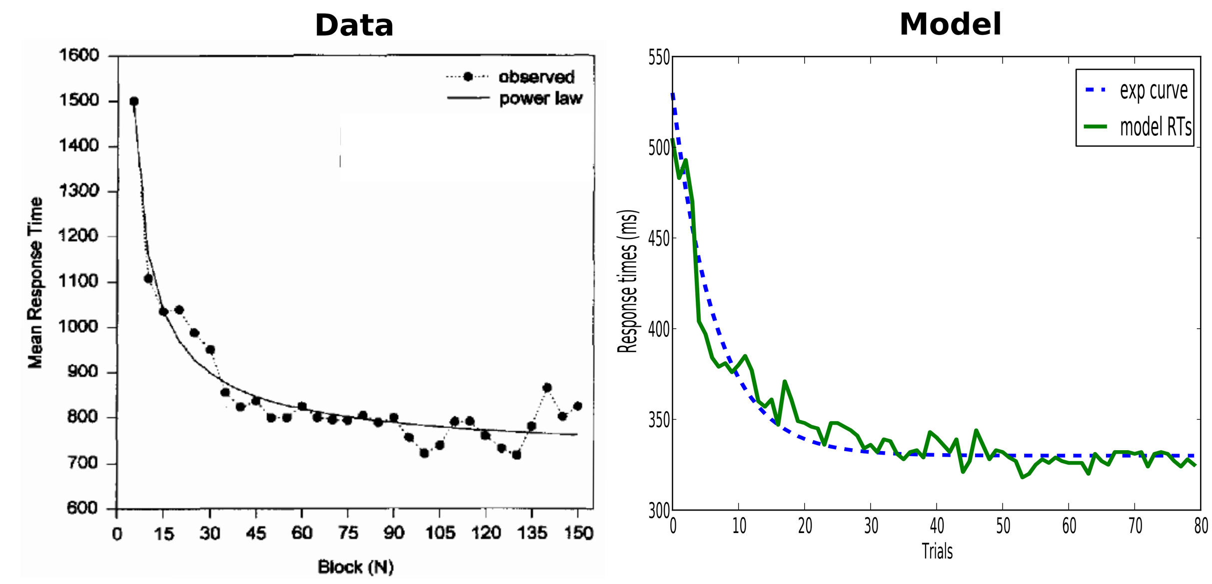
Results



Striatal dropout: At the beginning of learning there is substantial neural activity in the striatum just before the lever press. With practice, the timing of the neural activity shifts to after the press, and eventually disappears (Carelli, Wolske, & West 1997).



Effect of DA throughout learning: During early trials, injecting dopamine (DA) into the striatum causes a significant increase in error. However, as expertise develops and the subcortical system contributes less and less to execution of the task, the effect is reduced (Choi et al, 2005).



Response time profile: Humans have a highly stereotyped response time (RT) profile over the course of learning a skill, where the mean RT exponentially decreases as a function of the amount of practice (Nosofsky & Palmeri, 1997). Here we show the model RT across trials fit to an exponential curve, as seen in humans.

Conclusion

We have presented a biologically plausible model of the development of expertise. The model learns to perform tasks with response time profiles that match human data, and shows the same striatal dropout and DA injection effects seen in rat recordings. We are aware of no other model at this level of complexity.

View this poster online at `http://compneuro.uwaterloo.ca/publications/dewolf2013.html`