Amygdala Induced Plasticity in an Integrated Computational Model of the Two-Phase Theory of Conditioning

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INTRODUCTION

In the early 1960's Konorski has proposed that the associative processes underlying classical conditioning can be separated in a fast non-specific learning systems (NLS) and a slow specific one (SLS) [1]. We show an integrated model of the amygdala, basal forebrain and auditory cortex as an example of NLS [2] and the cerebellum as a model of SLS [3]. The amygdala's ability to code valence quality of stimuli [4] builds the theoretical framework for the induction of plasticity in our model.

MODEL

Non-specific Learning System NLS

Cortical learning has been simulated by a spike-time dependent learning rule STDP (Fig. 1). Back-Propagating Action potentials (BAP) are responsible for an increased sensitivity in the post synaptic cell [5]. The unconditioned stimulus (US) induces a burst of the amygdala and the cholinergic nucleus basalis (NB), which suppresses the BAP inhibition on cortical synapses(Fig 2).

Specific Learning System SLS

In the cerebellum the coincidence of CS and US induces LTD at the level of the parallel fiber - Purkinje cell (PU) synapse. Due to this LTD the PU will cease to fire dis-inhibiting to neurons of the deep cerebellar nucleus (DN), triggering so a conditioned response (CR) that is matched to the experimental interstimulus interval (ISI).

preSyn	postSyn	Result
+	+	LTP
+	-	LTD
-	+	HLTD
-	-	-

Figure 1: The STDP Learning Rule of the NLS: The timing of Pre- and Post-Synaptice activity are the curical factors for the induction of LTP, LTD and HLTD in the auditory cortex.

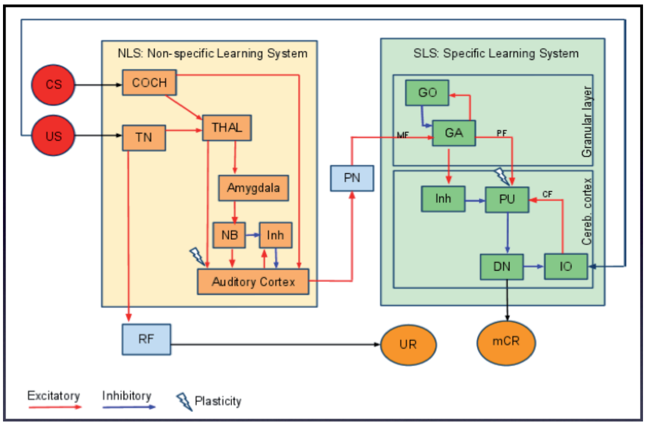


Figure 2: Model architecture of the two phase theory of conditioning.

SIMULATION

The model is based on the experimental concept of a delayed eye-blink conditioning. We tested the credibility of our model using the following protocol:

- 5 auditory stimuli (1 CS)
- 1 aversive stimulus (US)
- 30 trials of conditioning: 400ms CS, 100ms US, 300ms ISI
- Control: 5 stimuli without US

After the conditioning phase an increased reactivity to the CS can be observed in the auditory cortex (Fig. 3). In the SLS the CR is elicited by the NLS induced increased activity in the parallel fibre (Fig. 4).

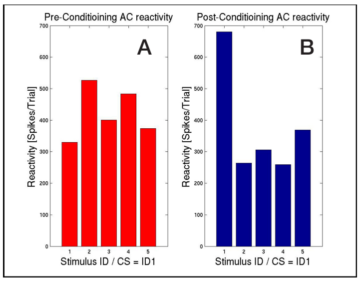


Figure 3: Cortical reactivity to the CS (Stimulus 1) before (A) and after (B) conditioning. Stimulus 2-5 are unassociated control stimuli.

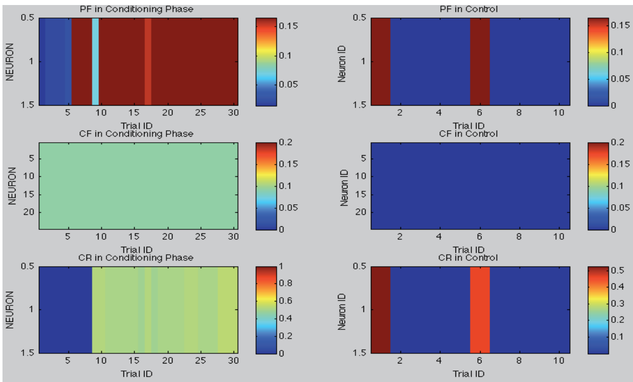


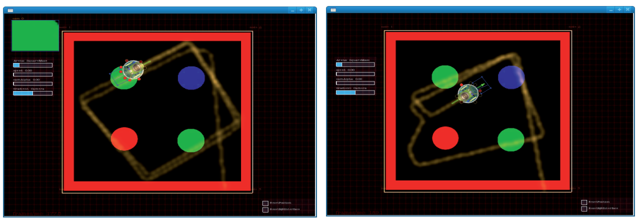
Figure 4: SLS reactivity to the CS before (top) and after (lowest) conditioning.

ROBOT APPLICATION

The real-time performance and ecological validity of the model is tested using a robot object avoidance tasks where the US is signaled by a proximity sensor and the CS by a red color detector (Fig. 5). The ISI varies between 0.3 - 1.5 seconds. The US induced increase of cortical representation of the CS is used to bost the SLS.

The CR is expressed as a CS dependent modification in the robot's trajectory in the arena (Fig. 5, right).

Figure 5: Free moving behaviour of the robot in an open field arena before conditioning (left). After conditioning the robot avoids the red color path that was associated with the US (right).



CONCLUSION

The amygdala coded valence value of the US acts as an inductor of cortical representational maps in the NSL. These increased stimuli representation can trigger guided CR in the SLS. The mossyfibre-granule synapse acts as a filter allowing to pass only high amplitude signals [6]. The tonic and spillover inhibition observed in the CE [7] are used to interrupt the information flow as soon as some action potentials are generated in direction to the PU by the NLS. The model can be used to control in real time a robot object avoiding task.

References

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