

Un nouveau modèle neurocomputationnel d'automatisme en production de séquences

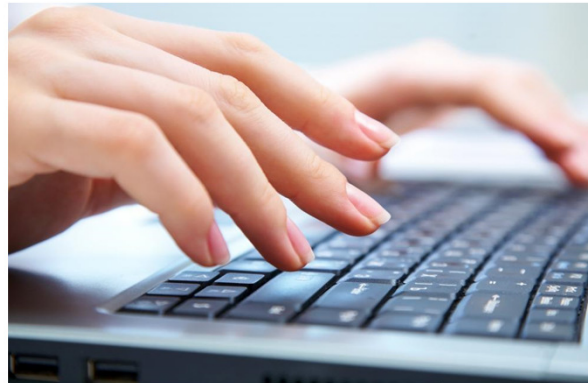
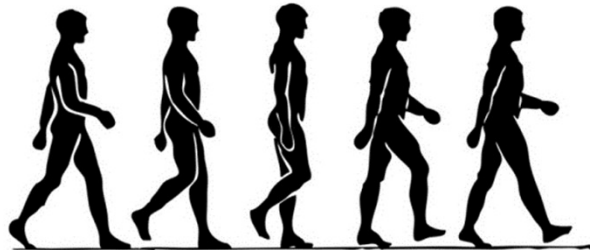
Sébastien Hélie

Department of Psychological Sciences

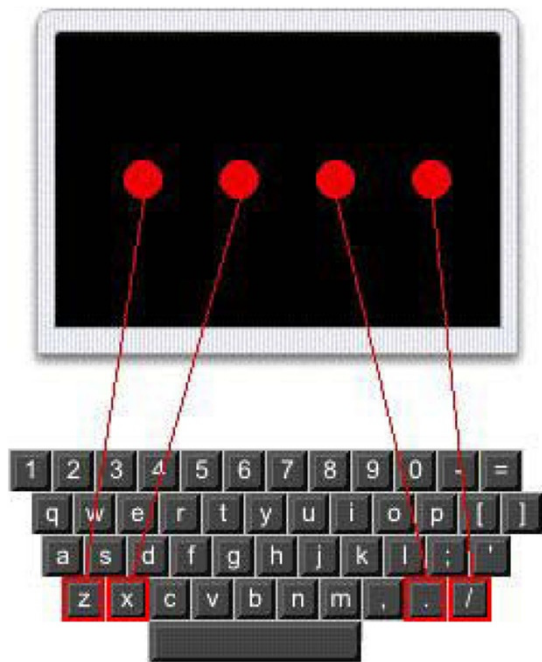
Purdue University

Apprentissage de séquences

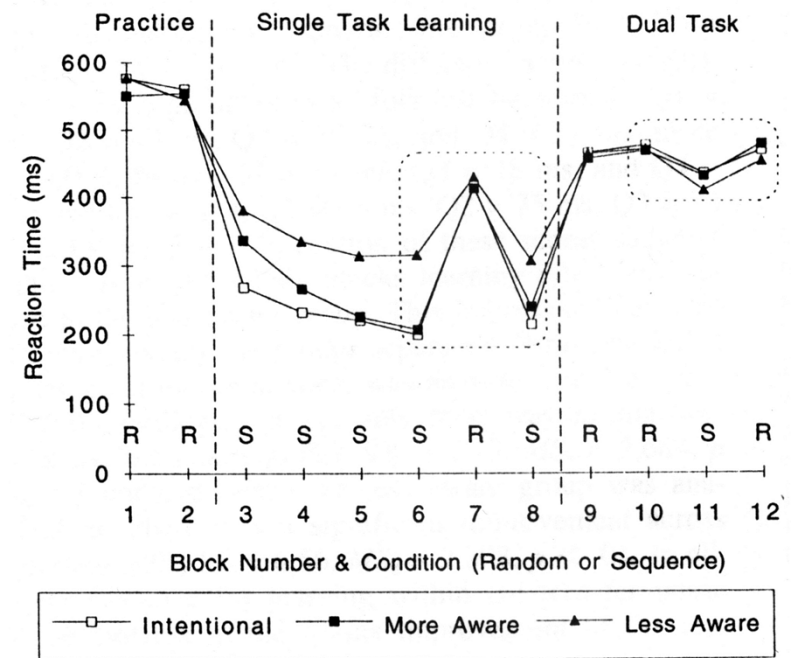
- La plupart de nos activités quotidiennes peuvent être décomposées en séquences



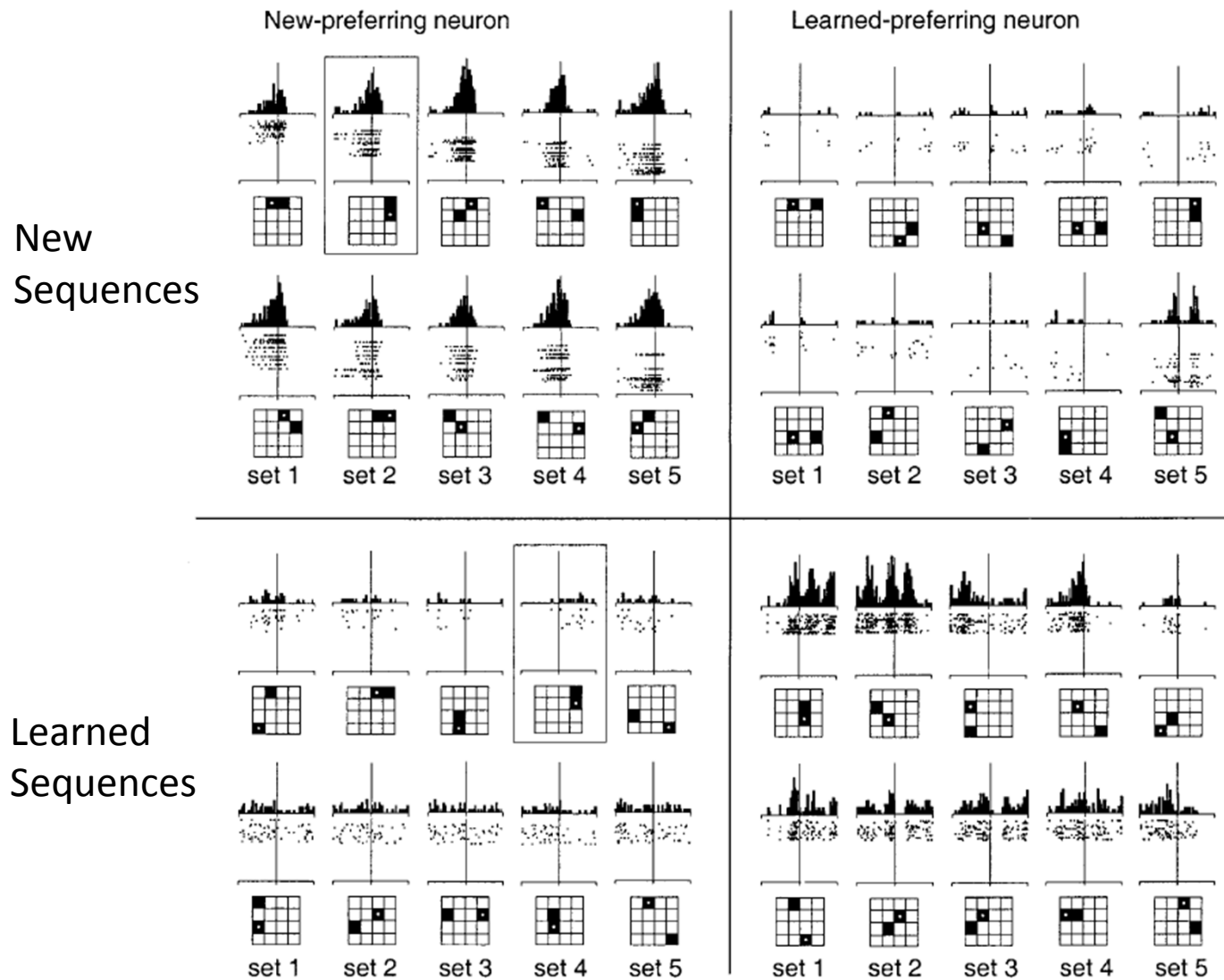
The serial reaction time task



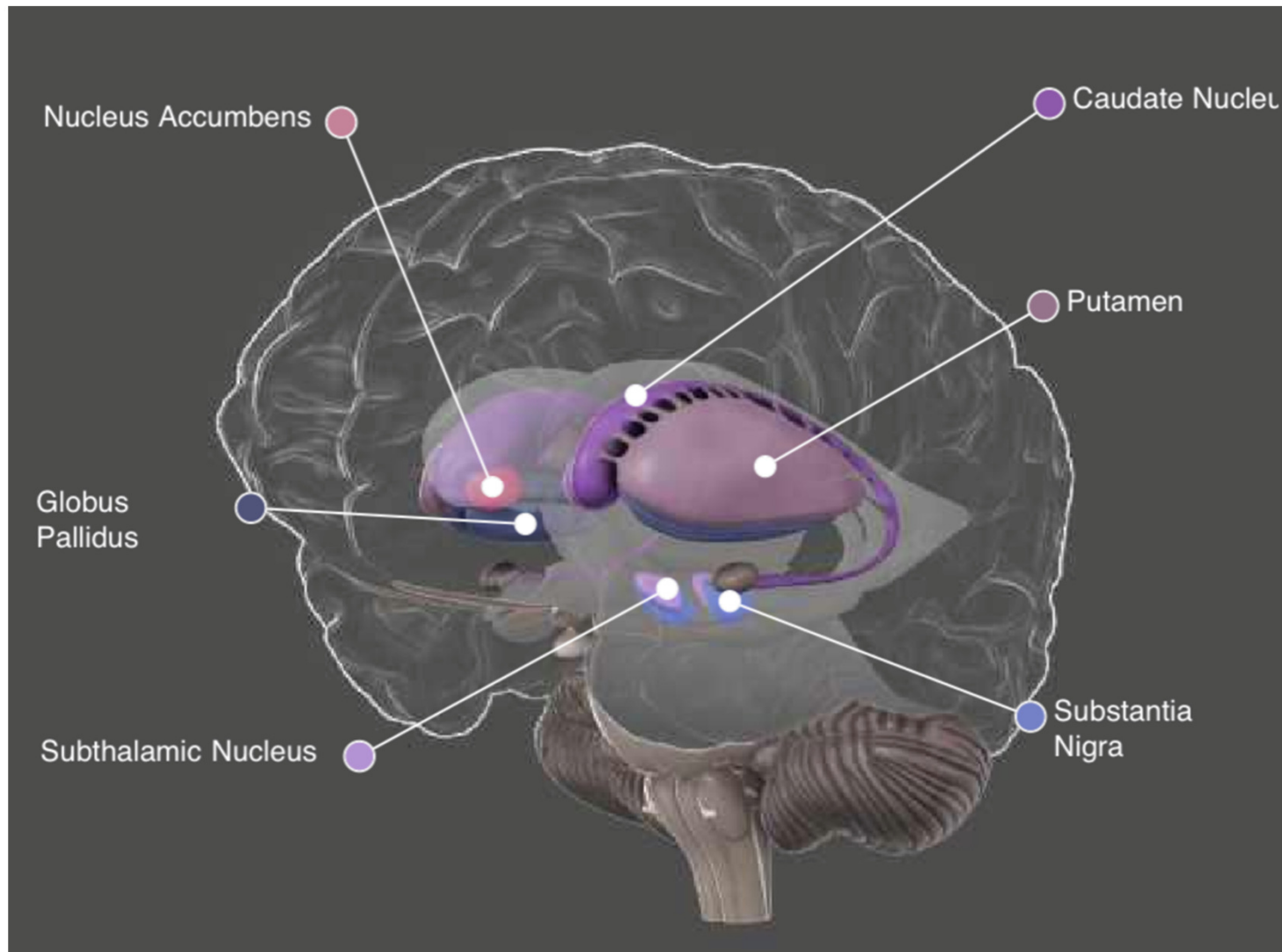
1 – 2 – 3 – 2 – 4 – 3...



Neurones sélectives pour la tâche (Miyachi et al., 2002)



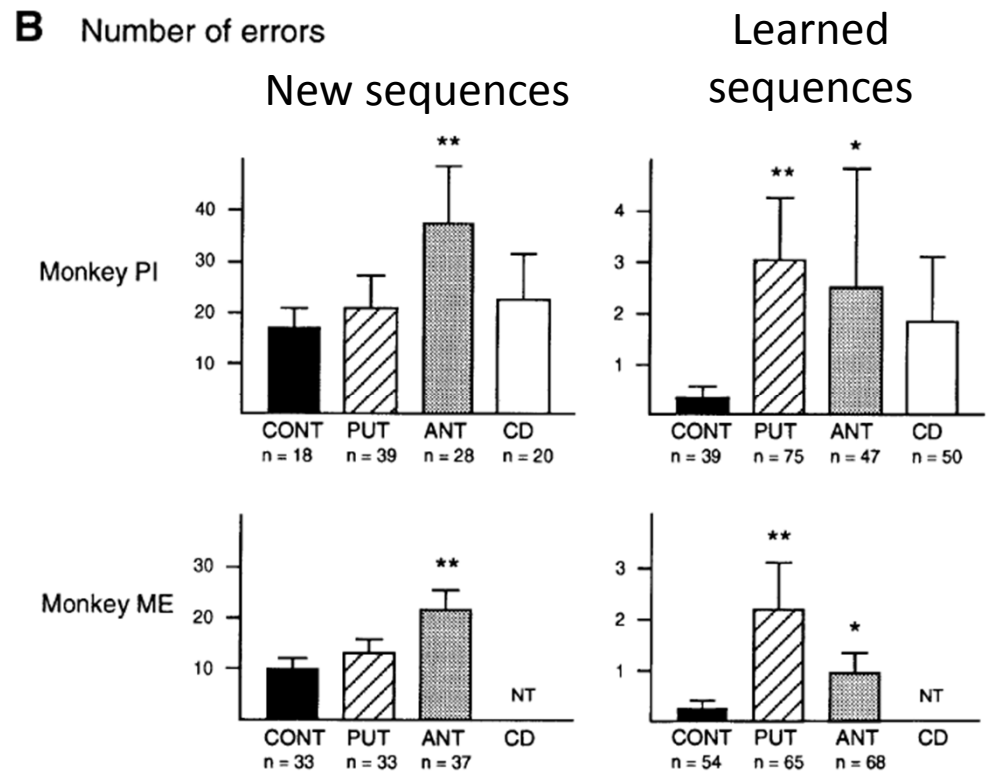
Striatum



Retrieved from <http://brainposts.blogspot.com/2012/09/the-gamblers-brain-striatum-responsivity.html>

Injection de muscimole (Miyachi et al., 1997)

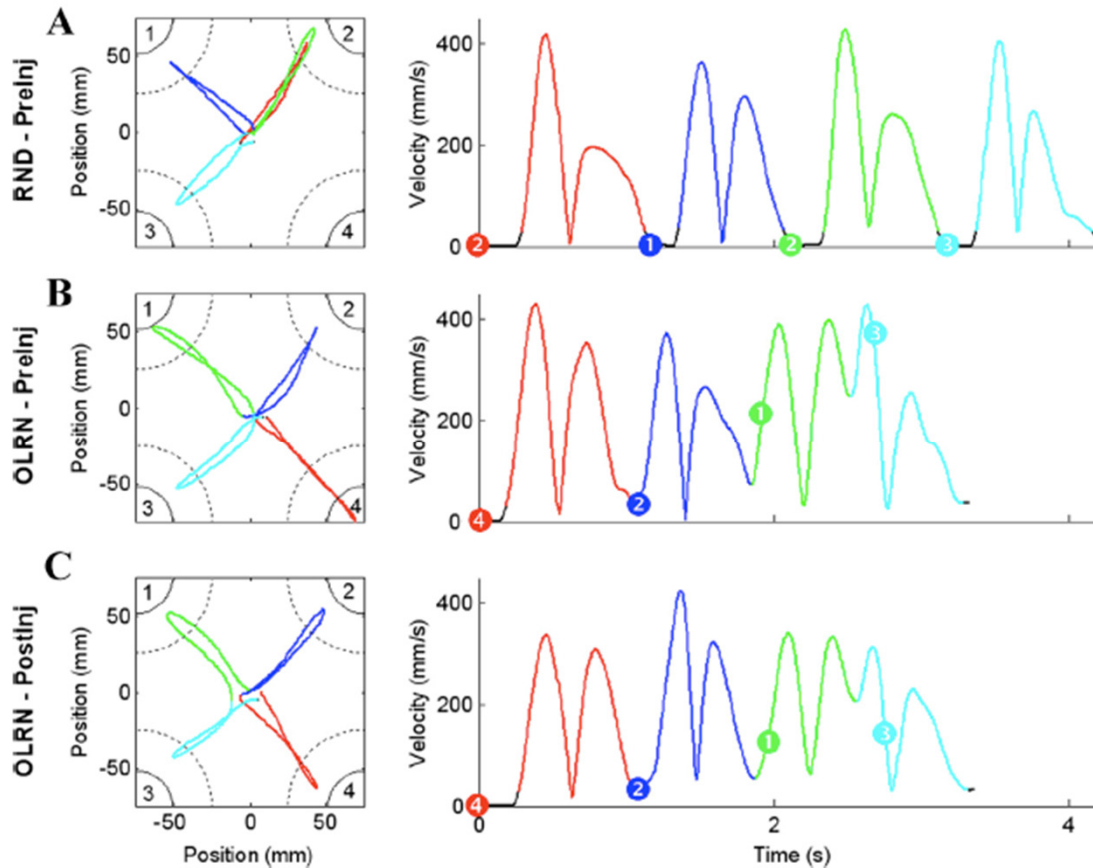
- L'injection de muscimole dans le striatum antérieur affecte les nouvelles séquences;
- L'injection de muscimole dans le putamen médian/postérieur affecte les séquences pratiquées.



Le modèle “standard” (Nakahara et al., 2001)

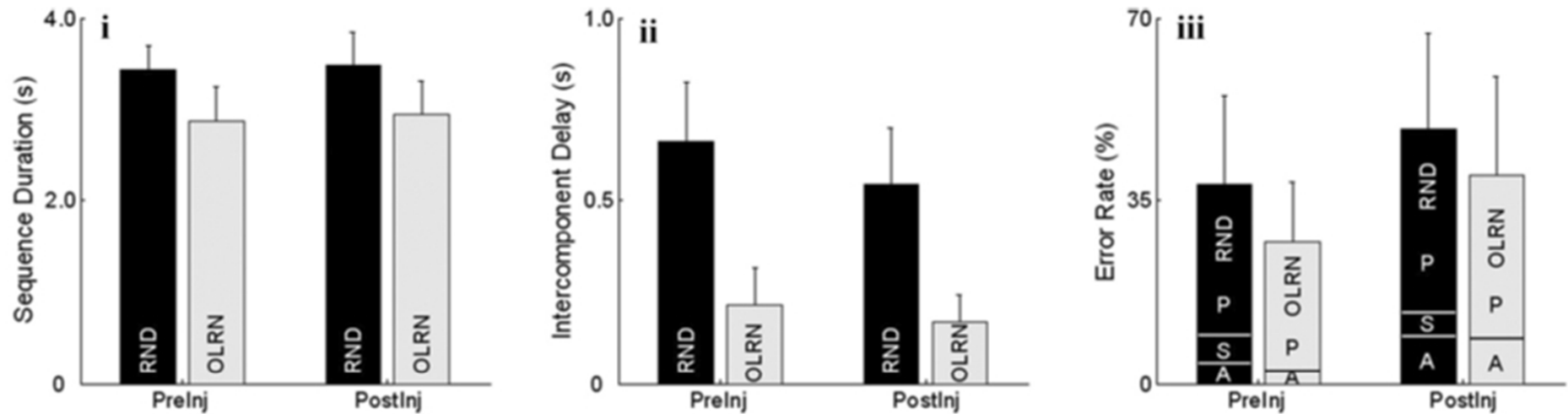
- Le striatum est essentiel pour l'apprentissage et la production de séquences;
- La séquence est représenté dans le striatum;
- La production automatique de séquences est obtenue par un transfert graduel de la représentation entre le striatum associatif et le striatum sensorimoteur.

Séquence de mouvements à l'aide d'un joystick



Desmurget, M., & Turner, R. S. (2010). Motor sequences and the Basal Ganglia: kinematics, not habits. *Journal of neuroscience*, 30, 7685-7690.

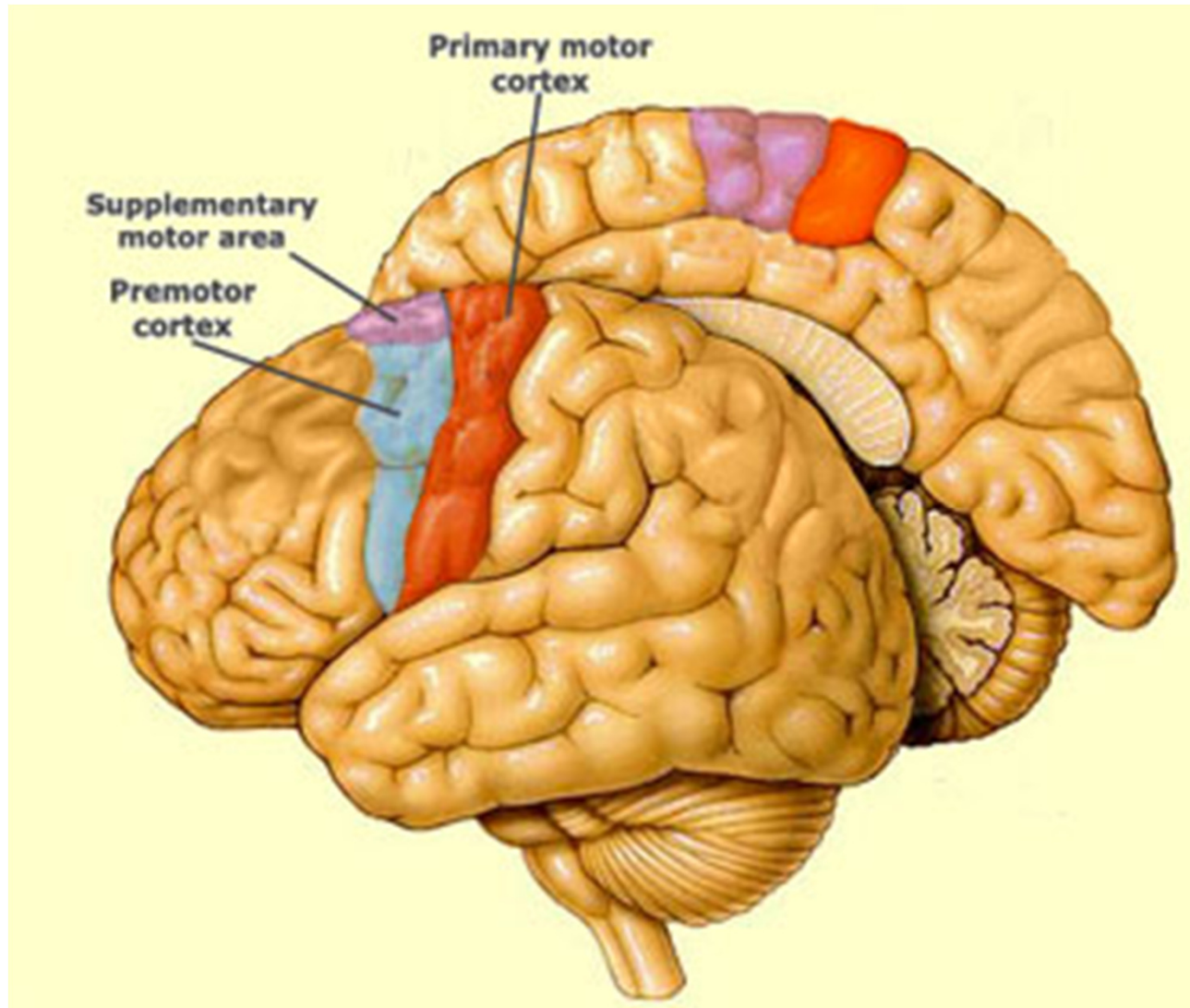
Injection de muscimole



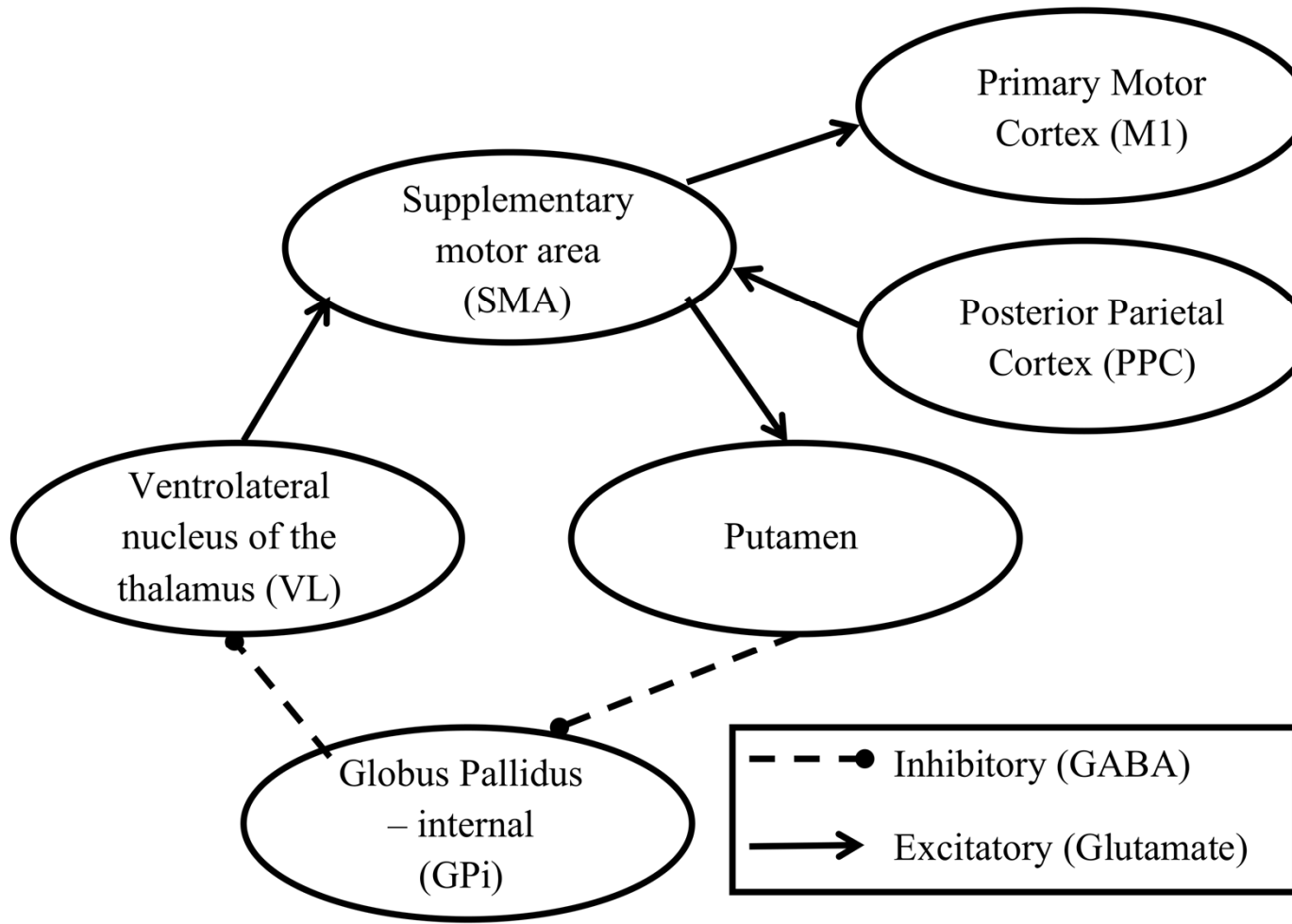
Les GB ne sont pas impliqués dans la représentation de séquences!

Desmurget & Turner (2008). *Journal of Neuroscience*.

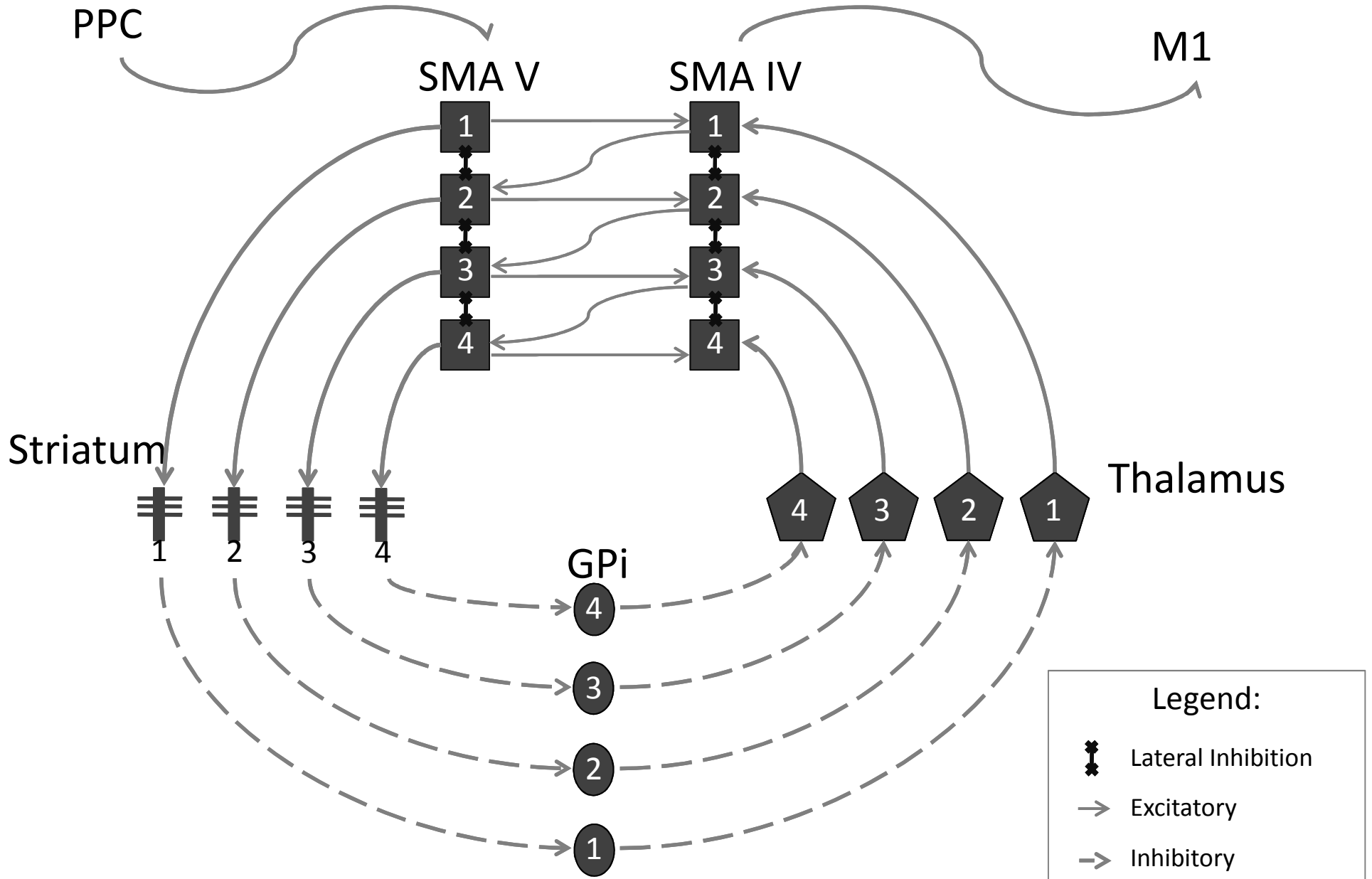
Quelques zones motrices corticales



Modèle général



Circuit neuronal



Modèle cellulaire

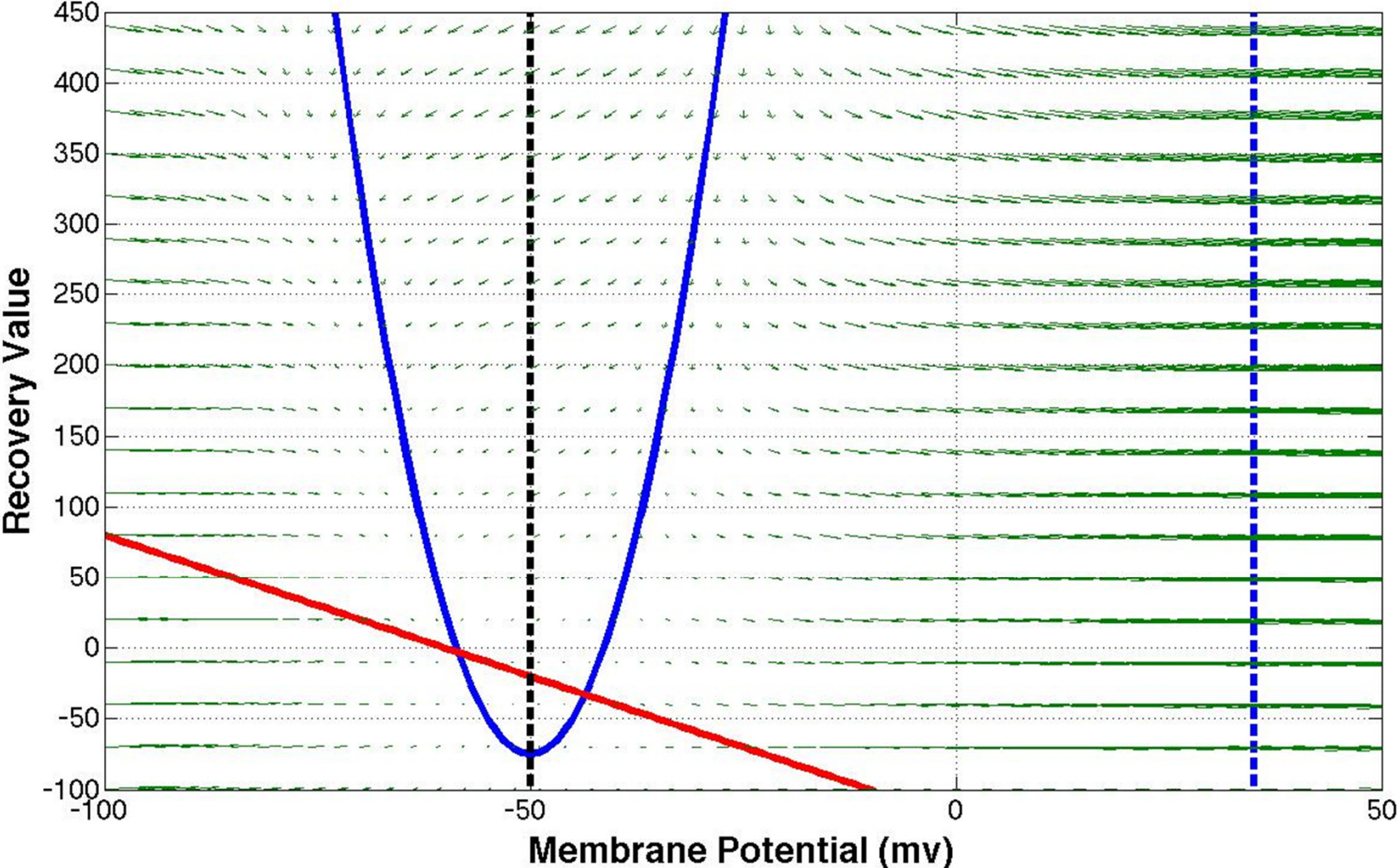
- Le modèle d'Izhikevich (2007) :

$$C \frac{dV(t)}{dt} = \beta + \gamma[V(t) - V_r][V(t) - V_t] - U(t) + I(t) + \varepsilon(t)$$

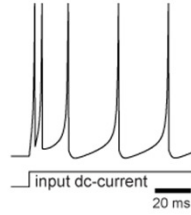
$$\frac{1}{\varphi} \frac{dU(t)}{dt} = \kappa[V(t) - V_r] - U(t)$$

Quand $V(t)$ atteint 35 mV, un spike est enregistré et $V(t)$ est remis à V_{reset} . De plus, $U(t)$ est remis à $U(t) + U_0$.

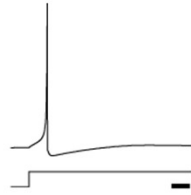
Modèle cellulaire



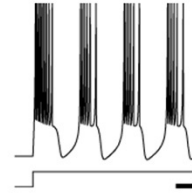
(A) tonic spiking



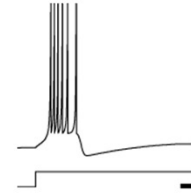
(B) phasic spiking



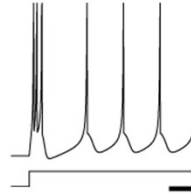
(C) tonic bursting



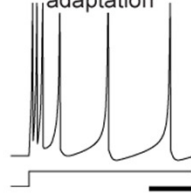
(D) phasic bursting



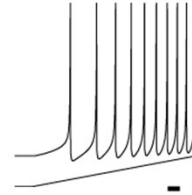
(E) mixed mode



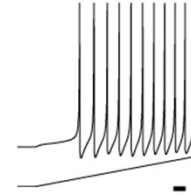
(F) spike frequency adaptation



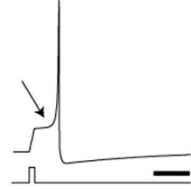
(G) Class 1 excitable



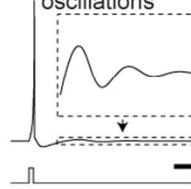
(H) Class 2 excitable



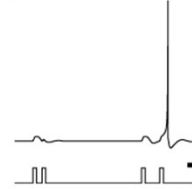
(I) spike latency



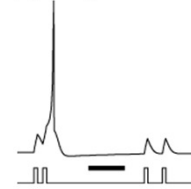
(J) subthreshold oscillations



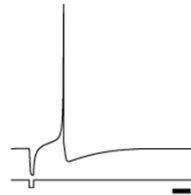
(K) resonator



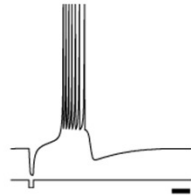
(L) integrator



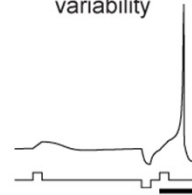
(M) rebound spike



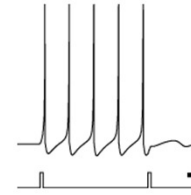
(N) rebound burst



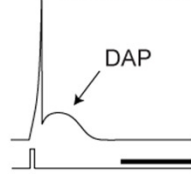
(O) threshold variability



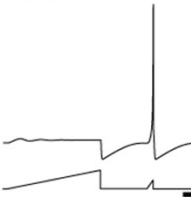
(P) bistability



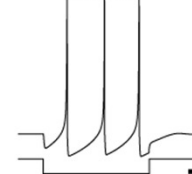
(Q) depolarizing after-potential



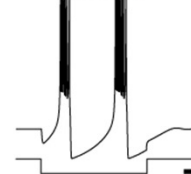
(R) accommodation



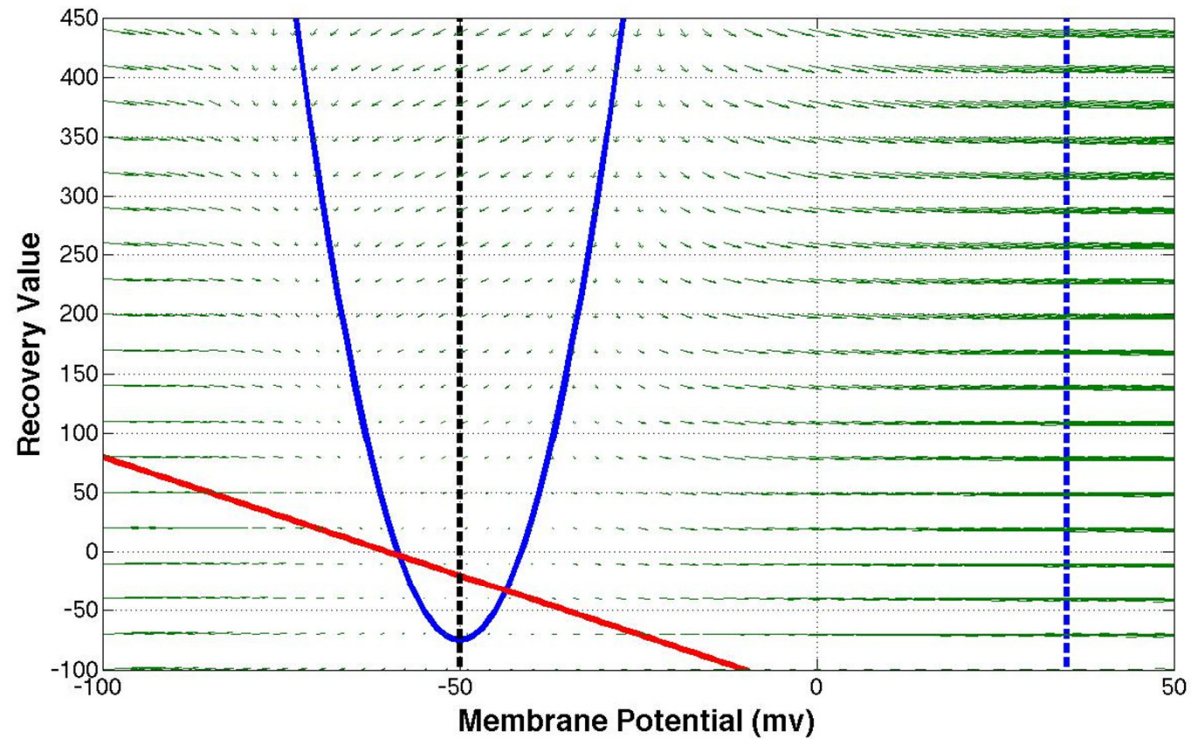
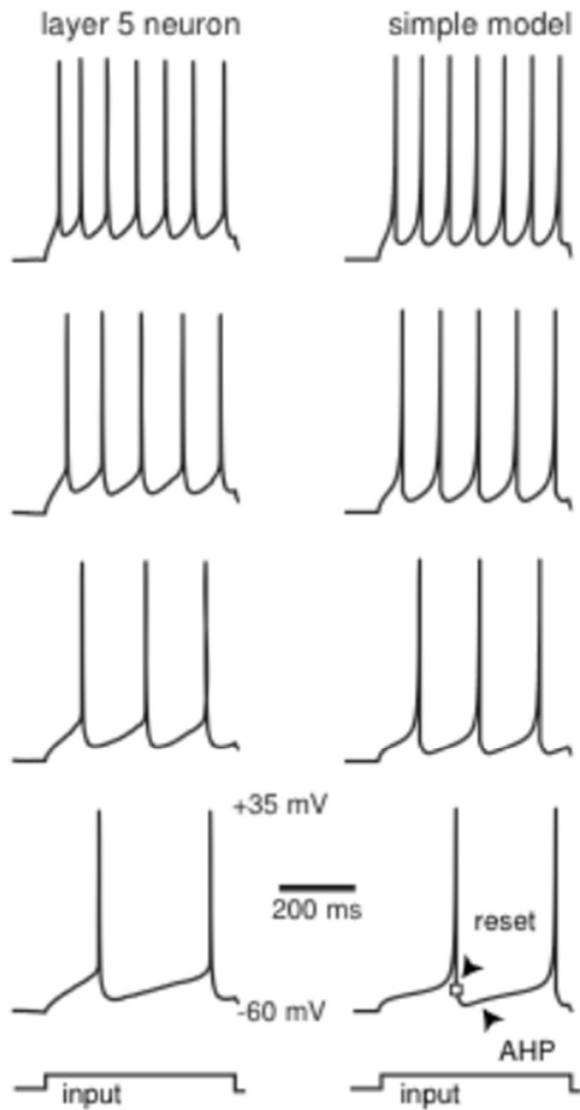
(S) inhibition-induced spiking



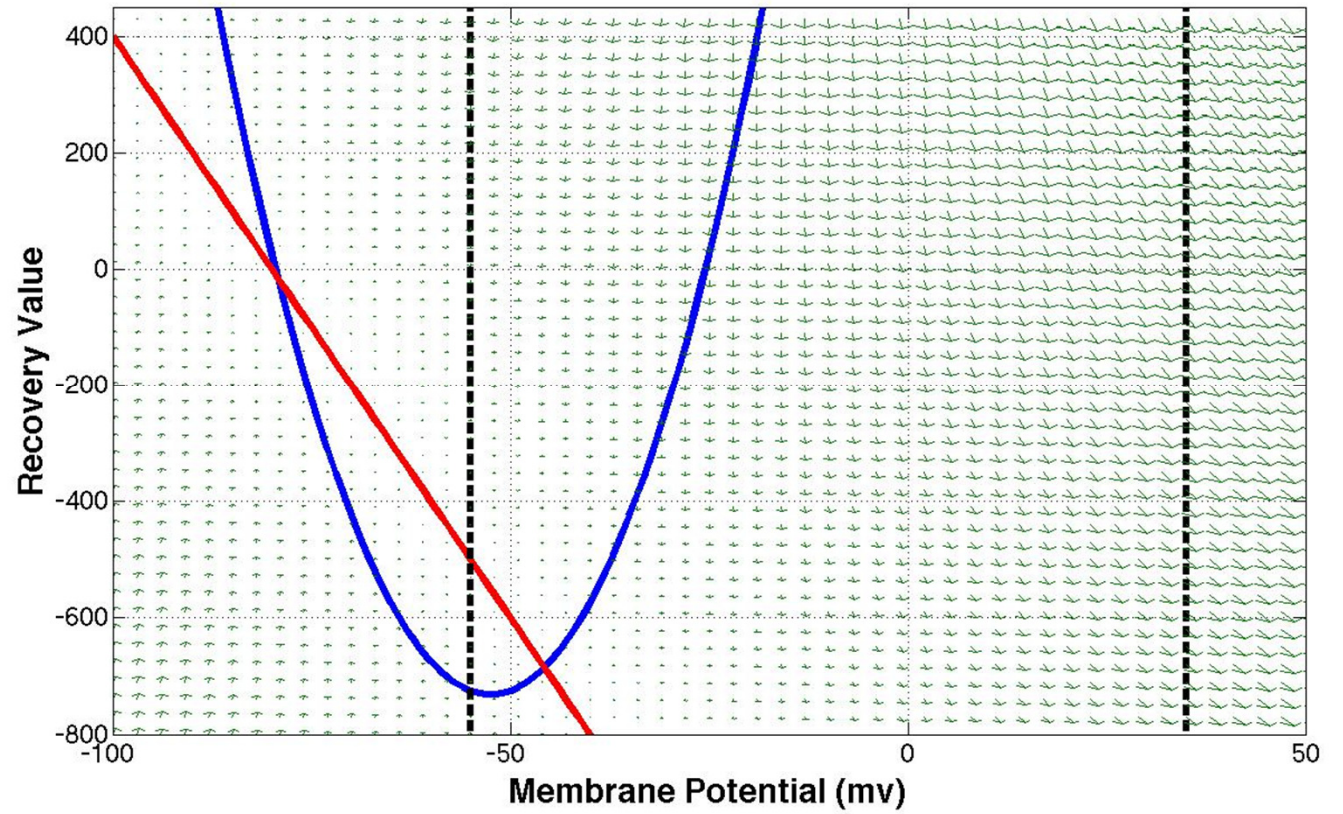
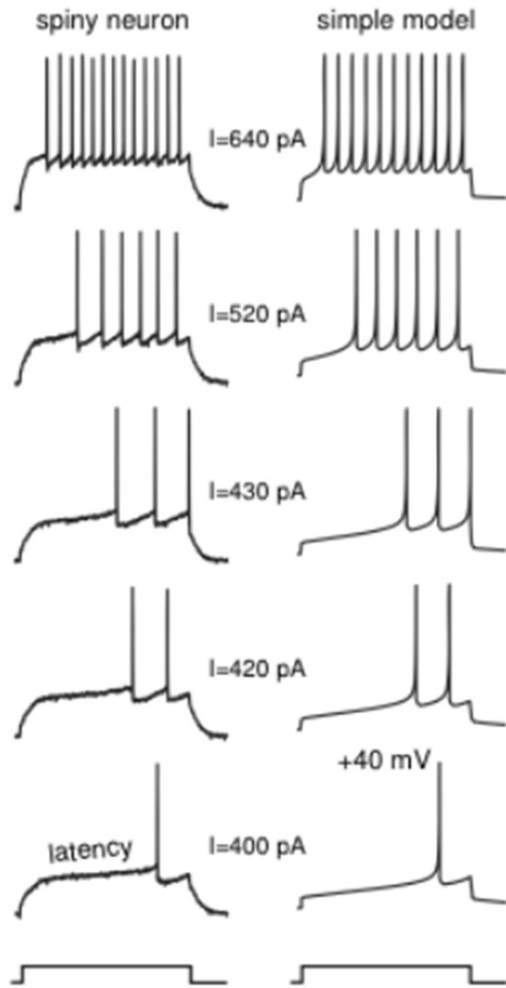
(T) inhibition-induced bursting



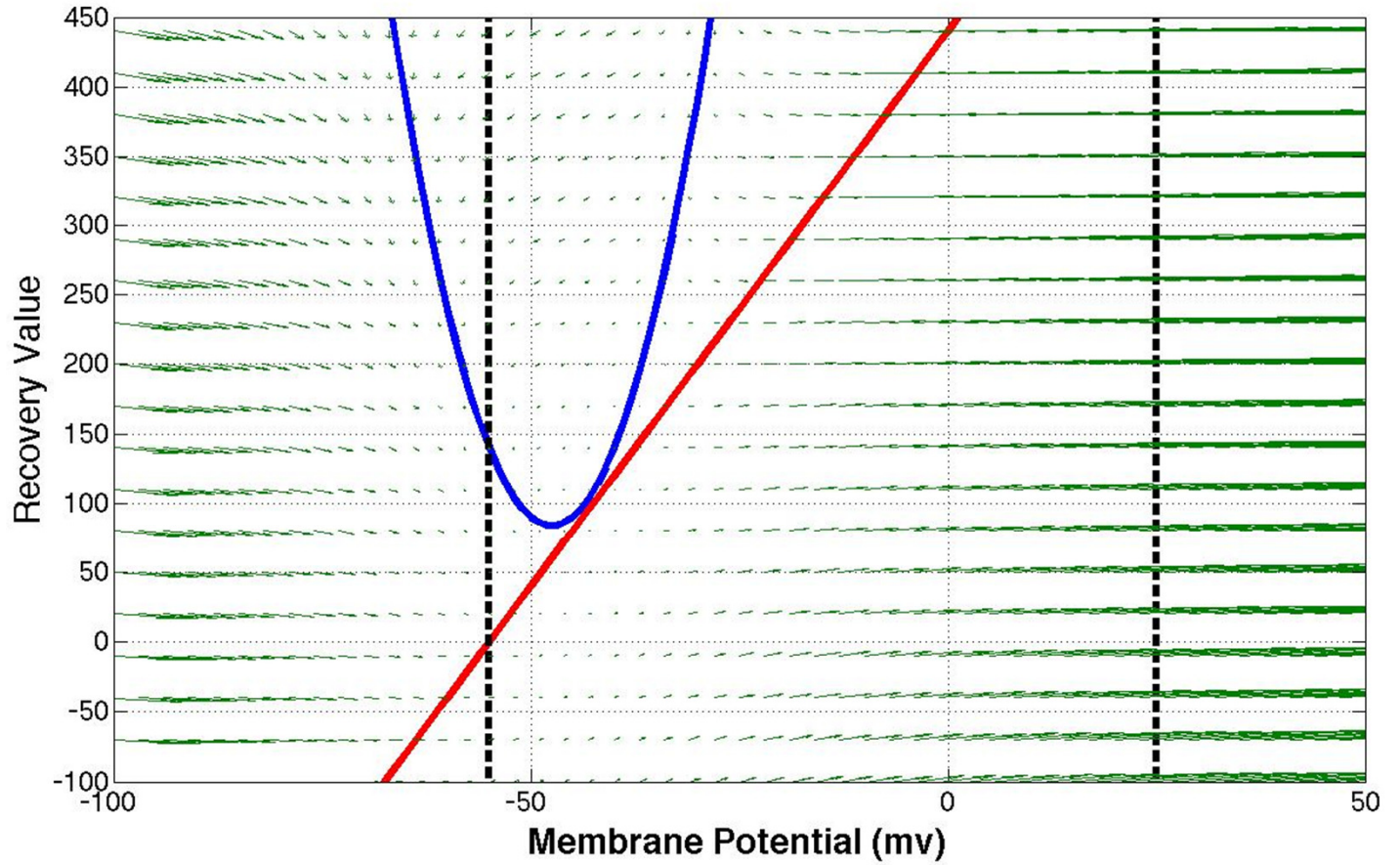
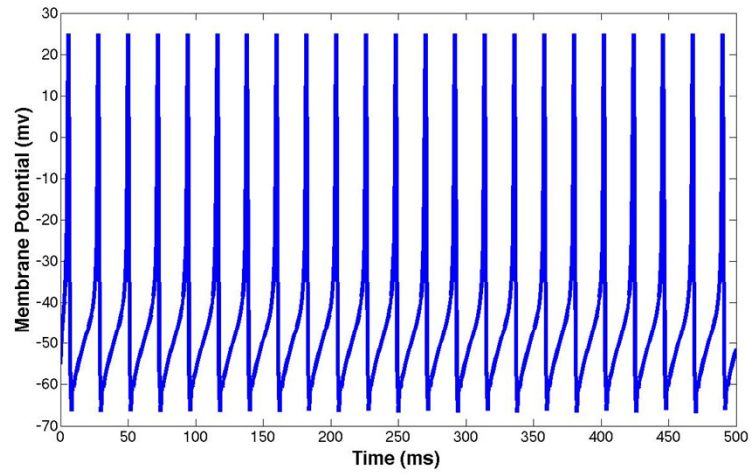
Aire motrice supplémentaire



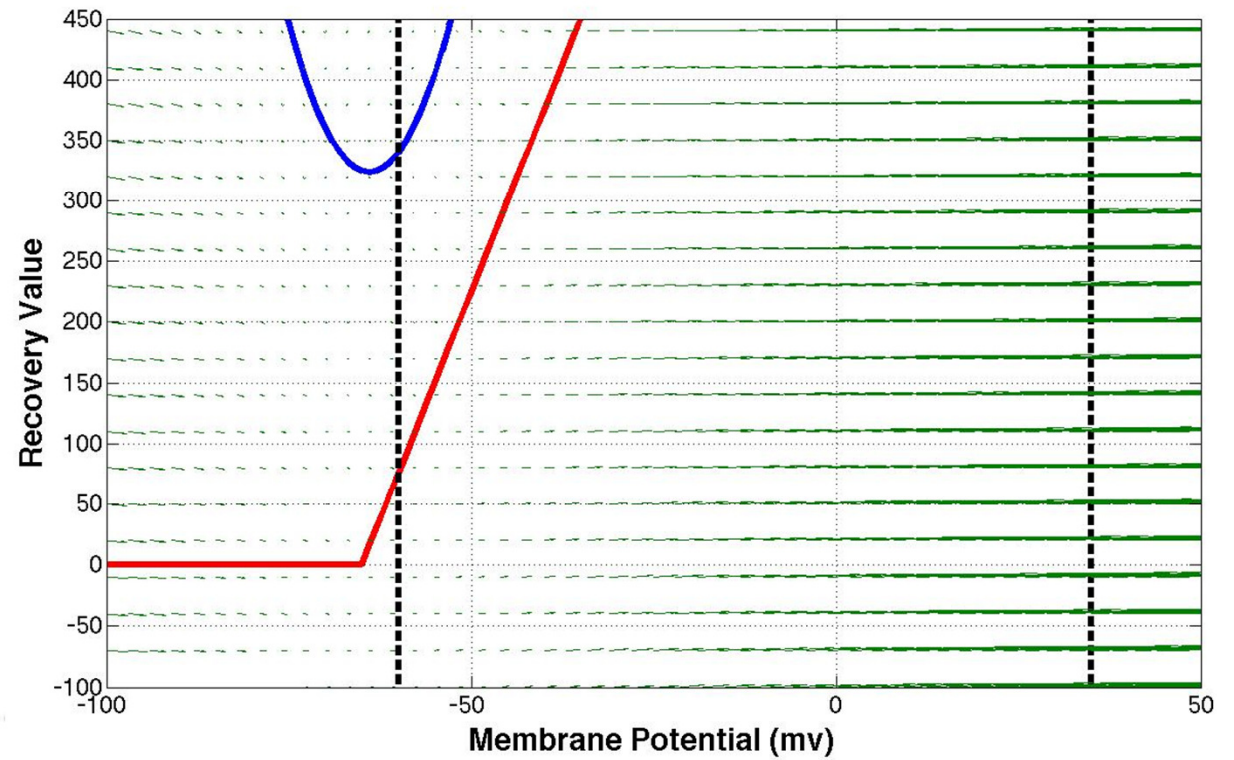
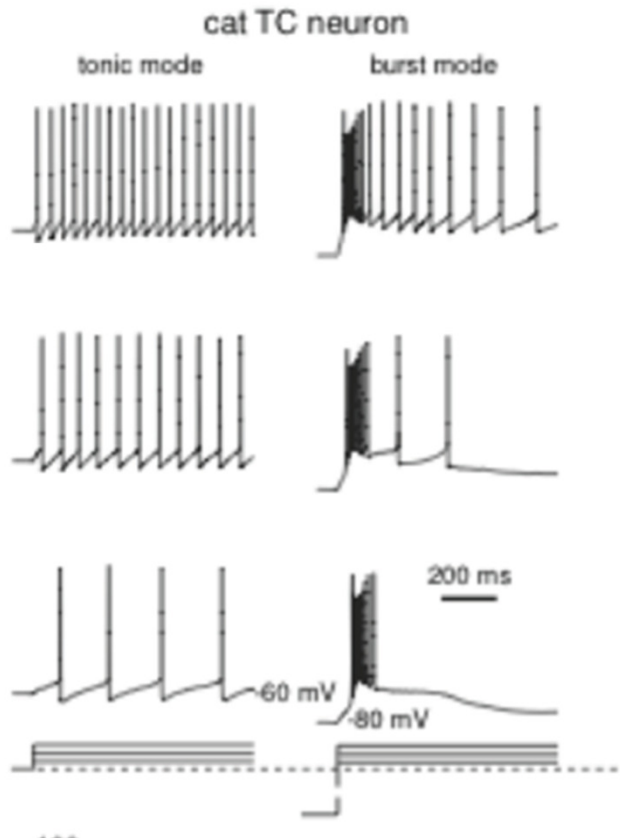
Striatum



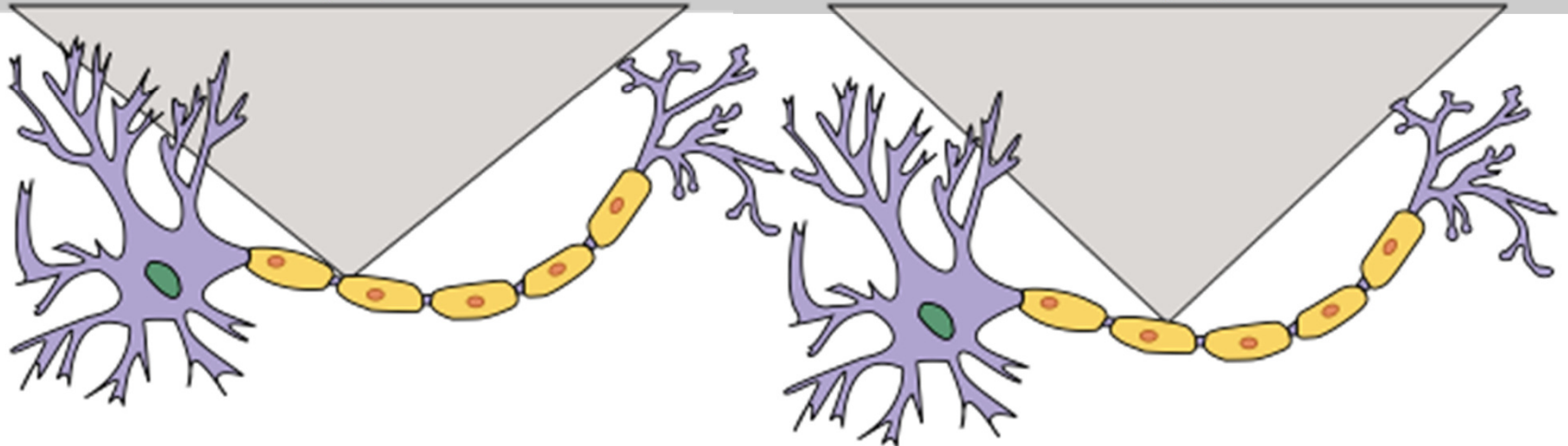
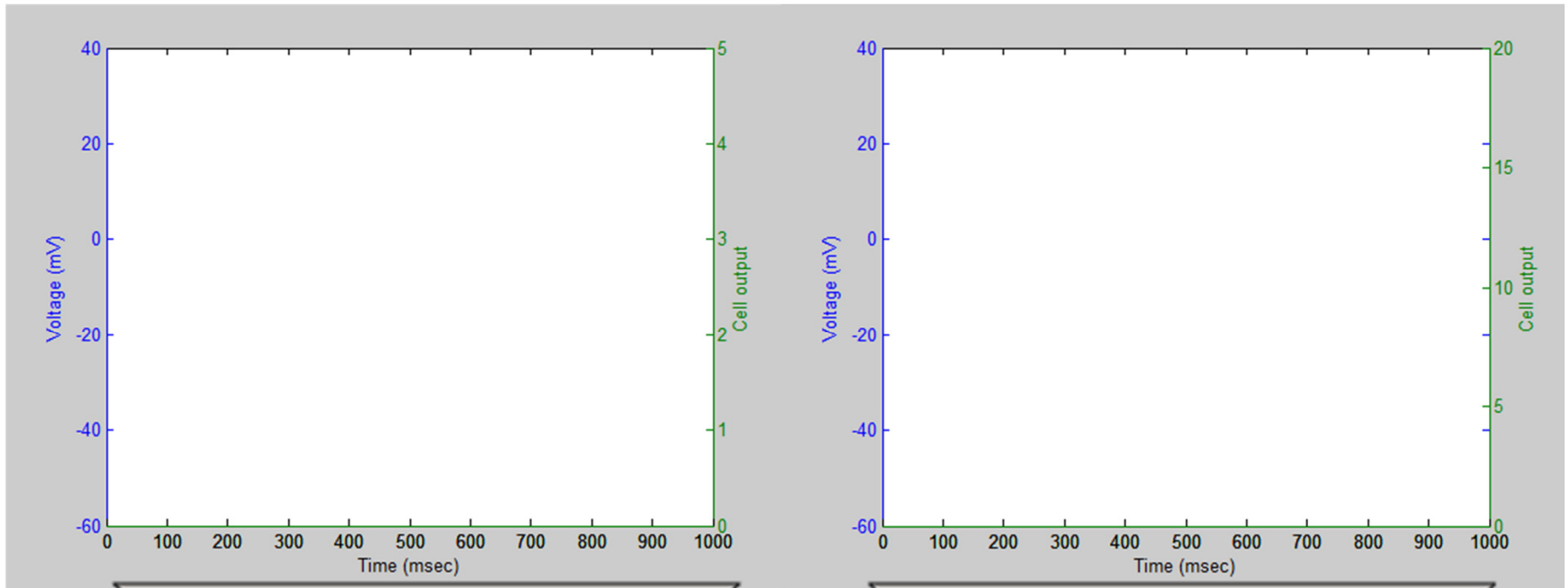
GPI



Thalamus



Transmission cellulaire



Apprentissage Hebbien (AMS)

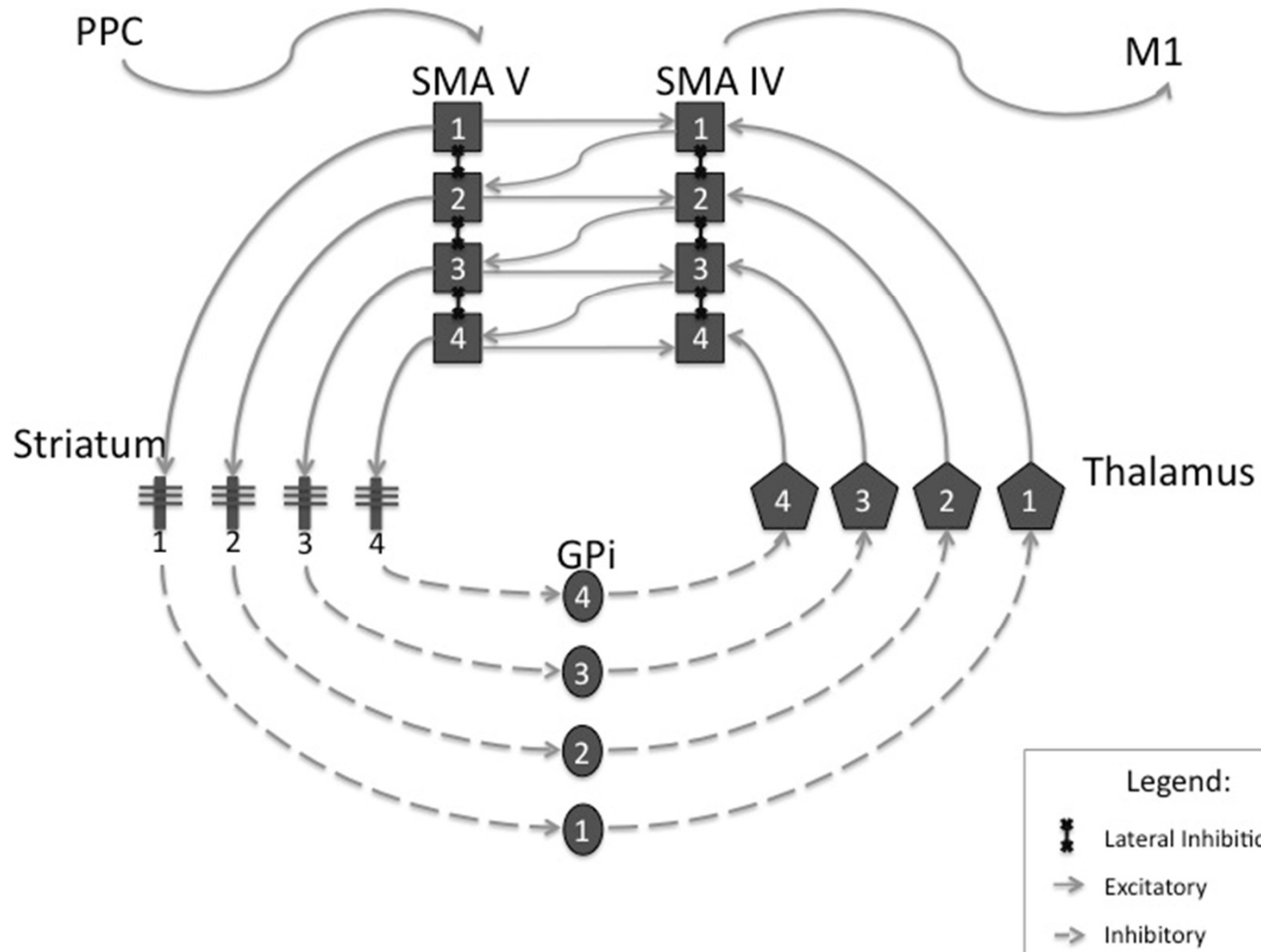
- Séquence:

$$w_{i,j}^{4 \rightarrow 5}(n+1) = w_{i,j}^{4 \rightarrow 5}(n) + \eta_{S,LTP} \int_t \alpha_{SMA4,i}(n-1,t) dt \left[\int_t \alpha_{SMA5,j}(n,t) dt - \theta_{NMDA} \right]^+ \left[w_{\max} - w_{i,j}^{4 \rightarrow 5}(n) \right] \\ - \eta_{S,LTD} \int_t \alpha_{SMA4,i}(n-1,t) dt \left[\theta_{NMDA} - \int_t \alpha_{SMA5,j}(n,t) dt \right]^+ \left[\int_t \alpha_{SMA5,j}(n,t) dt - \theta_{AMPA} \right]^+ w_{i,j}^{4 \rightarrow 5}(n)$$

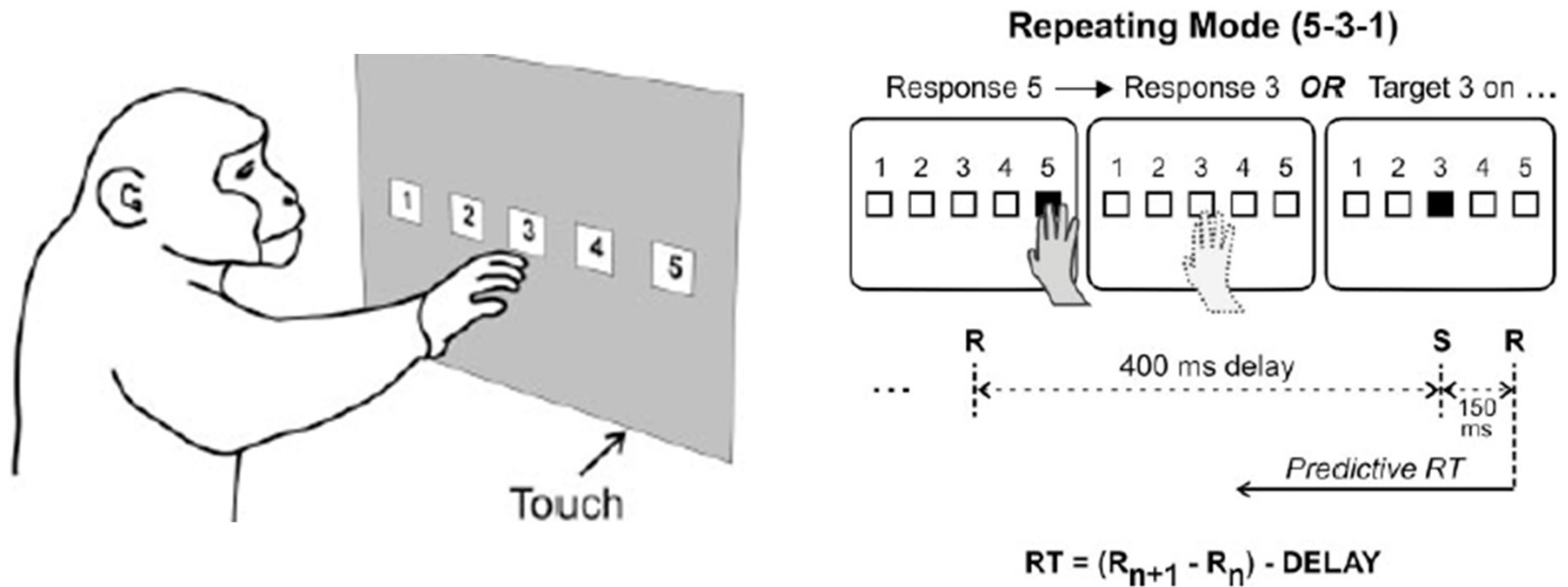
- Production:

$$w_{i,j}^{5 \rightarrow 4}(n+1) = w_{i,j}^{5 \rightarrow 4}(n) + \eta_{A,LTP} \int_t \alpha_{SMA5,i}(n,t) dt \left[\int_t \alpha_{SMA4,j}(n,t) dt - \theta_{NMDA} \right]^+ \left[w_{\max} - w_{i,j}^{5 \rightarrow 4}(n) \right] \\ - \eta_{A,LTD} \int_t \alpha_{SMA5,i}(n,t) dt \left[\theta_{NMDA} - \int_t \alpha_{SMA4,j}(n,t) dt \right]^+ \left[\int_t \alpha_{SMA4,j}(n,t) dt - \theta_{AMPA} \right]^+ w_{i,j}^{5 \rightarrow 4}(n)$$

Circuit neuronal

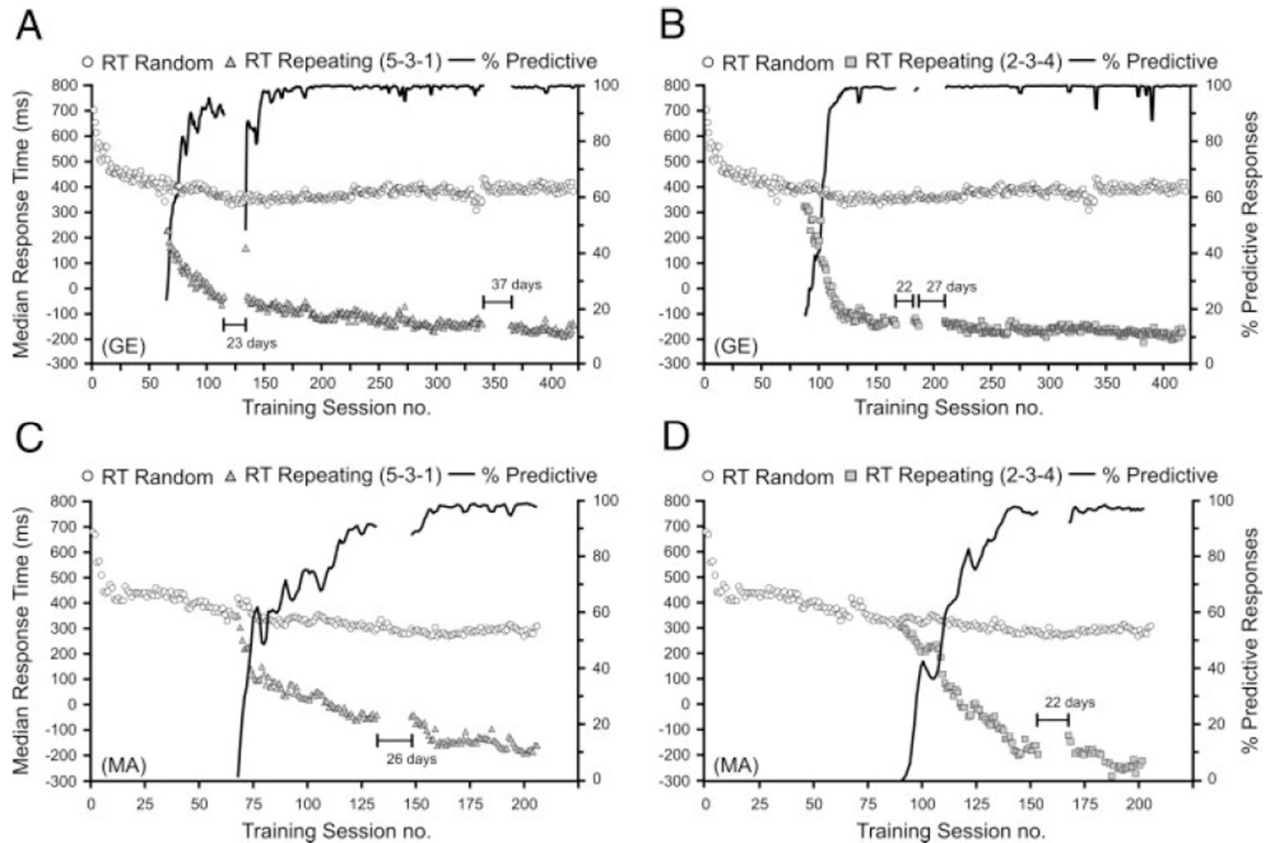


La tâche DSP



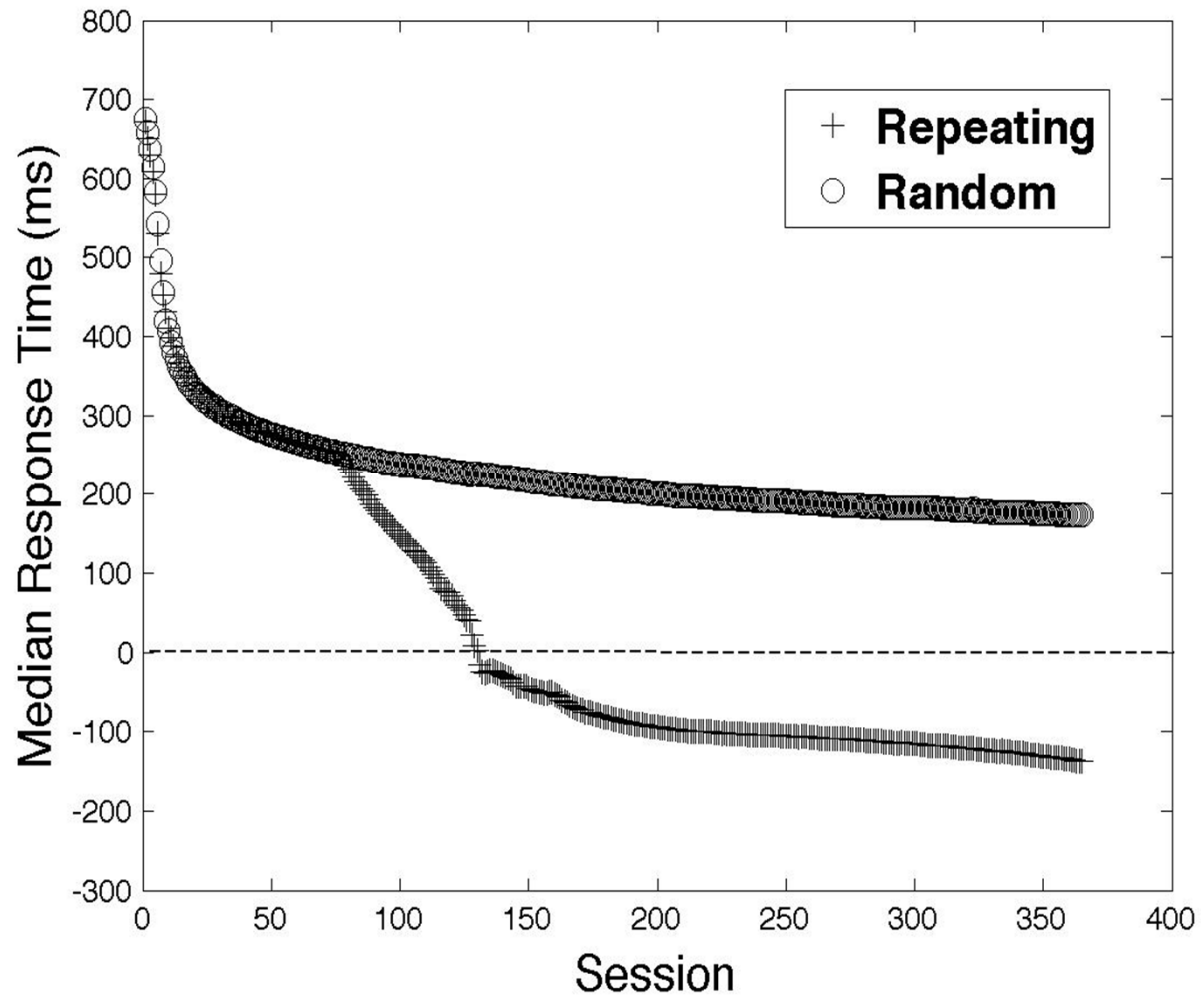
Matsuzaka, Y., Picard, N., & Strick, P. L. (2007). Skill representation in the primary cortex after long-term practice. *Journal of Neurophysiology*, 97, 1819-1832.

Résultats dans la tâche de DSP



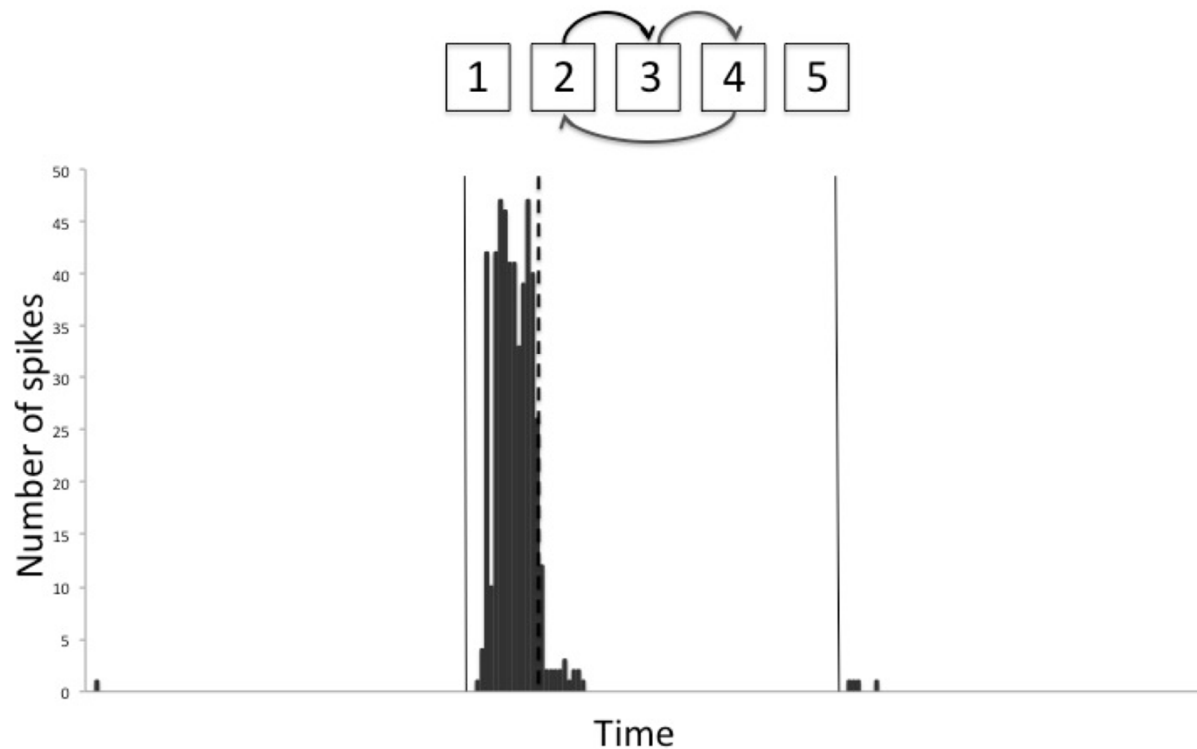
Matsuzaka, Y., Picard, N., & Strick, P. L. (2007). Skill representation in the primary cortex after long-term practice. *Journal of Neurophysiology*, 97, 1819-1832.

Résultats de la simulation



Primate GE, $r^2 = 0.872$

Enregistrement cellulaire



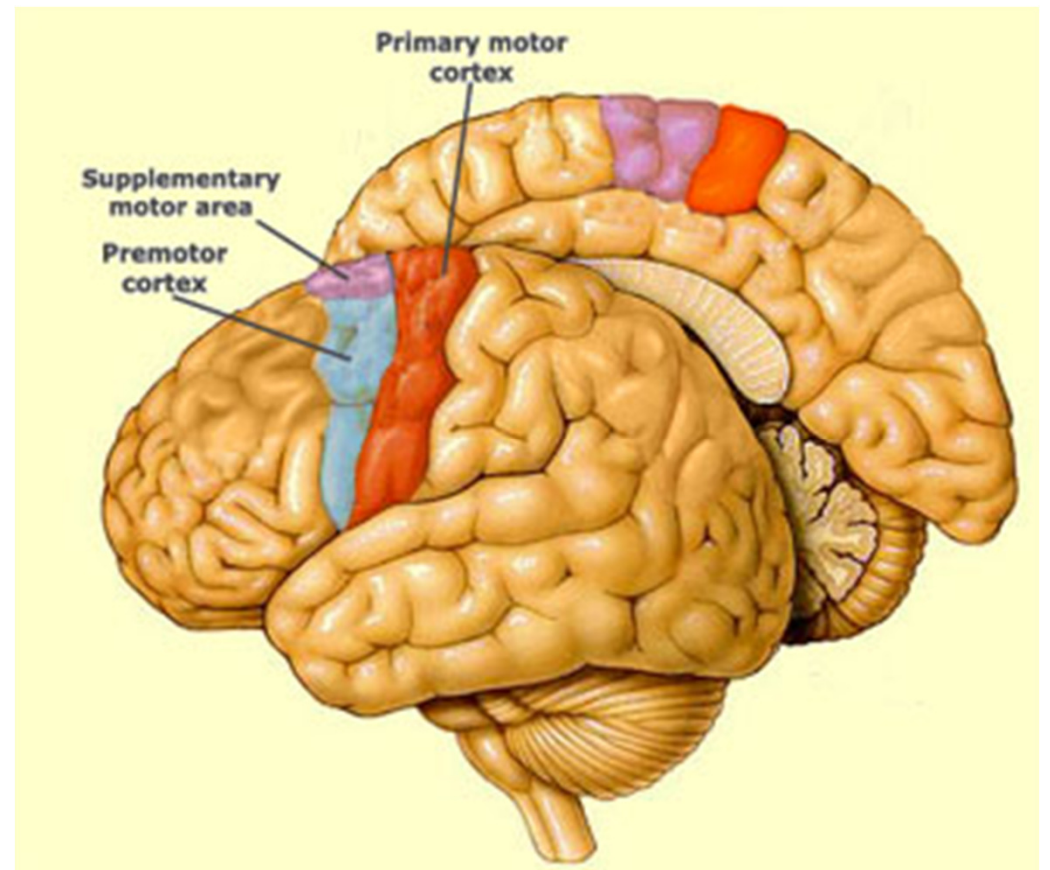
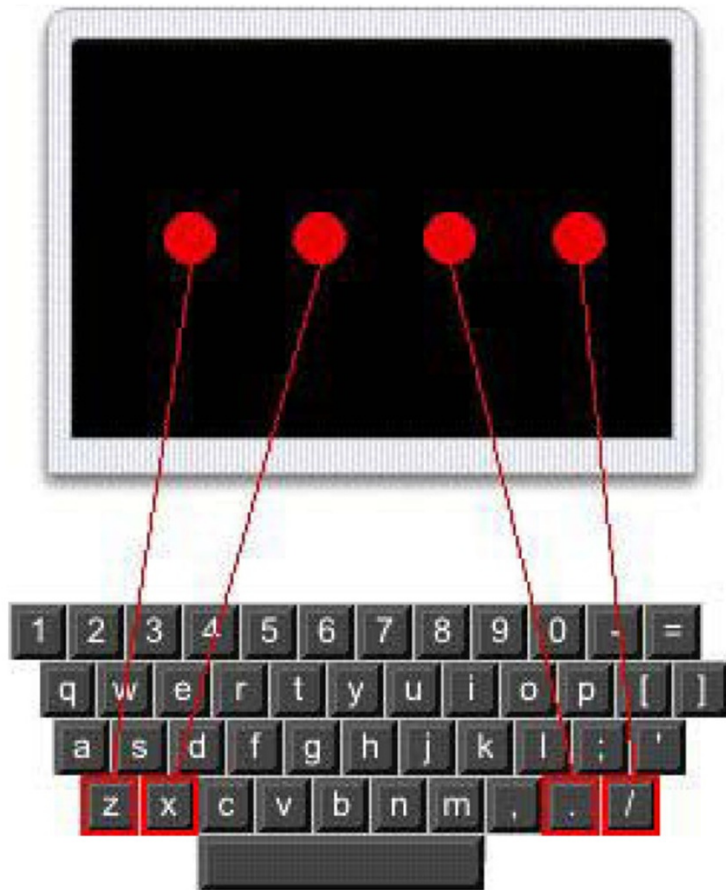
- Les neurones dans la couche V de l'AMS représentent les transitions (comme dans Shima & Tanji, 2000)

Stimulation magnétique transcrânienne

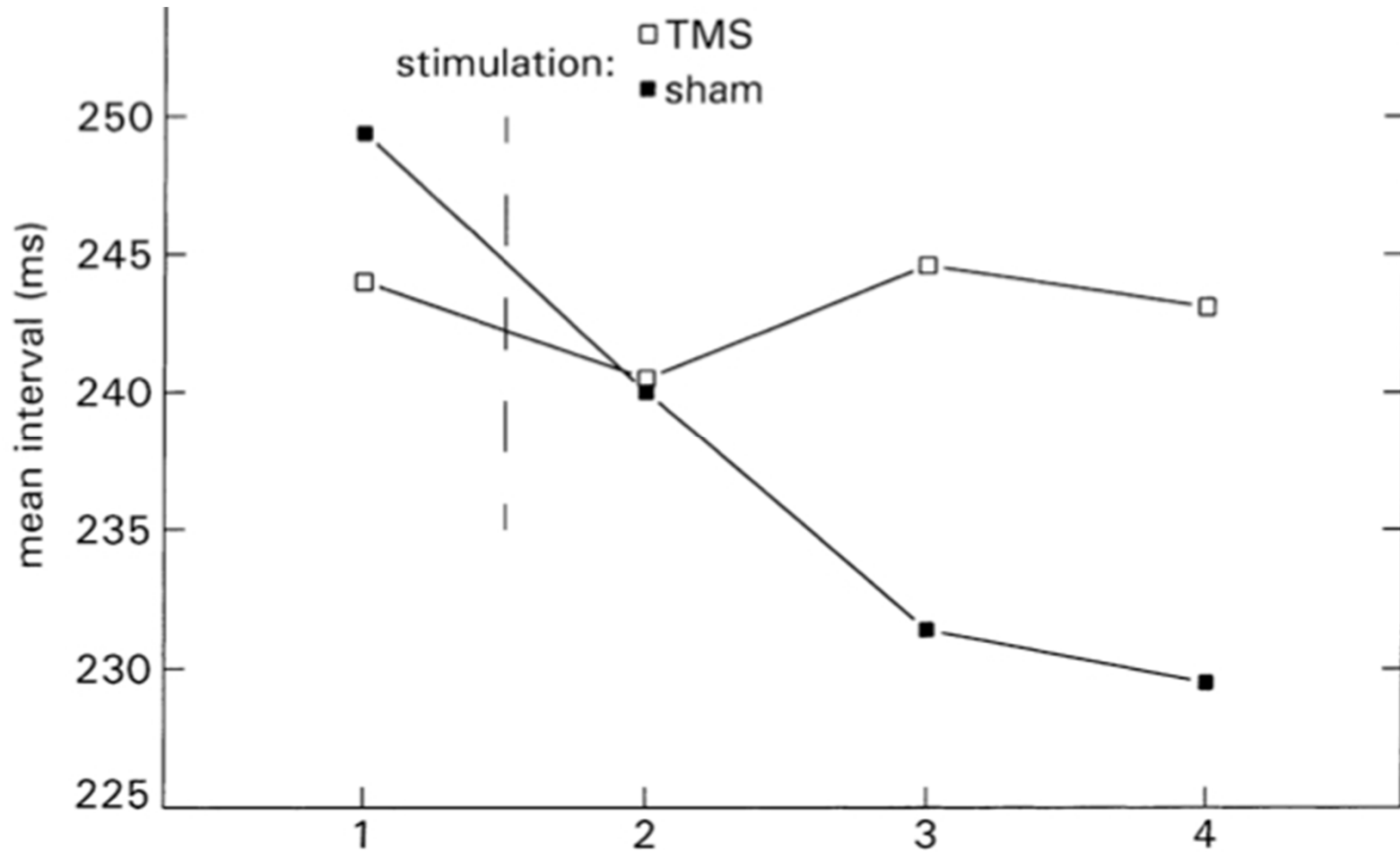


Stimulation magnétique transcrânienne

- Apprentissage de séquences



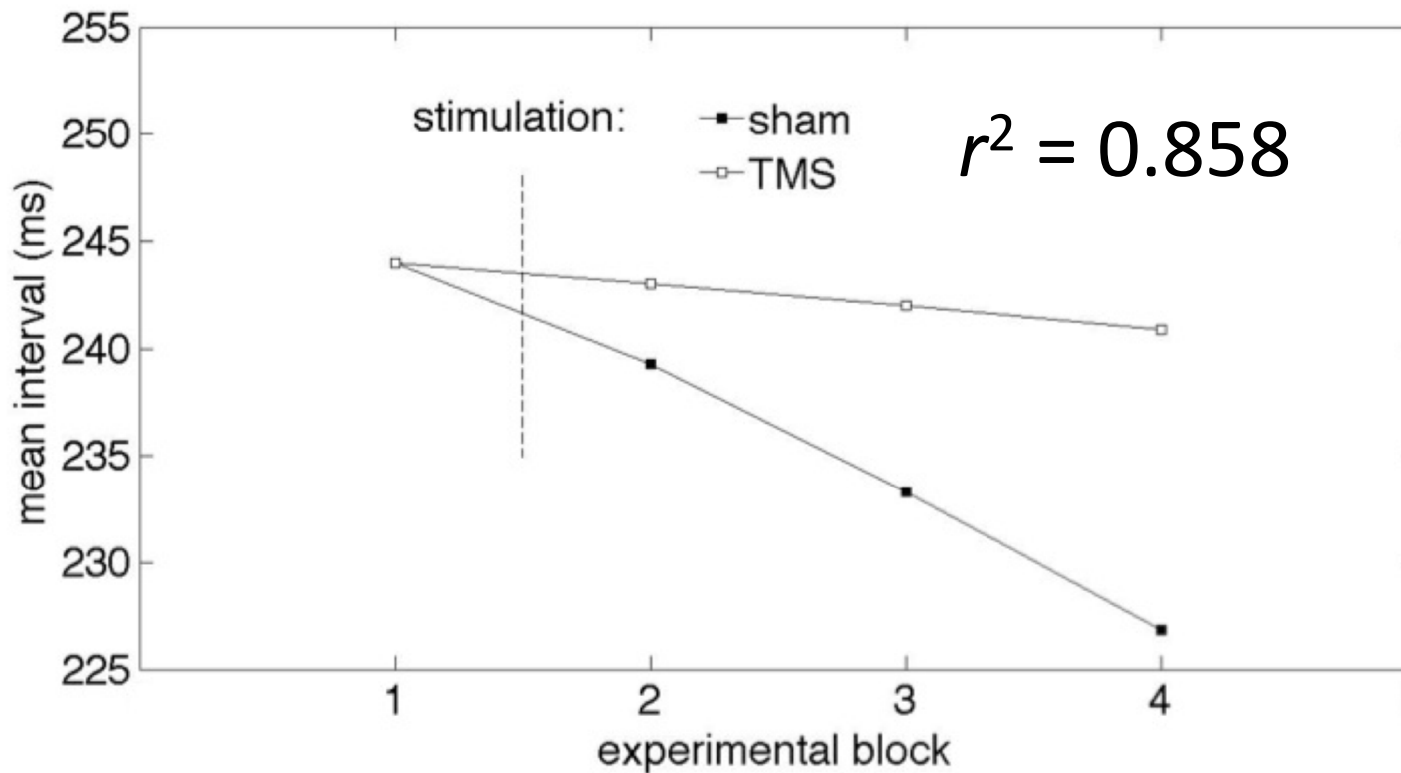
Stimulation magnétique transcrânienne



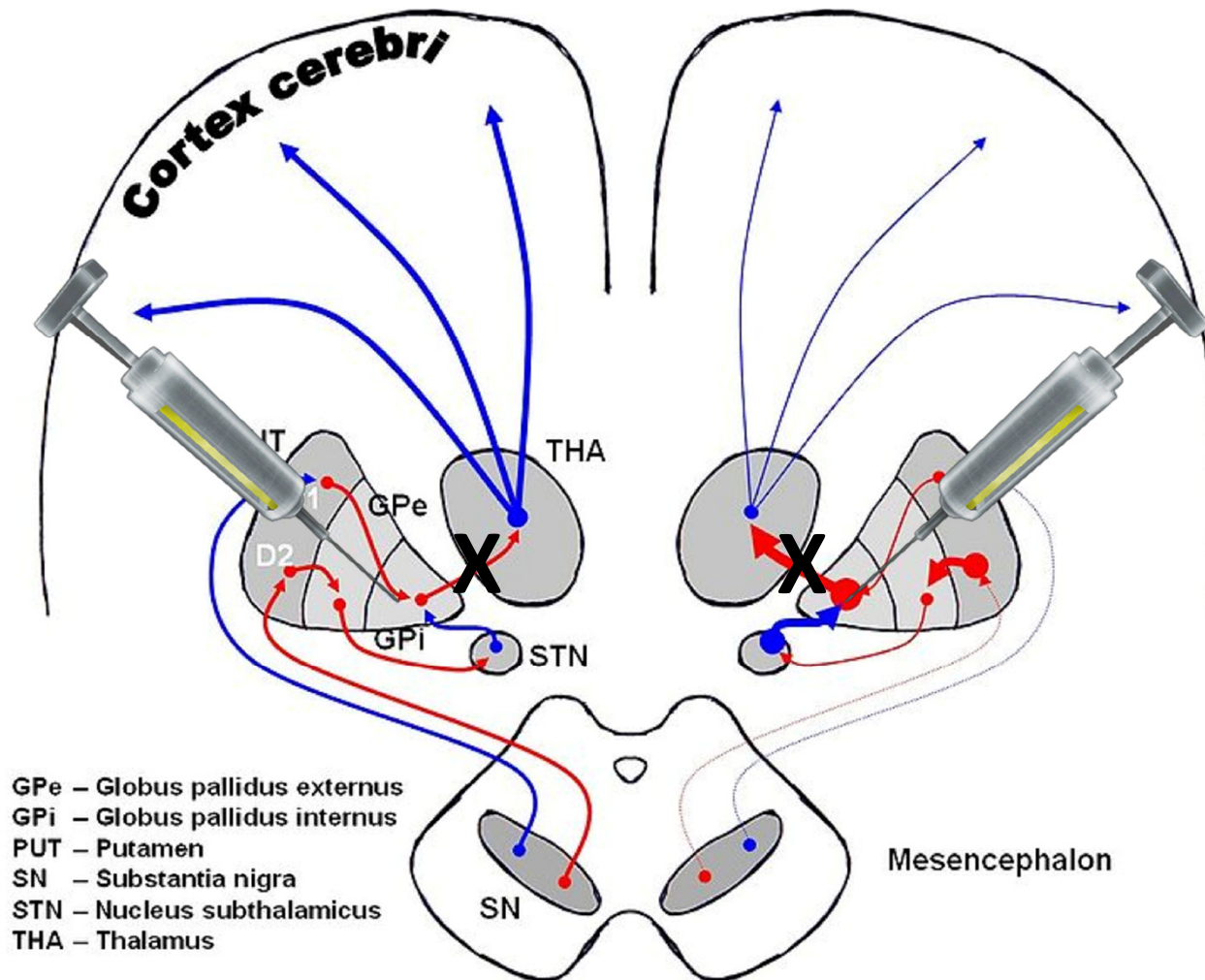
Verwey et al. (2002). *Neuropsychologia*.

Résultats de la simulation

- rTMS fût simulé par l'augmentation du critère NMDA dans les règles d'apprentissage (Ca^{2+});

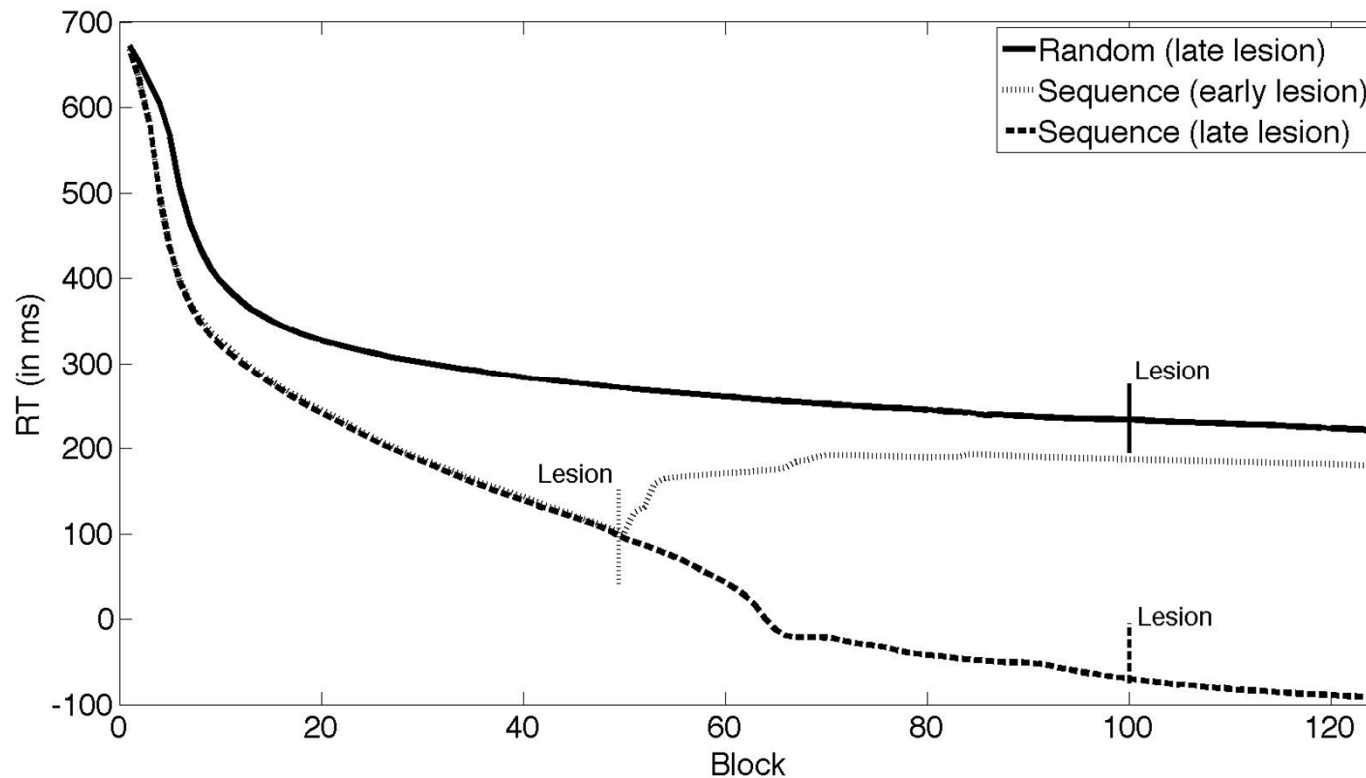


Le role des GB dans la production de séquences



Résultats de la simulation

- L'injection de muscimole fût simulée par une réduction de 90% de la connection GPI → VL



Take home

- Les GB sont nécessaires pour apprendre à construire des tâches automatiques;
- Cependant, la séquence est représentée dans le cortex;
- Ceci est en accord avec les données suggérant que l'automatisme ne dépend pas des niveaux de dopamine (e.g., *habit* learning, Parkinson);
- Ceci suggère un nouveau rôle pour les GB en tant que processus général d'apprentissage.



Merci!!

– Greg Ashby



Lauren Vucovich



– Dennis Runger



Jessica Roeder

