A LONG JOURNEY INTO REPRODUCIBLE COMPUTATIONAL NEUROSCIENCE

100% PYTHON ! SPIKE FREE !

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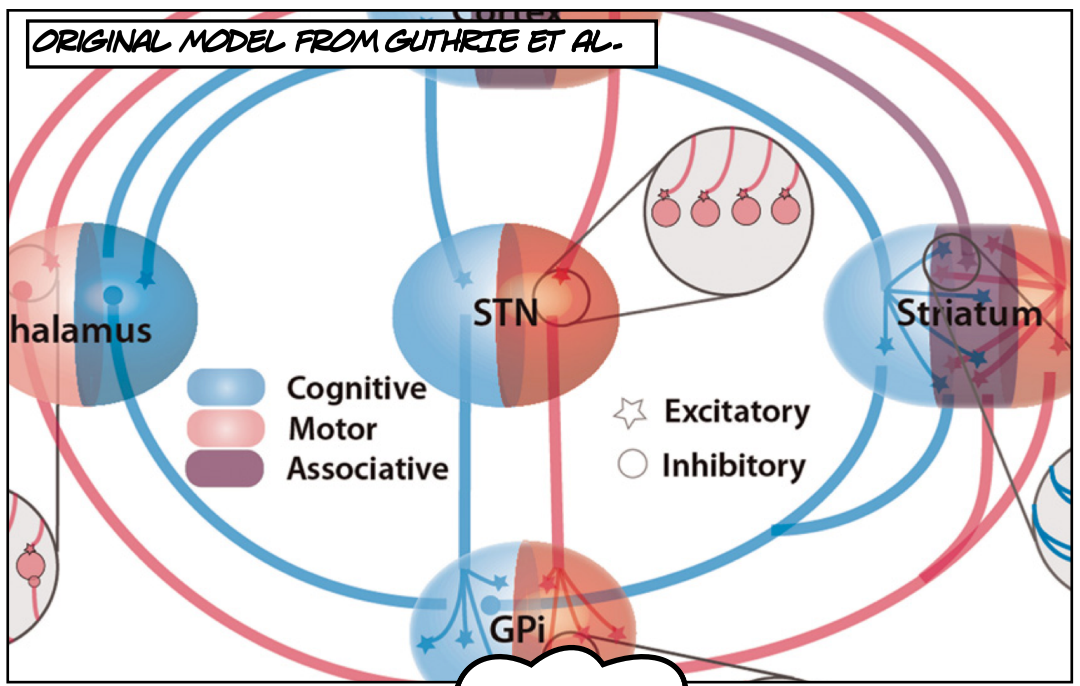
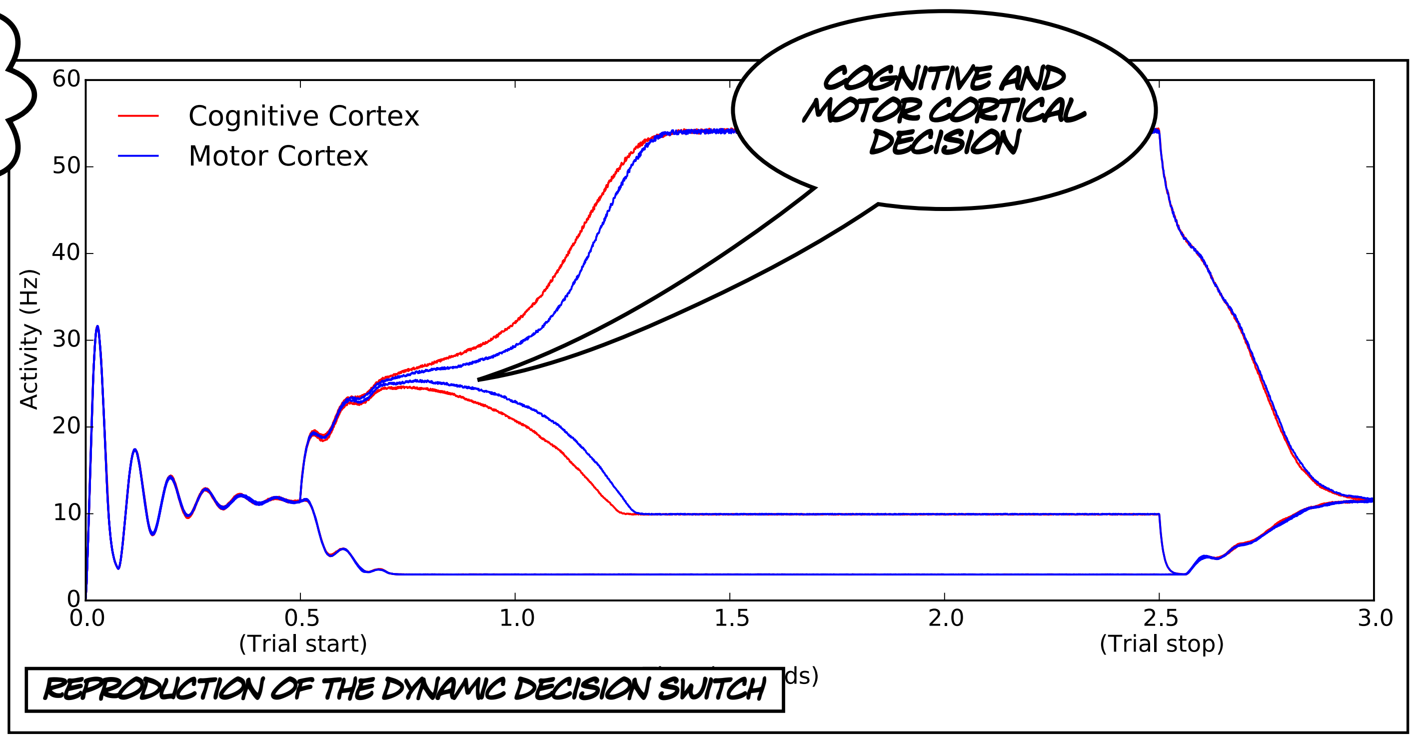
ORIGINAL MODEL FROM GUTHRIE ET AL.



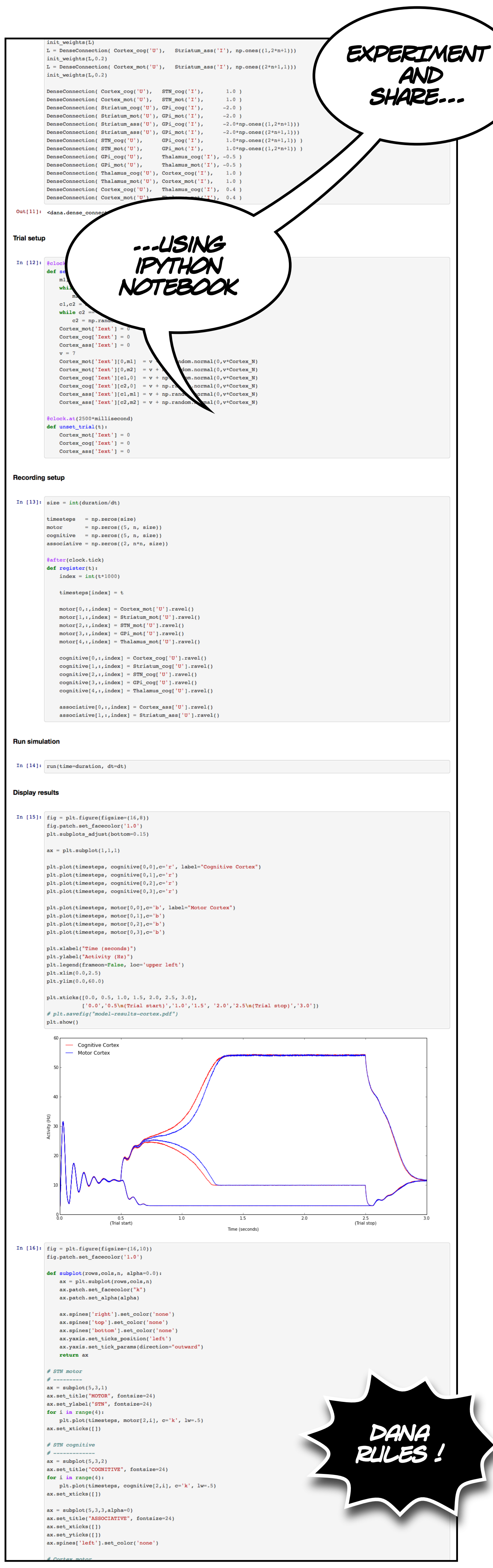
IN A PREVIOUS MODELLING STUDY, LEBLOIS ET AL. (2006) DEMONSTRATED AN ACTION SELECTION MECHANISM IN CORTICO-BASAL GANGLIA LOOPS BASED ON COMPETITION BETWEEN THE POSITIVE FEEDBACK, DIRECT PATHWAY THROUGH THE STRIATUM AND THE NEGATIVE FEEDBACK, HYPERDIRECT PATHWAY THROUGH THE SUBTHALAMIC NUCLEUS. IN GUTHRIE ET AL. (2013), AUTHORS INVESTIGATED HOW MULTIPLE LEVEL ACTION SELECTION COULD BE PERFORMED BY THE BASAL GANGLIA. TO DO THIS, THE MODEL HAS BEEN EXTENDED IN A MANNER CONSISTENT WITH KNOWN ANATOMY AND ELECTRO-PHYSIOLOGY IN THREE MAIN AREAS. UNFORTUNATELY, THE INFORMATION PROVIDED BY THE ARTICLE WERE NOT SUFFICIENT TO REPRODUCE THE MODEL !!!

IF REPRODUCIBILITY IS THE HALLMARK OF SCIENCE, NON-REPRODUCIBILITY SEEMS TO BE THE HALLMARK OF COMPUTATIONAL NEUROSCIENCES. GUTHRIE ET AL. (2013) IS A PROTOTYPIC CASE OF SUCH NON-REPRODUCIBLE COMPUTATIONAL NEUROSCIENCE RESEARCH EVEN THOUGH THE PROPOSED MODEL GIVES A FAIR ACCOUNT OF DECISION MAKING IN THE BASAL GANGLIA COMPLEX. WHILE TRYING TO REPLICATE RESULTS STARTING FROM THE ARTICLE DESCRIPTION, WE SOON REALISED SOME INFORMATION WERE UNDISCLOSED; SOME OTHER WERE AMBIGUOUS AND THERE WERE ALSO SOME FACTUAL ERRORS. EVEN AFTER ACCESSING THE ORIGINAL SOURCES (6000 LINES OF PASCAL), WE WERE STILL UNABLE TO UNDERSTAND HOW THE MODEL WORKED. IN THE END, ONLY THE ORIGINAL MATERIAL (A BINARY EXECUTABLE) AND A DIRECT CONTACT WITH THE AUTHORS ALLOWED US TO ACCESS THE WHOLE PICTURE. AFTER TWO MONTHS OF INTENSIVE REFACTORING, WE WERE FINALLY ABLE TO REPLICATE RESULTS USING ONLY 200 LINES OF PYTHON.

HTTP://GITHUB.COM/ROUGIER/NEUROSCIENCES

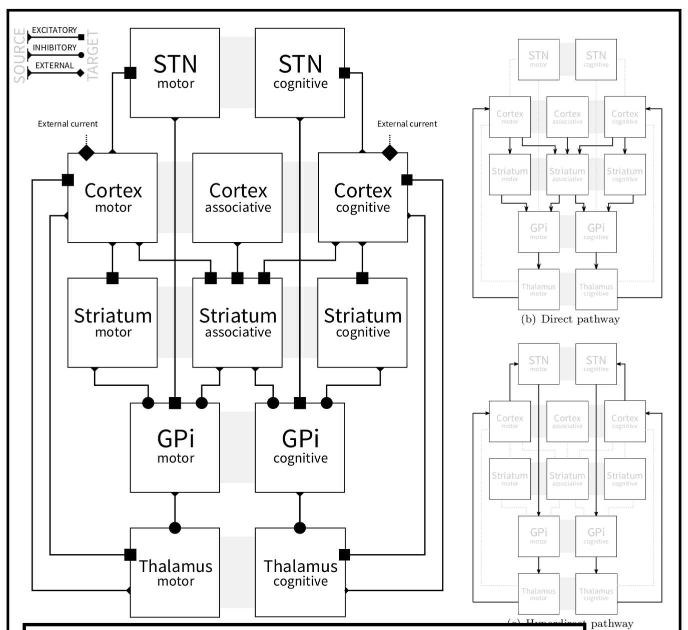


REPRODUCTION OF THE DYNAMIC DECISION SWITCH



FROM THIS EXPERIENCE, WHICH IS UNFORTUNATELY NOT AN ISOLATED CASE, WE WOULD LIKE TO SHARE A SIMPLE MESSAGE WITH THE COMPUTATIONAL NEUROSCIENCE COMMUNITY: "DESIGNING COMPUTATIONAL MODELS IS NOT ALL ABOUT WRITING & RUNNING PROGRAMS". IF A MODEL IS TO BE REVIEWED, UNDERSTOOD, USED, REPLICATED AND INTEGRATED, IT REQUIRES A MINIMAL AMOUNT OF COORDINATED EFFORTS. OR THE MODEL WILL BE SOON FORGOTTEN.

TO BE CONTINUED...



CLEAN AND NON AMBIGUOUS FIGURES

BORING BUT INCREDIBLY USEFUL !

A Model Summary

Populations	Twelve: Cortex (motor, associative & cognitive), Striatum (motor, associative & cognitive), GPi (motor & cognitive), STN (motor & cognitive), Thalamus (motor & cognitive)
Topology	–
Connectivity	one to one, one to many (divergent), many to one (convergent)
Neuron model	Dynamic rate model
Channel model	–
Synapse model	Linear synapse
Plasticity	Reinforcement learning rule
Input	External current in cortical areas (motor, associative & cognitive)
Measurements	Firing rate

B Populations

Name	Elements	Size	Threshold (h)	Noise	Initial state
Cortex motor	Linear neuron	1×4	-3	1.0%	0.0
Cortex cognitive	Linear neuron	4×1	-3	1.0%	0.0
Cortex associative	Linear neuron	4×4	-3	1.0%	0.0
Striatum motor	Sigmoidal neuron	1×4	0	0.1%	0.0
Striatum cognitive	Sigmoidal neuron	4×1	0	0.1%	0.0
Striatum associative	Sigmoidal neuron	4×4	0	0.1%	0.0
GPi motor	Linear neuron	1×4	+10	3.0%	0.0
GPi cognitive	Linear neuron	4×1	+10	3.0%	0.0
STN motor	Linear neuron	1×4	-10	0.1%	0.0
STN cognitive	Linear neuron	4×1	-10	0.1%	0.0
Thalamus motor	Linear neuron	1×4	-40	0.1%	0.0
Thalamus cognitive	Linear neuron	4×1	-40	0.1%	0.0
Values (V_i)	Scalar	4	–	–	0.5

C Connectivity

Source	Target	Pattern	Weight (W)	Gain (G)	Plastic
Cortex motor	Thalamus motor	$(1,i) \rightarrow (1,i)$	1.0	0.4	No
Cortex cognitive	Thalamus cognitive	$(i,1) \rightarrow (i,1)$	1.0	0.4	No
Cortex motor	STN motor	$(1,i) \rightarrow (1,i)$	1.0	1.0	No
Cortex cognitive	STN cognitive	$(i,1) \rightarrow (i,1)$	1.0	1.0	No
Cortex motor	Striatum motor	$(1,i) \rightarrow (1,i)$	$\mathcal{N}(0.5, 0.005)$	1.0	Yes
Cortex cognitive	Striatum cognitive	$(i,1) \rightarrow (i,1)$	$\mathcal{N}(0.5, 0.005)$	1.0	Yes
Cortex motor	Striatum associative	$(1,i) \rightarrow (*,i)$	$\mathcal{N}(0.5, 0.005)$	0.2	Yes
Cortex cognitive	Striatum associative	$(i,1) \rightarrow (i,*)$	$\mathcal{N}(0.5, 0.005)$	0.2	Yes
Cortex associative	Striatum associative	$(i,j) \rightarrow (i,j)$	$\mathcal{N}(0.5, 0.005)$	1.0	Yes
Thalamus motor	Cortex motor	$(1,i) \rightarrow (1,i)$	1.0	1.0	No
Thalamus cognitive	Cortex cognitive	$(i,1) \rightarrow (i,1)$	1.0	1.0	No
GPi motor	Thalamus motor	$(1,i) \rightarrow (1,i)$	1.0	-0.5	No
GPi cognitive	Thalamus cognitive	$(i,1) \rightarrow (i,1)$	1.0	-0.5	No
STN motor	GPi motor	$(1,i) \rightarrow (1,i)$	1.0	1.0	No
STN cognitive	GPi cognitive	$(i,1) \rightarrow (i,1)$	1.0	1.0	No
Striatum cognitive	GPi cognitive	$(i,1) \rightarrow (i,1)$	1.0	-2.0	No
Striatum motor	GPi motor	$(i,1) \rightarrow (i,1)$	1.0	-2.0	No
Striatum associative	GPi motor	$(*,i) \rightarrow (1,i)$	1.0	-2.0	No
Striatum associative	GPi cognitive	$(i,*) \rightarrow (i,1)$	1.0	-2.0	No

D1 Neuron Model

Name	Linear neuron
Type	Rate model
Membrane Potential	$\tau dV/dt = -V + I_{syn} + I_{ext} - h$
	$U = max(V, 0)$

D2 Neuron Model

Name	Sigmoidal neuron
Type	Rate model
Membrane Potential	$\tau dV/dt = -V + I_{syn} + I_{ext} - h$
	$U = V_{min} - (V_{max} - V_{min}) / \left(1 + e^{\frac{V_h - V}{V_c}}\right)$

E Synapse

Name	Linear synapse
Type	Weighted sum
Output	$I_{syn}^{B} = \sum_{A \in sources}(G_{A \rightarrow B} W_{A \rightarrow B} U_A)$

F Plasticity

Name	Reinforcement learning
Type	Delta rule
Delta	$\Delta W_{A \rightarrow B} = \alpha \times PE \times U_B$
	$PE = Reward - V_i$
	$\alpha = 0.01$ if $PE < 0$ (LTD), $\alpha = 0.02$ if $PE > 0$ (LTP)

G Input

Type	Cortical input
Description	A trial is preceded by a settling period (500ms) and followed by a reset period. At time $t = 0$, two shapes are presented in cortical cognitive area ($I_{ext} = 7$ at $\{i_1, i_2\}$) at two different locations in cortical motor area ($I_{ext} = 7$ at $\{j_1, j_2\}$) and the cortical associate area is updated accordingly ($I_{ext} = 7$ at $\{i_1, i_2\} \times \{j_1, j_2\}$).
Timing	Trial start -500ms; Stimulus onset 0; Stimulus offset 2500 ms; Reset 3000 ms

H Measurements

Site	Cortical areas
Data	Activity in cognitive and motor cortex
	Cortico-striatal weights

I Environment

OS	OSX 10.9 (maverick)
Language	Python 2.7.6 (brew installation)
Libraries	Numpy 1.8.1 (pip installation)
	SciPy 0.13.3 (pip installation)
	IPython 1.2.1 (pip installa
	Matplotlib 1.3.0 (pip insta
	DANA 0.5.0 (pip installati
Tools	Safari browser (native)

TABULAR DESCRIPTION OF THE MODEL (SEE NORDLIE ET AL. (2009))

DANA RULES !