A NEUROCOMPUTATIONAL MODEL FOR NICOTINE ADDICTION

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What is our goal? To develop a neurocomputational model to demonstrate that addiction is a kind of goal-directed behavior adopted by reinforcement learning

How do we model? Along with brain substructures, the effects of neurotransmitters are taken into account and action selection, action evaluation and value assignment subsystems are realized as interconnected dynamic loops.

Abstract

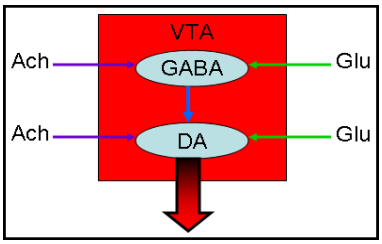
- The model realizes DA secretion from the VTA to the cortico-striato-talamic loop by utilizing reinforcement learning.
- DA secretion, action evaluation, and value assignment subsystems are modeled as nonlinear dynamical systems.
- Error in expectation symbolizes the modifying effects of the neurotransmitters, changes the output of dorsal striatum, amplifies the emotional input, updates the stimulus value.
- Past actions contribute to the evaluation.

Nicotine Addiction and Reinforcement Learning

- addiction is a behavior adopted through reinforcement
- repetition of behaviors defines the dynamical process
- reinforcing effect of pleasure affects as a reward
- reinforcers: positive (e.g. pleasure)
  negative (e.g. healing of coughs)

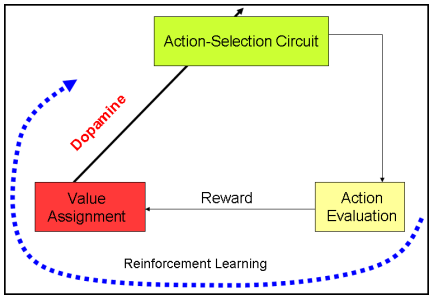
The Interaction of Dopamine & GABA

- major neurotransmitter responsible in reward and action selection is dopamine
- dopamine secretion from VTA is modulated by the interaction of acetylcholine, glutamate, GABA

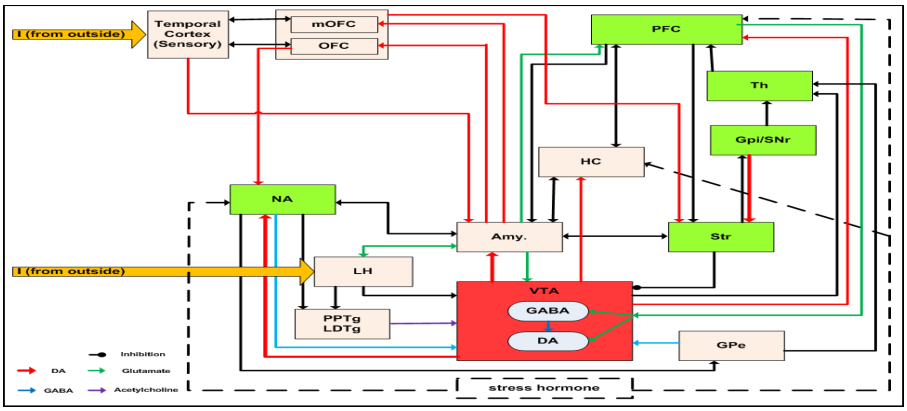


Our Model

- uses reinforcement learning
- dopamine secretion → VTA
  action selection → cortico-striato-thalamic loop
  action evaluation
- nonlinear dynamical systems
- rewards greater than a certain value are effective
- modulatory effects of neurotransmitters



Which Brain Substructures Play A Role?



Amy: amigdala GPe: globus pallidus externus GPi/SNr: globus pallidus internus/substantia nigra pars compacta
HC: hippocampus LH: lateral hypothalamus LDTg: lateral dorsal tegmental nucleus NA: nucleus accumbens Th: thalamus
I: inputs OFC: orbitofrontal cortex PFC: prefrontal cortex Str: dorsal striatum VTA: ventral tegmental area
PPTg/LDTg: pedunculopontine tegmental nucleus/laterodorsal tegmental nucleus mOFC: medial orbitofrontal cortex

Results

- 3 different behaviors: → addiction develops
  addiction does not develop
  indecisive behavior

Addiction develops

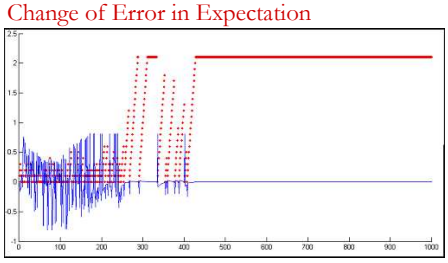
- In 20/50 trials
- 346/1000 steps in average
- with std deviation= 265,7671

Development of Addiction

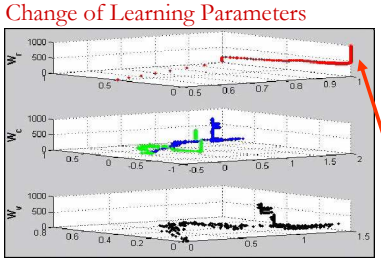
Learning Non-addict Behavior

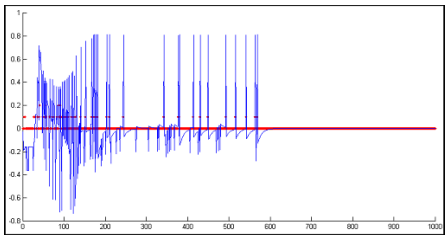
Indecisive Behavior

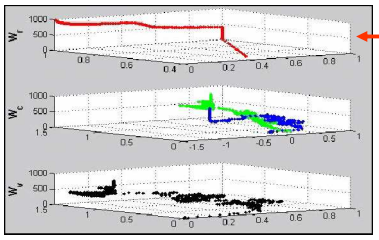
Change of Error in Expectation

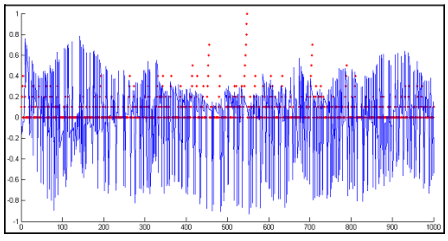


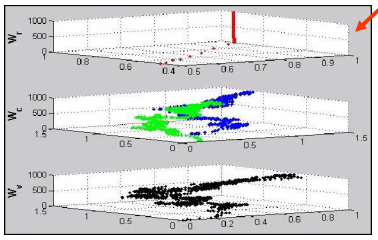
Change of Learning Parameters











The Effect of Reinforcement Learning and Dopamine

Conclusion & discussion

- A neurocomputational model for nicotine addiction, which considers the effects of neurotransmitters, is developed.
- It is demonstrated that addiction is a goal-directed behavior developed by reinforcement learning.
- The model can be improved by including a lower-level approach showing the effects of receptors and neurotransmitters on a molecular basis.

References

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Gutkin, B.S., Dehaene, S., Changeux, J.P., "A Neurocomputational Hypothesis for Nicotine Addiction", PNAS, vol.103, no.4, 1106-1111, Jan 24, 2006.