Rule learning in men, machines and avatars:

From the neuronal organization of the pre-frontal cortex to computational principles.

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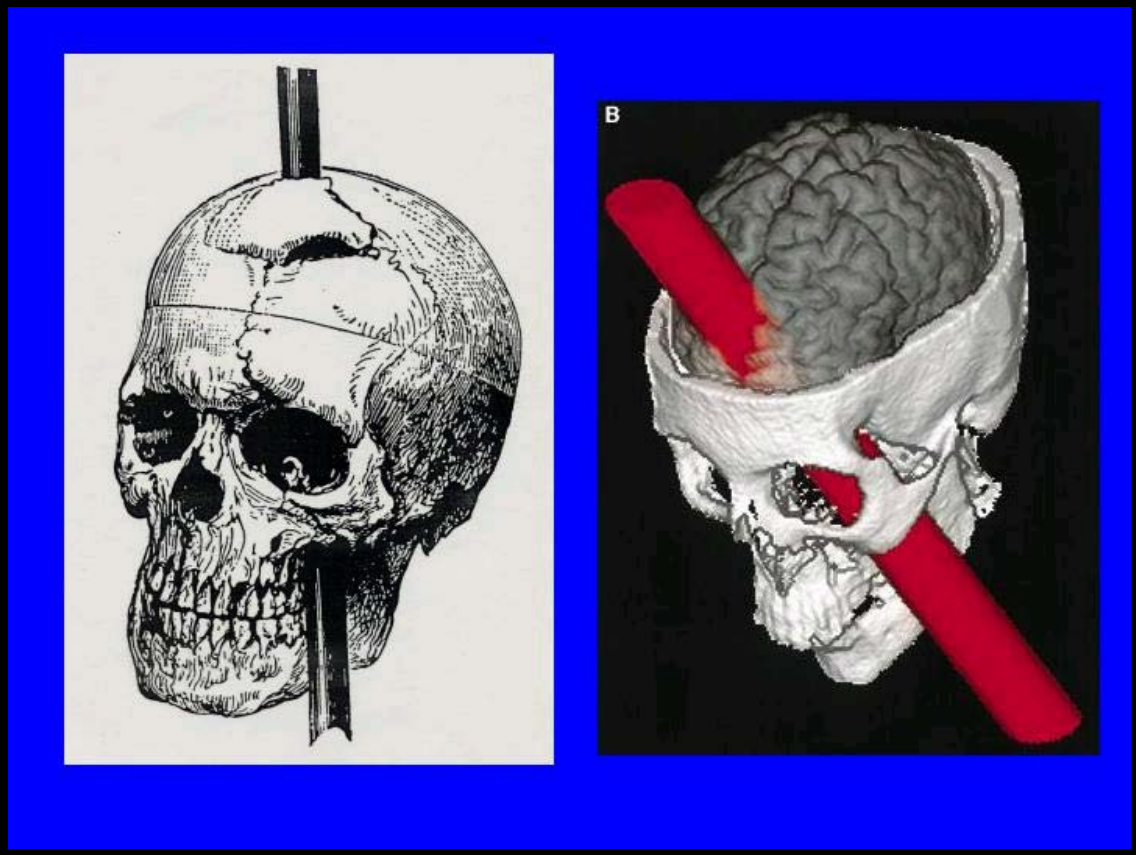
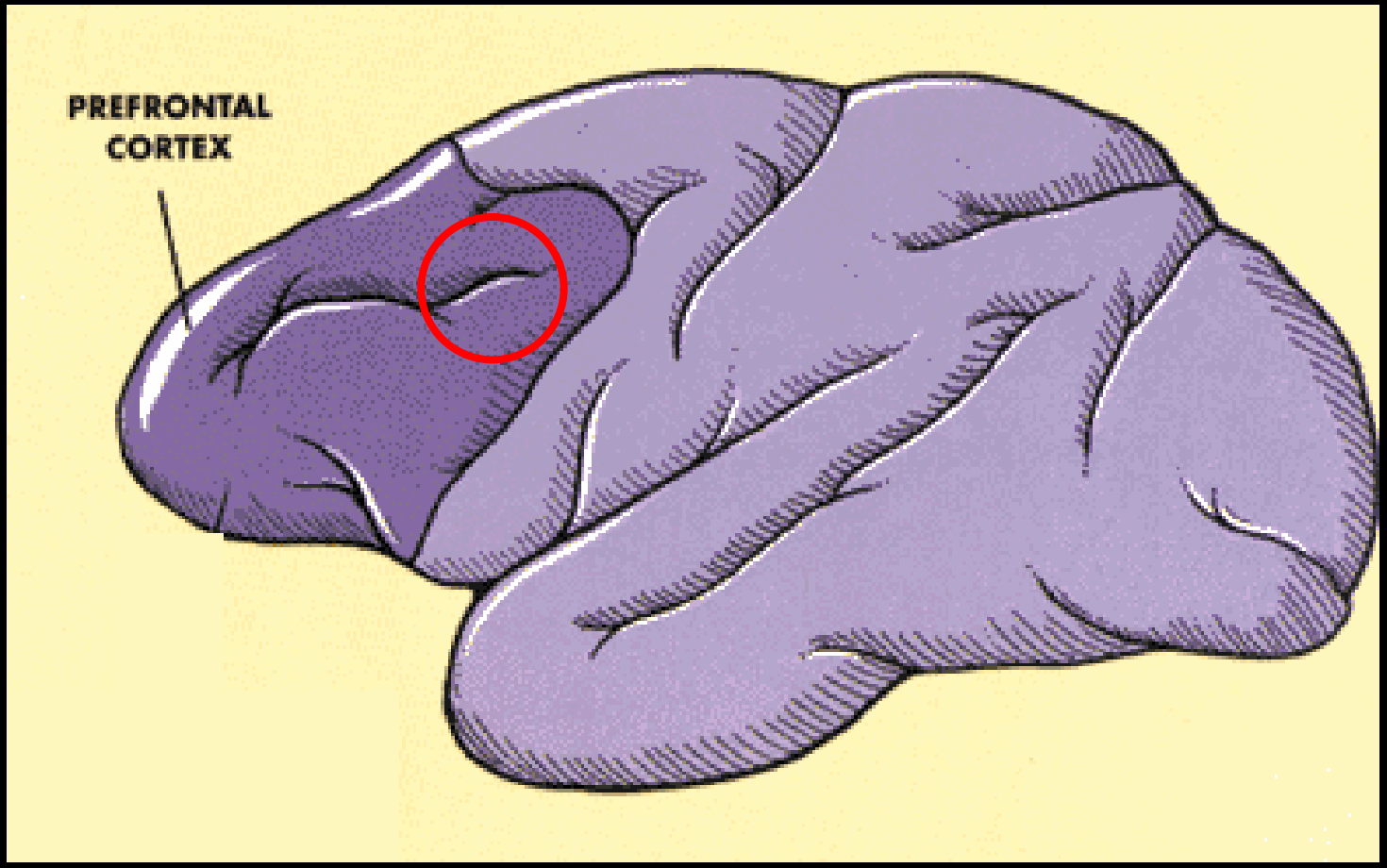
Knowledge and rules

Damage to the prefrontal cortex leads to deficits in Rule Learning

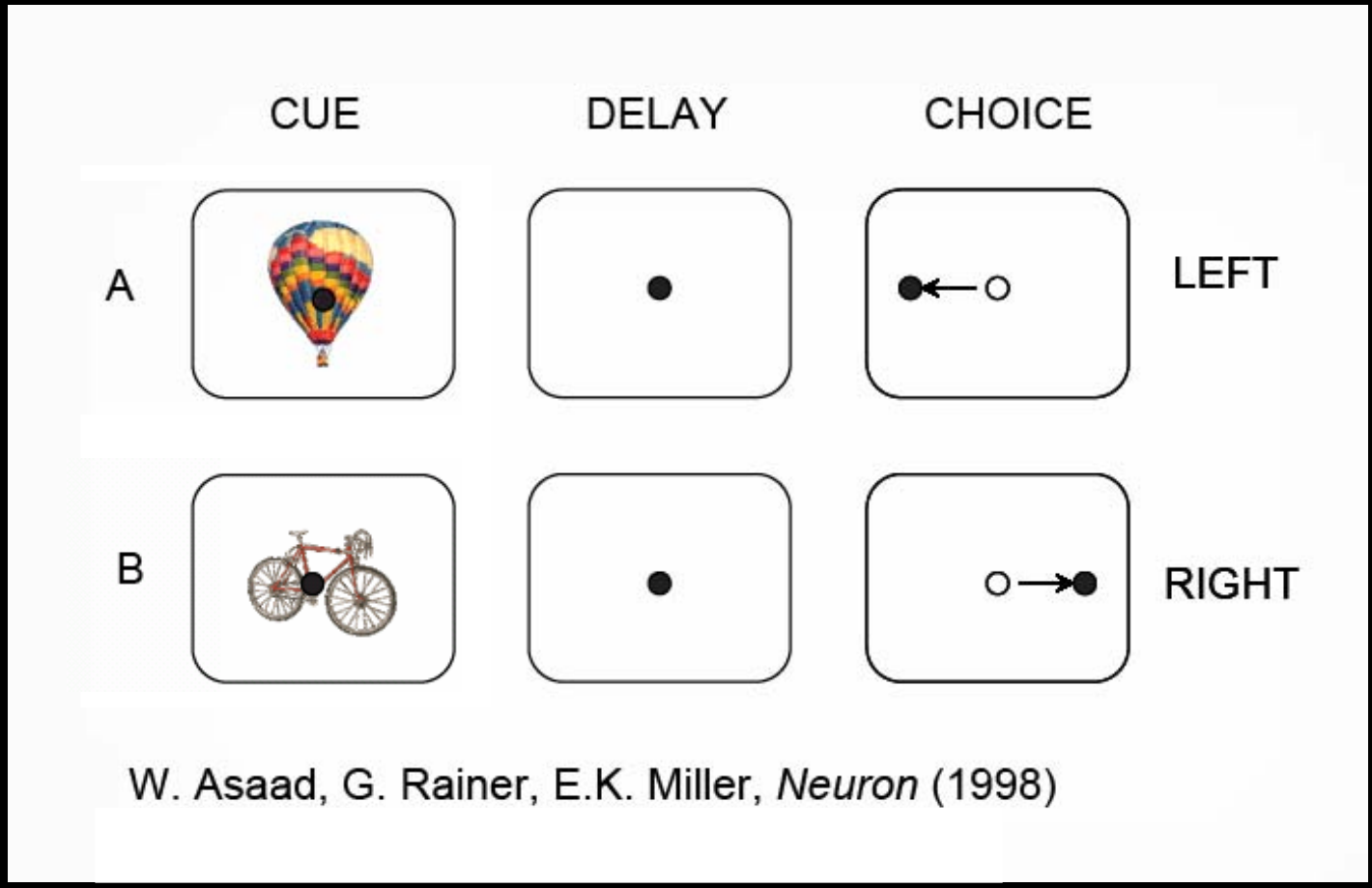


Phineas Gage 1848

PFC: Anatomy

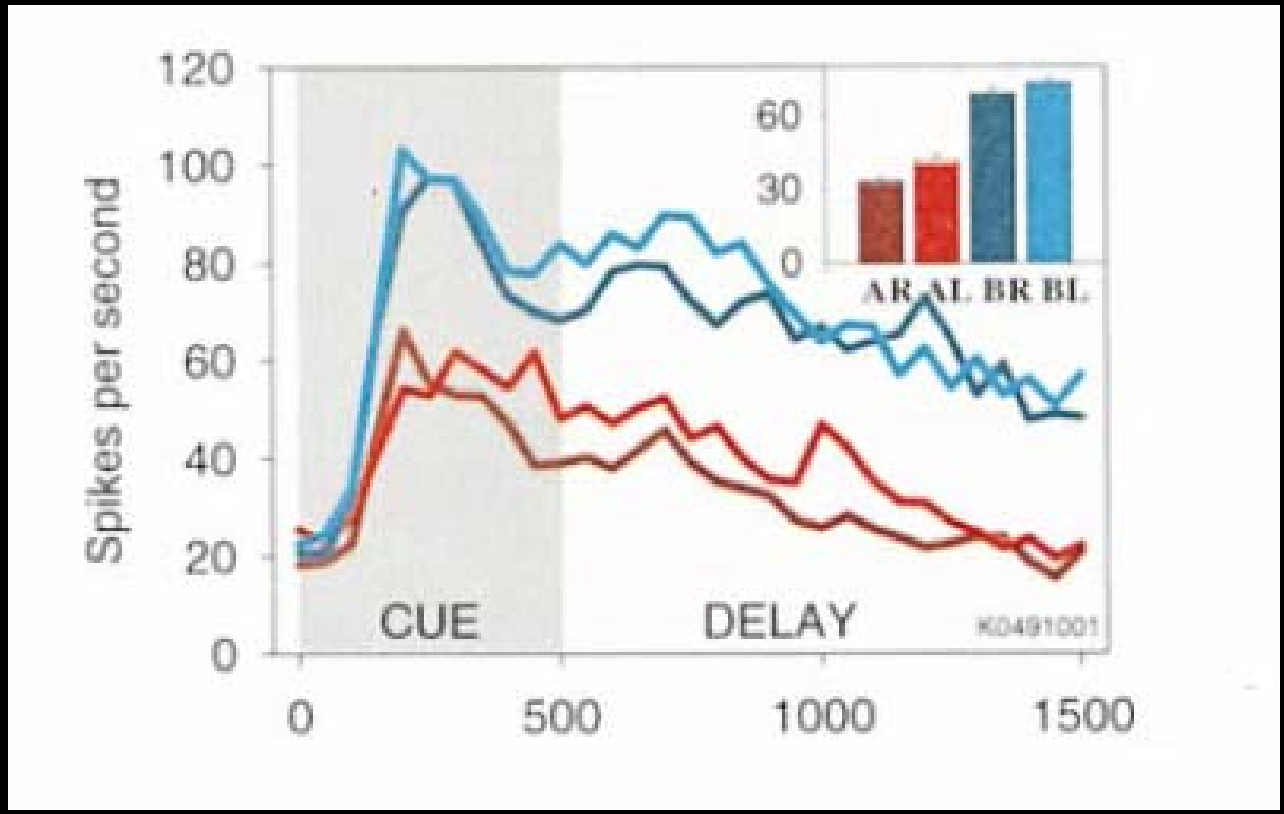


Rule learning and switching in the PFC



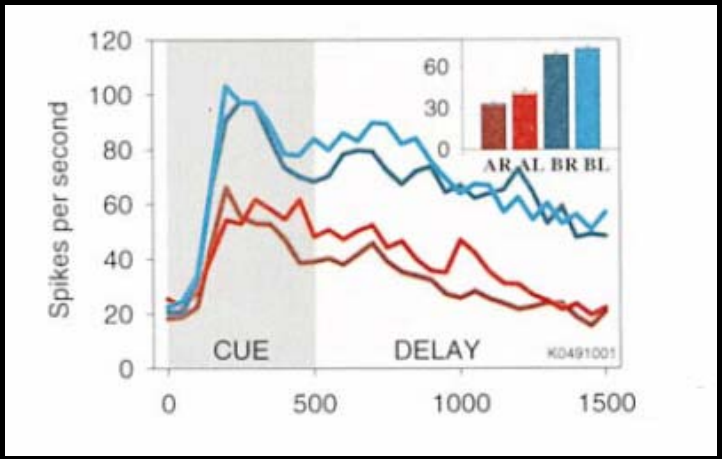
W. Asaad, G. Rainer, E.K. Miller, *Neuron* (1998)

PFC shows sustained activity

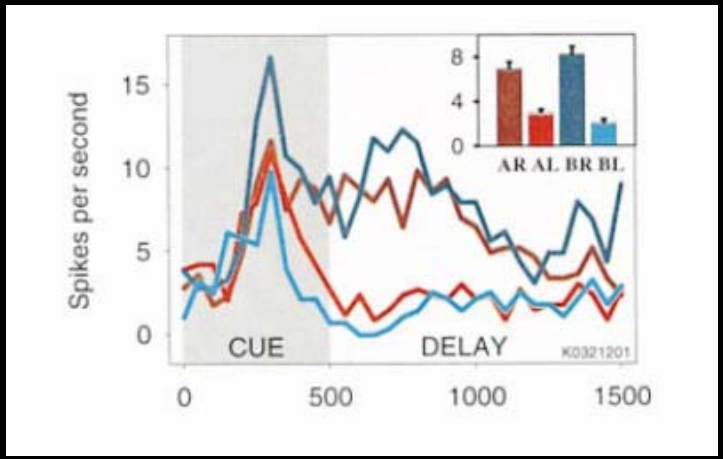


Neurons in the PFC shows cue and/or action specific delayed responses: the atoms of rules

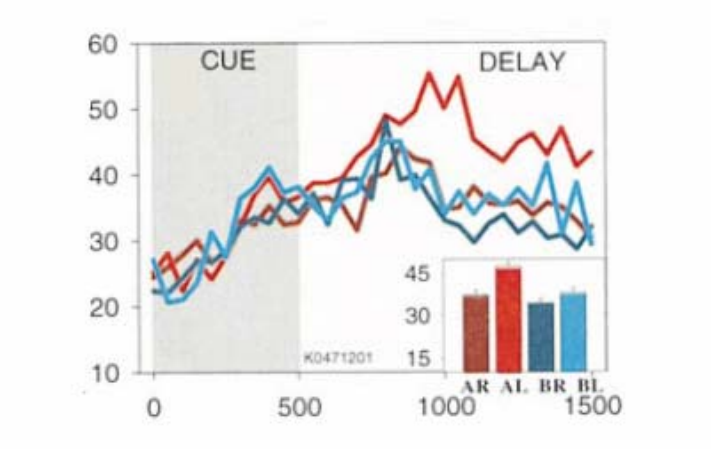
Cue Selective



Action Selective

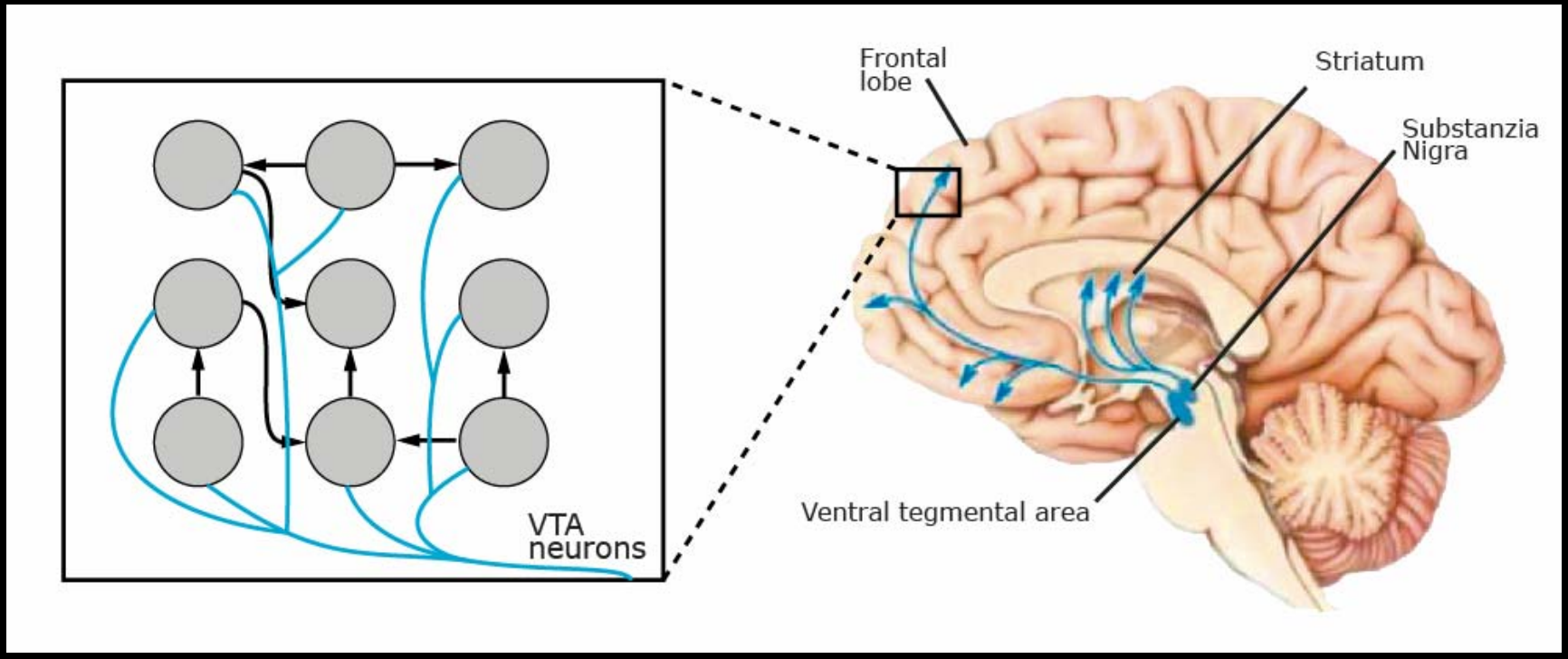


Cue and Action Selective



Principle:

Rules are encoded in the lateral connections that form PFC circuits modulated by reward signals



The question:

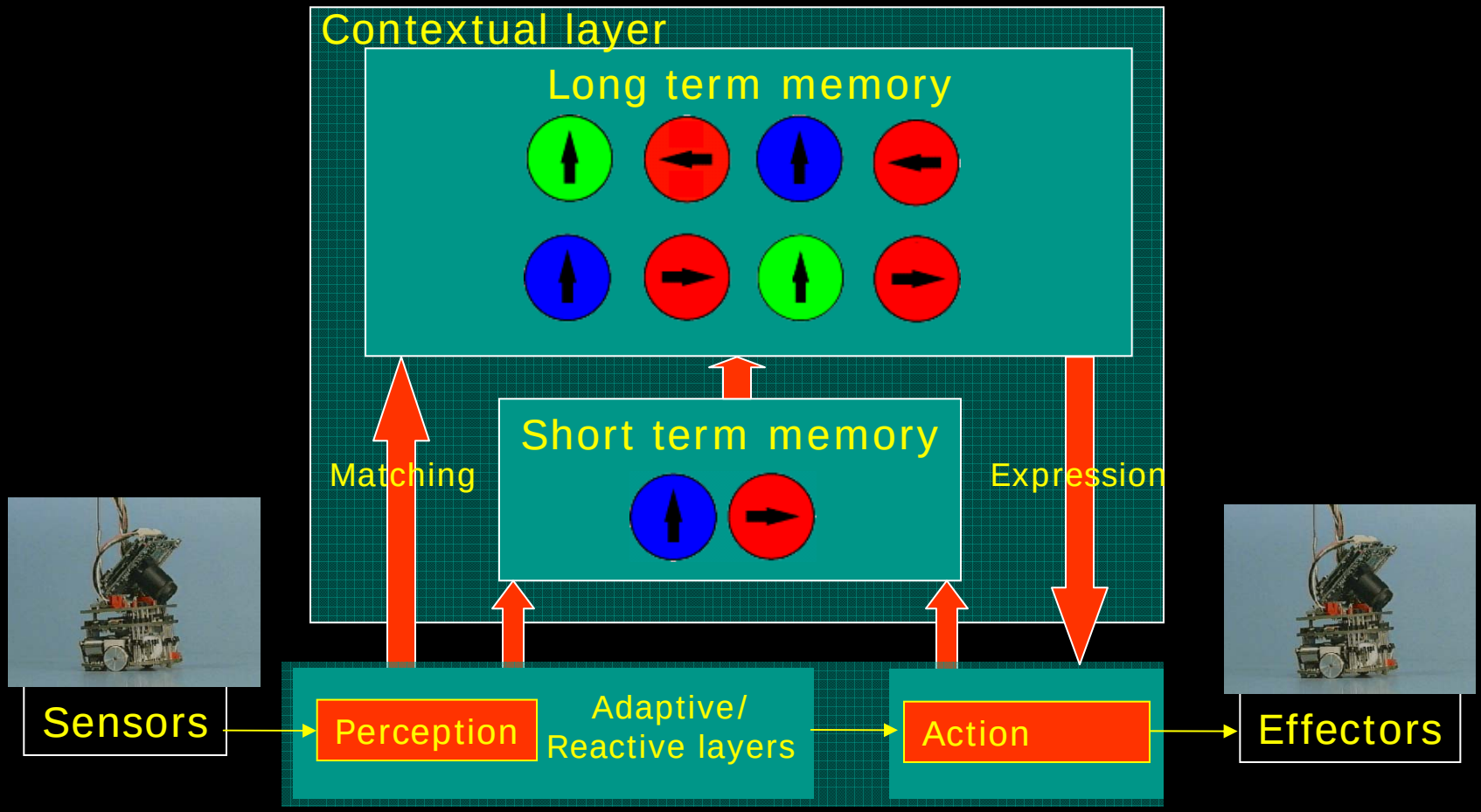
- How can local learning rules modify lateral connectivity in order to capture global properties of the real world, i.e. a rule?

Paradigm: Robot analog of a conditional association task (conserves the real-world and real-time properties)

Distributed Adaptive Control (DAC) Architecture

Verschure et al (2003) Nature, 425:620-24

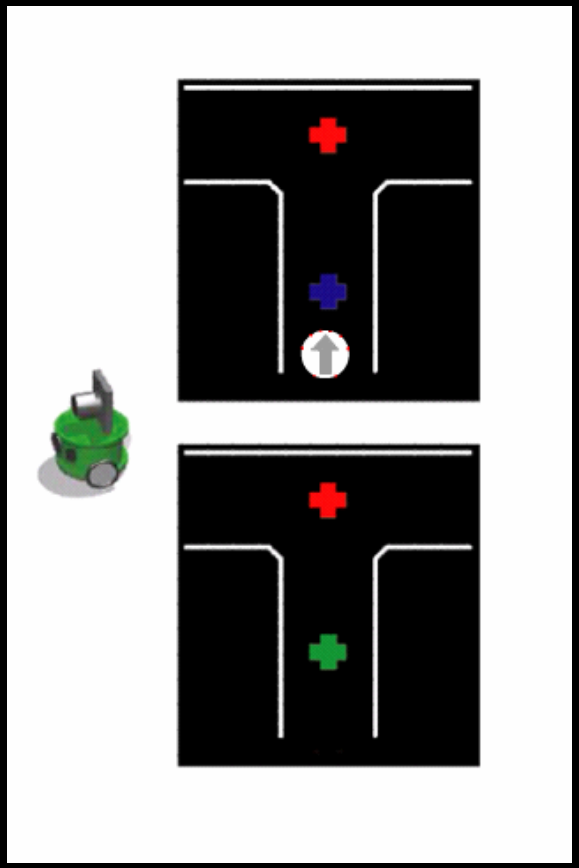
Distributed Adaptive Control (DAC) Architecture

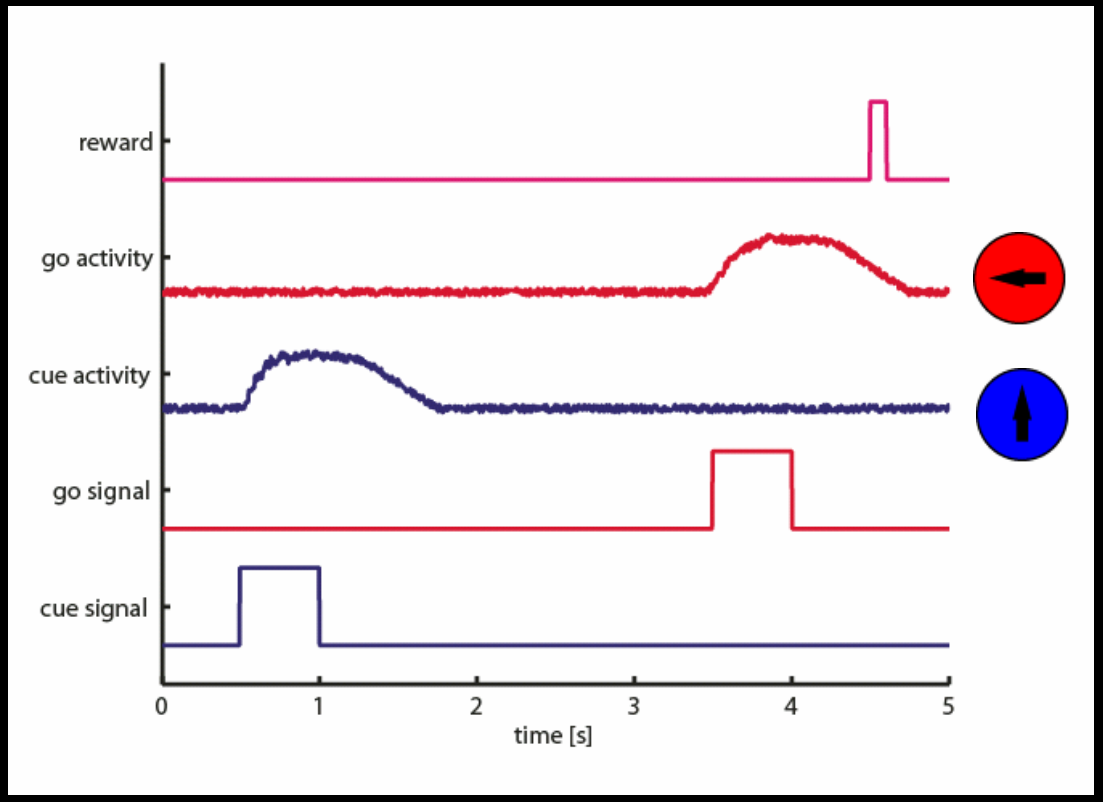


DAC acquires the knowledge to define LTM but not the rules of how to use it
It lacks a PFC

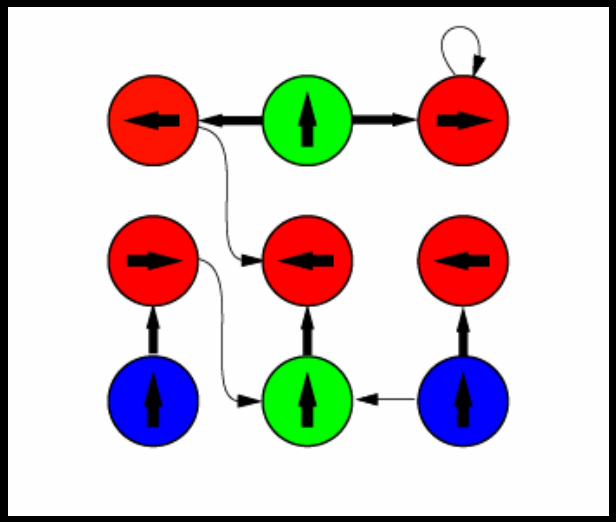
Verschure et al (2003) Nature, 425:620-24

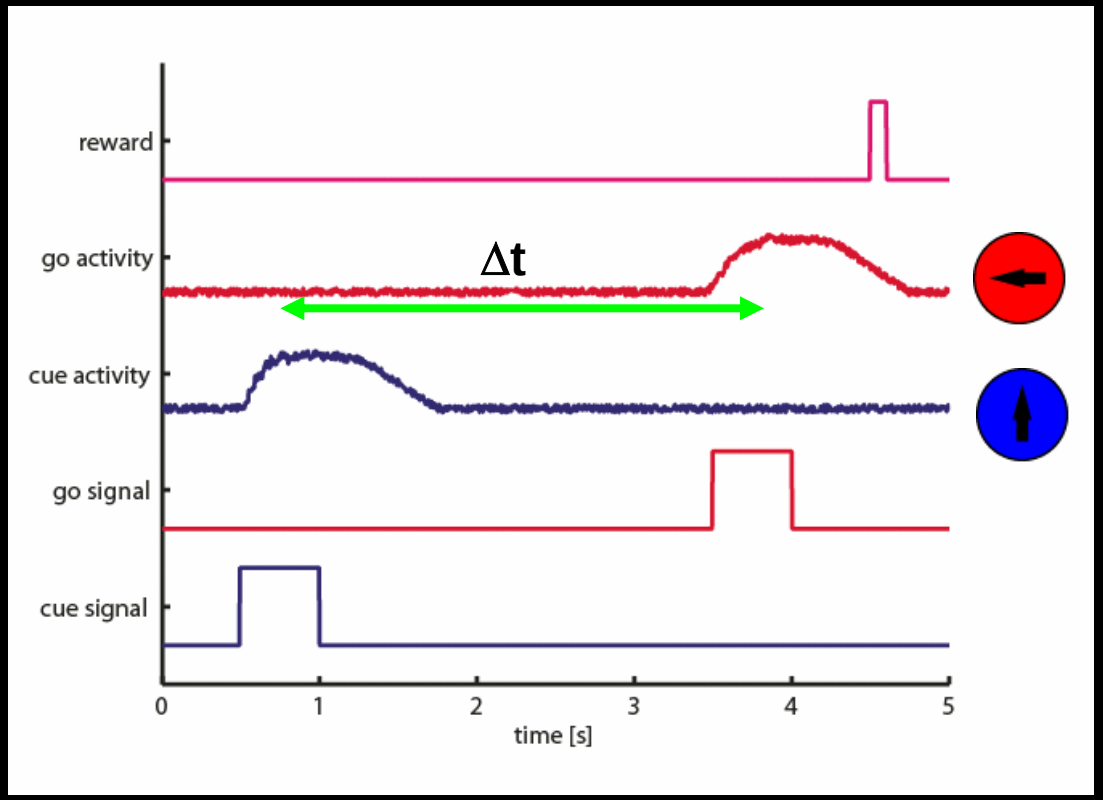
Task specific activity in LTM



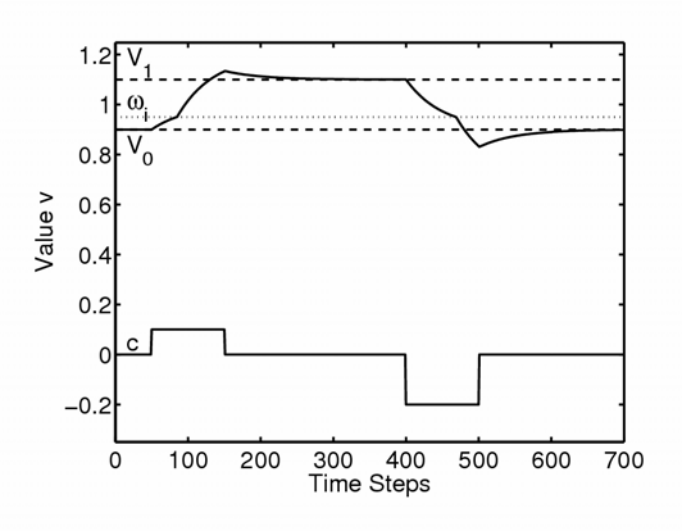


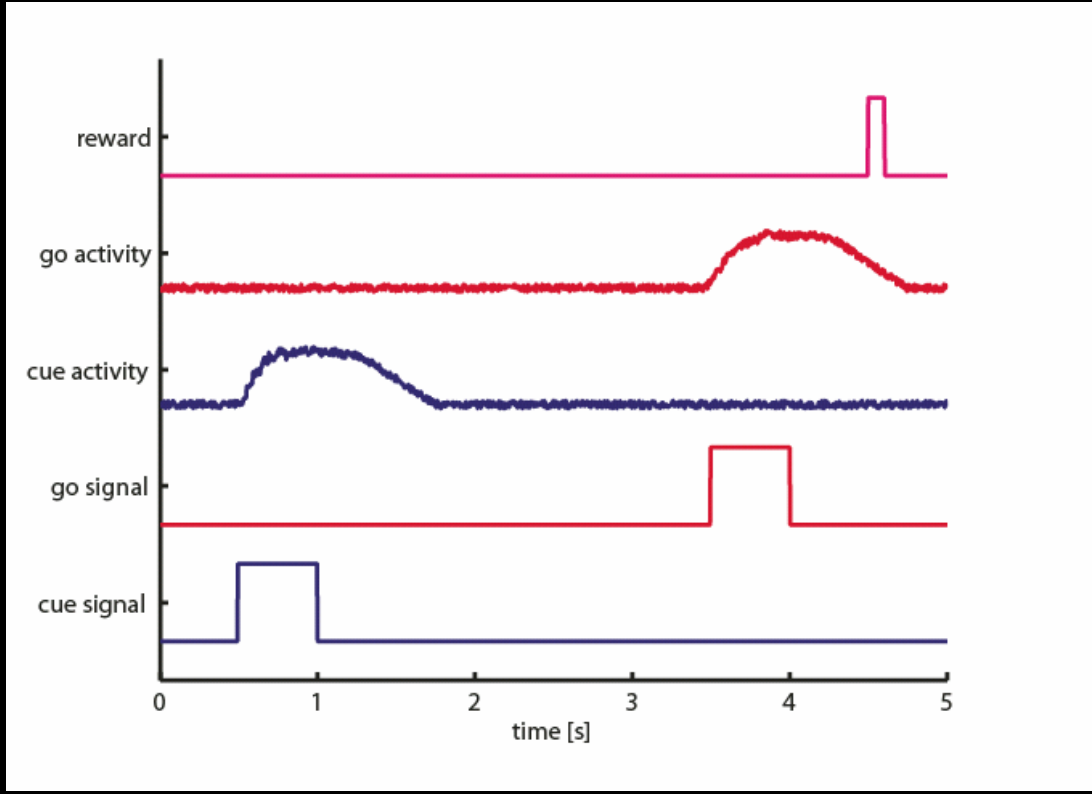
Lateral Connectivity





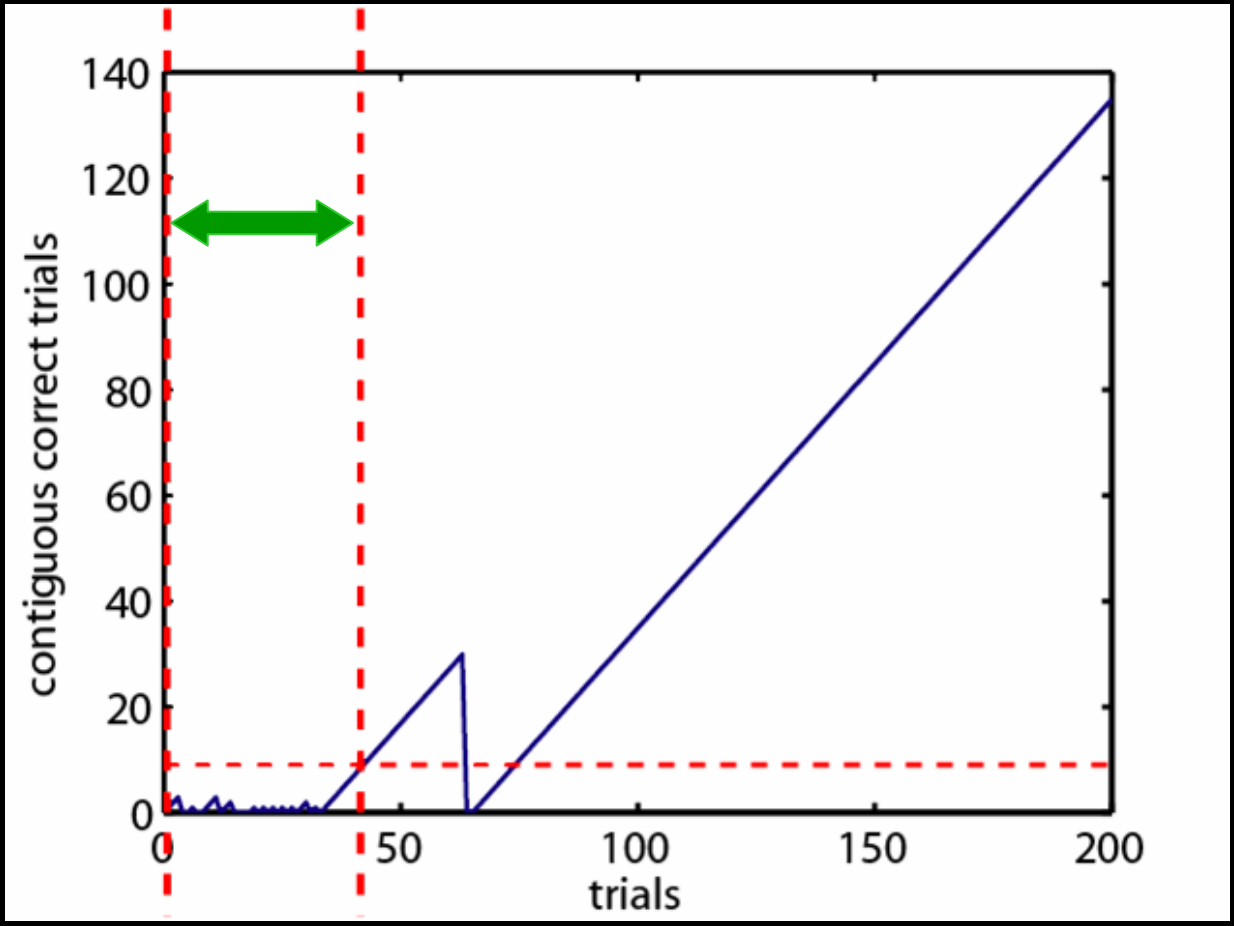
Reward System





Reward leads to potentiation $\eta+$ (>0) their absence to depression $\eta\_$ (<0) of synapses

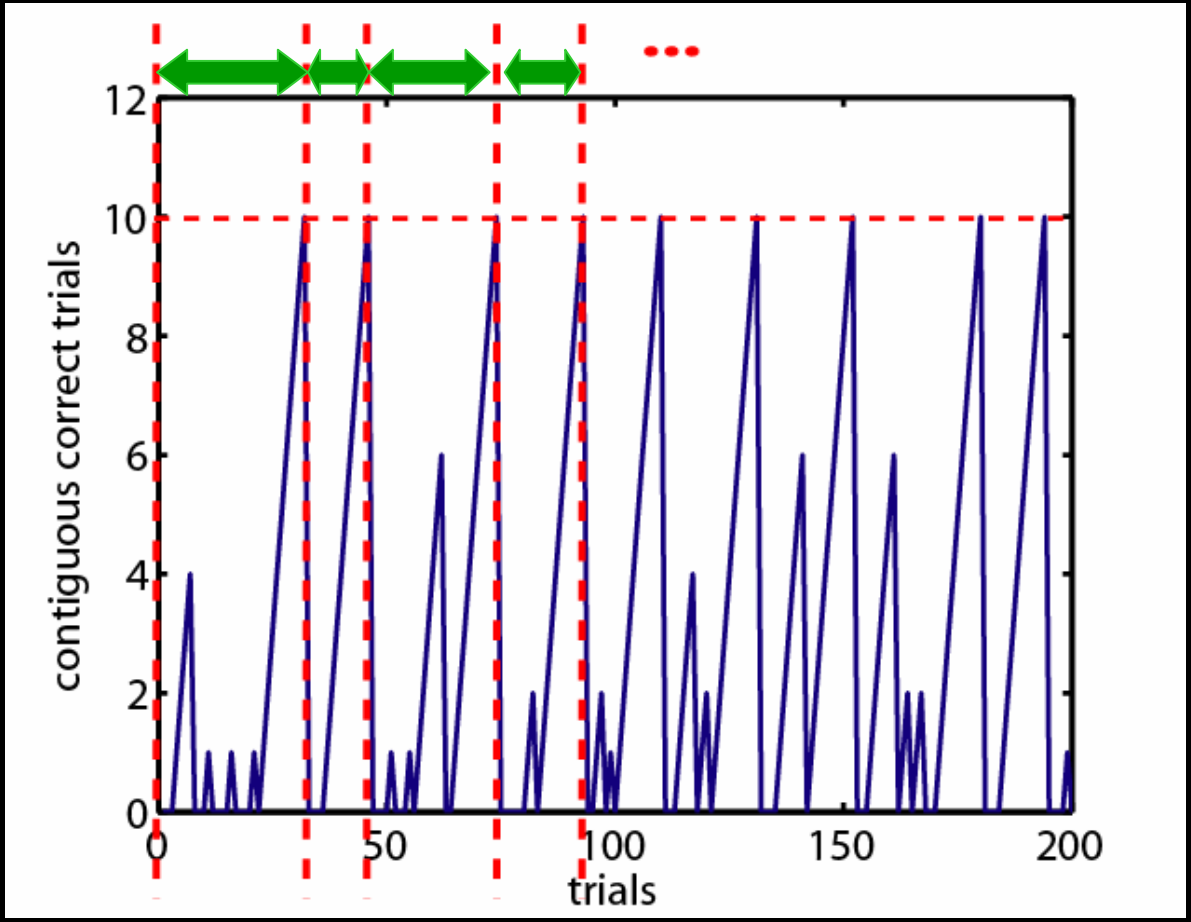
Learning Performance



Mean number of trials to criterion:

46±7 trials

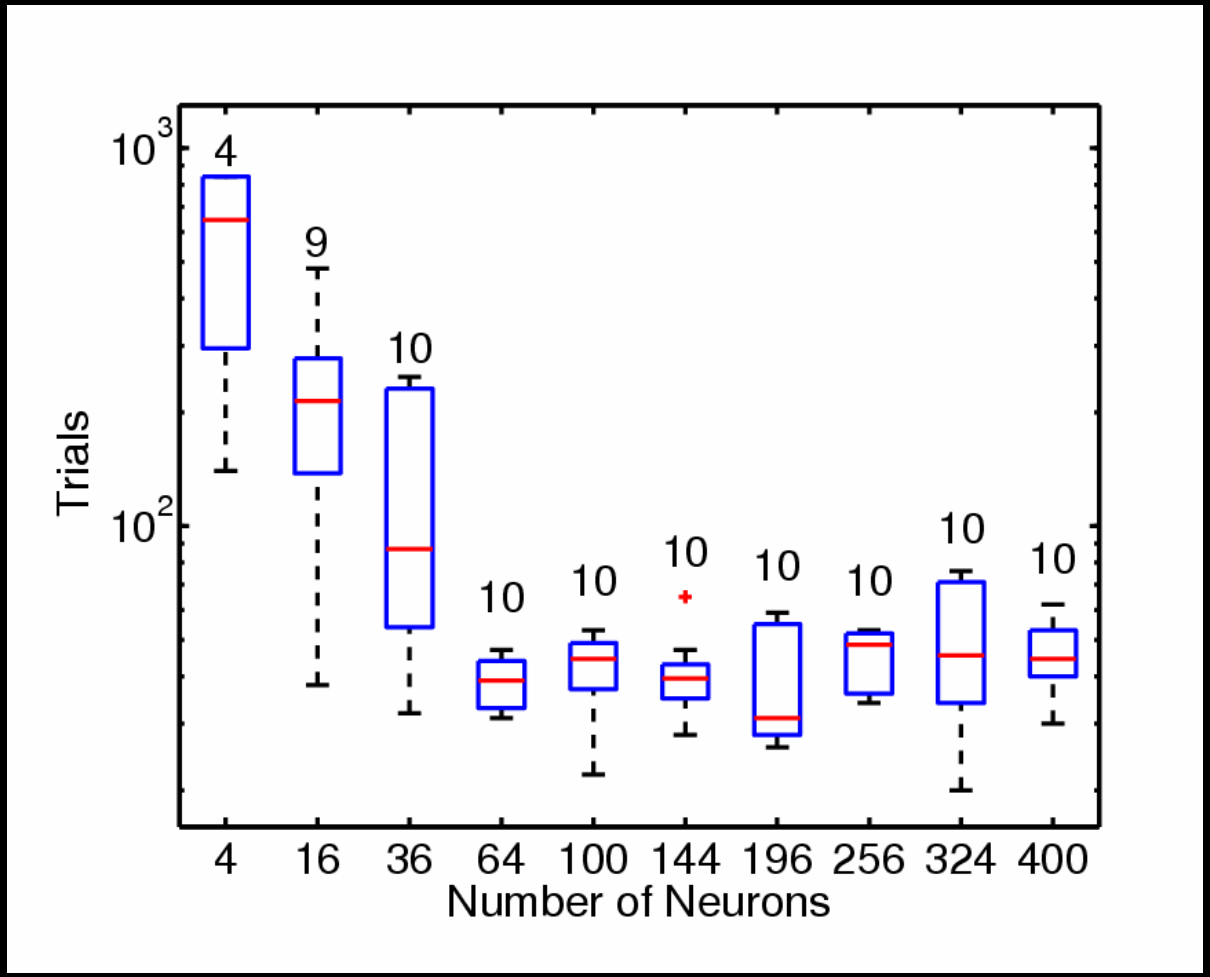
Switching Performance



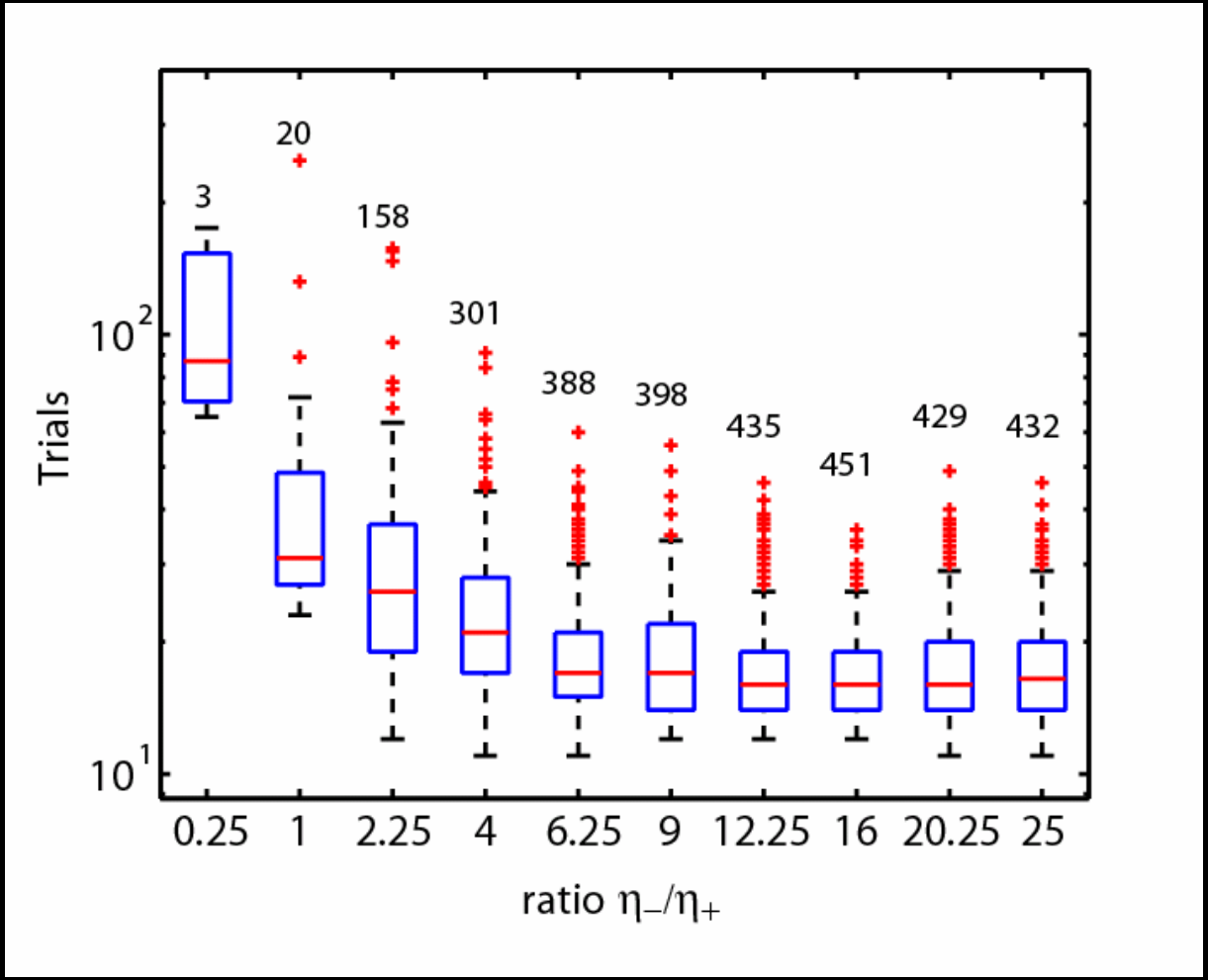
Mean number of trial to criterion:

22±10 trials

Memory Capacity



Depression vs. Potentiation



Conclusions

- DAC has a Rule Learning System
- Rule learning is stable in a real-time task
- Rule switching is significantly faster than rule learning
- Performance reaches a fixed optimum in terms of the number of neurons and the relation between depression and potentiation

Human - Avatar Communication

Thanks