

Goals and Habits in the Brain

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Model-based
Goal-directed
Prospective
Reflective

vs.

Model-free
Habitual
Retrospective
Reflexive



Decision

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Generation 4: Elaborations on **Model-Based** and **Model-free** Control

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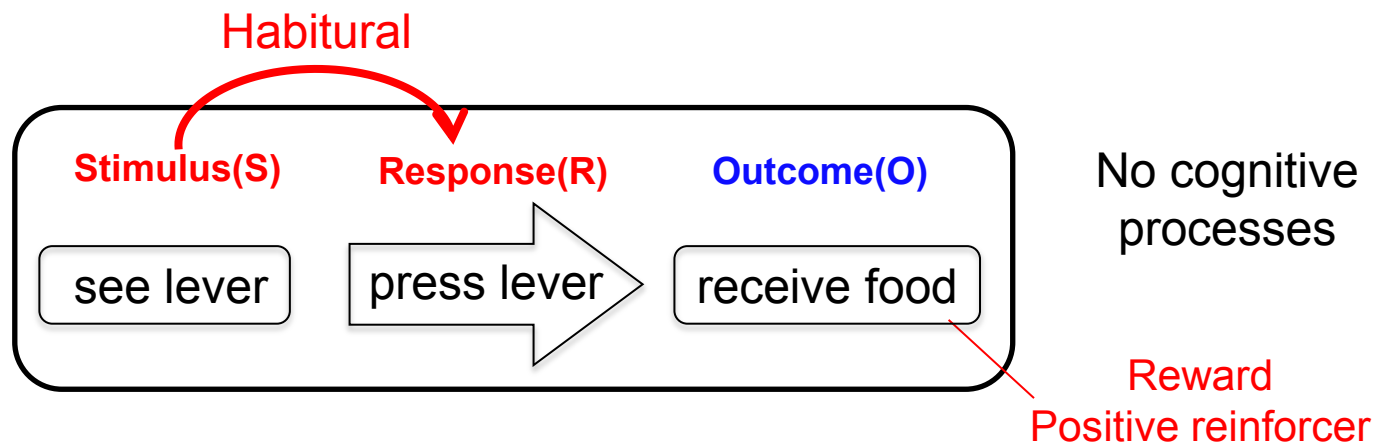
Psychopathology

Stimulus-response(S-R) theory



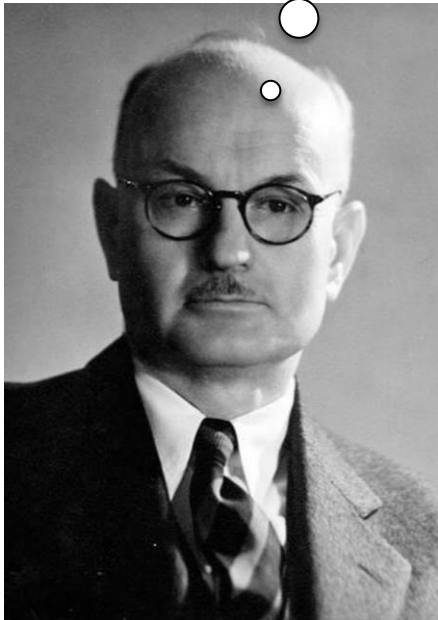
Edward L. Thorndike

- **Behavior** is due to the **association** of **stimulus(S)** and **response(R)** that is generated through those connections.
- **Law of Effect**
Animals learn based on the **outcome (O)** of their own actions.
- A **habit** is nothing more than a chain of **S-R** pairs.

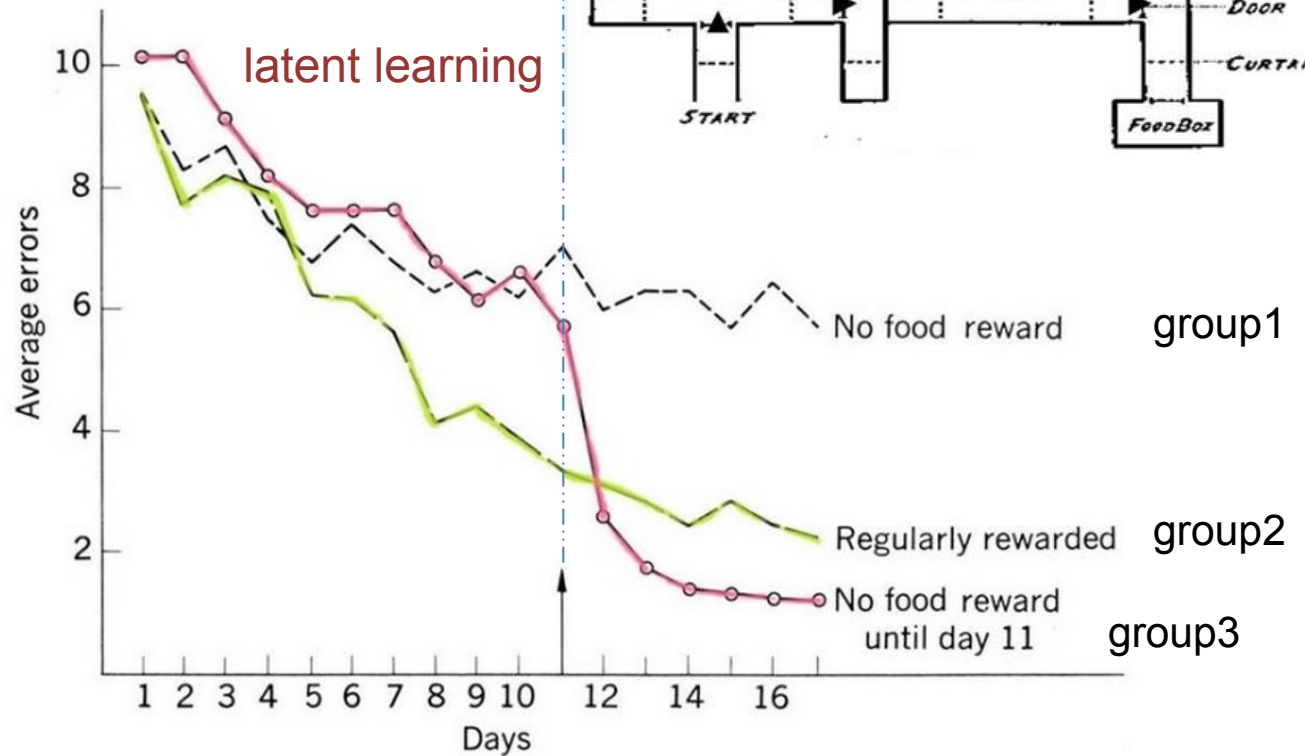
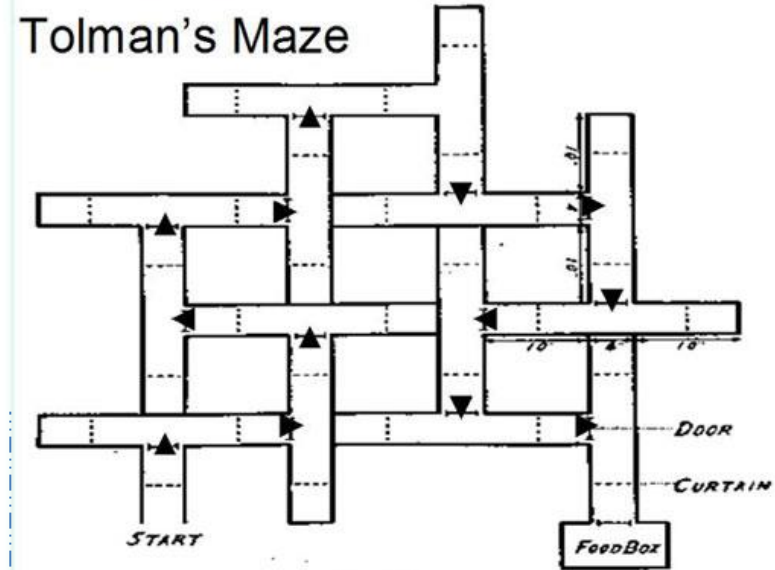


Generation 0: Cognitive Maps

Is **reward** necessary for leaning ??



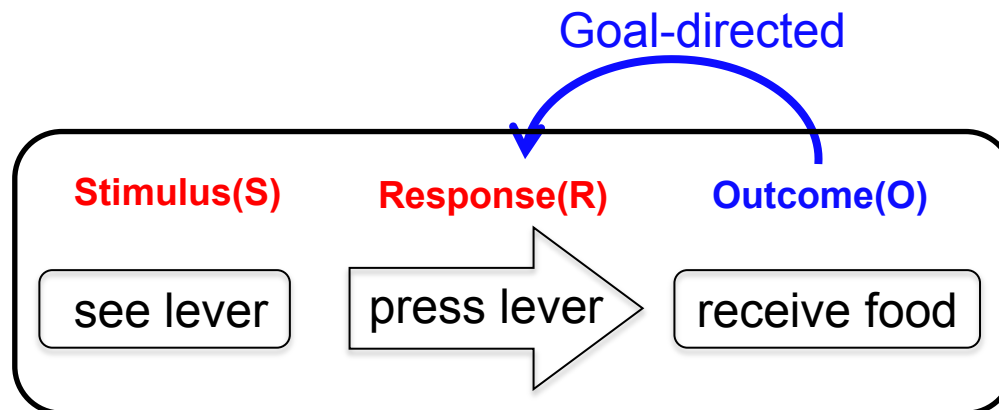
Edward Tolman



Generation 1: Goal-Directed Actions and Habits

Goal-directed instrumental behavior

- 1) It should **reflect knowledge of the relationship** between an **response (R)** and its **outcome (O)**. (**R-O** control)
 - 2) The outcome should be motivationally relevant or desirable at the moment of choice.
- > Active deliberation, high computational cost, and an adaptive flexibility to changing environmental contingencies.

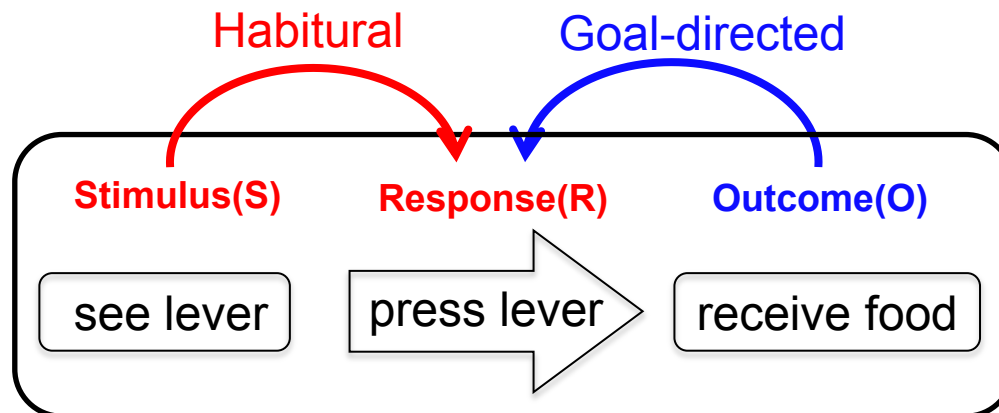


Generation 1: Goal-Directed Actions and Habits

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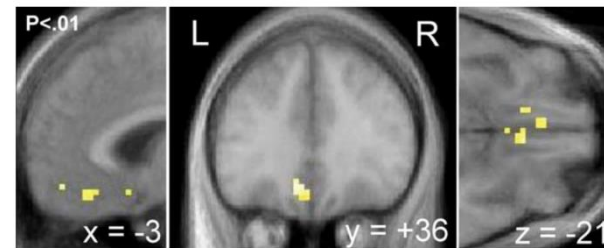


Generation 2: **Actions** and **Habits** in the Human Brain

Behavioral/Systems/Cognitive

Determining the Neural Substrates of **Goal-Directed** Learning in the Human Brain

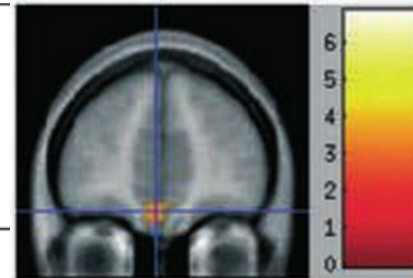
Vivian V. Valentin,^{1,2} Anthony Dickinson,³ and John P. O'Doherty^{1,2}



cortex, showed a strong modulation in its activity during selection of a devalued compared with a nondevalued action. These results suggest an important contribution of **orbitofrontal cortex** in guiding goal-directed instrumental choices in humans.

A specific role for posterior dorsolateral striatum in human **habit learning**

Elizabeth Tricomi,¹ Bernard W. Balleine^{2,6} and John P. O'Doherty^{3,4,5}



progressed. These results provide evidence for a shift from goal-directed to habit-based control of instrumental actions in humans, and suggest that cue-driven activation in a specific region of **dorsolateral posterior putamen** may contribute to the habitual control of behavior in humans.

Generation 3: **Model-Based** and **Model-free** Analyses

Reinforcement Learning (RL)

- **key quantities:**

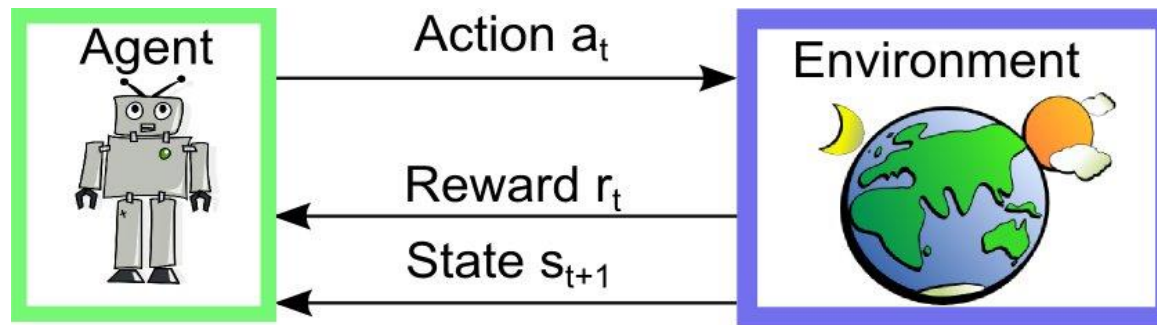
- (1) States (S) - contexts or stimuli

- (2) Actions (A)

- (3) Transition- the probability of transition from state to next state given action

- (4) Utilities- the expected reward (R) for taking action in state

- Agent has to find a optimal policy ($\pi(S) \rightarrow A$)



Reinforcement Learning Setup

Generation 3: Model-Based and Model-free Analyses

Reinforcement Learning (RL)

- **key quantities:**

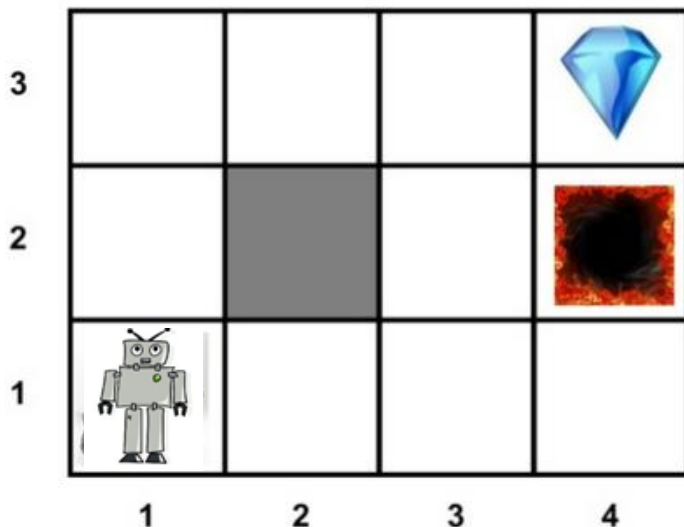
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- (4) Utilities- the expected reward (R) for taking action in state

- Agent has to find a optimal policy ($\pi(S) \rightarrow A$)



- States : Agent's location

- Actions : N,E,S,W

- Transition

- Rewards: -1 per time step, etc.

Generation 3: Model-Based and Model-free Analyses

Reinforcement Learning (RL)

- **key quantities:**

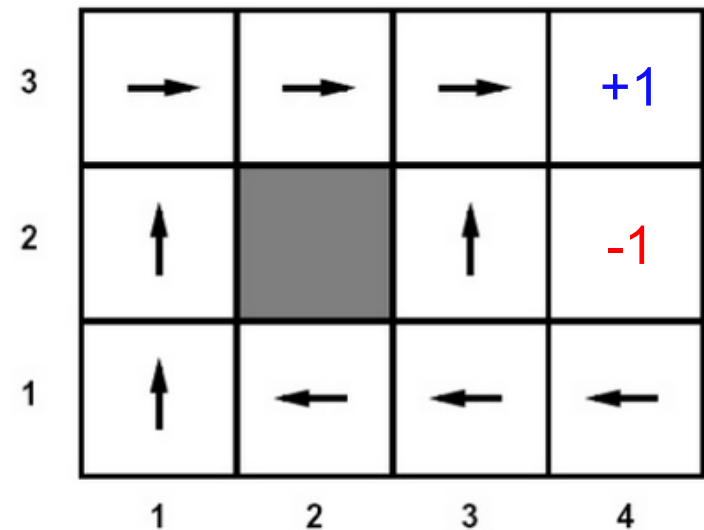
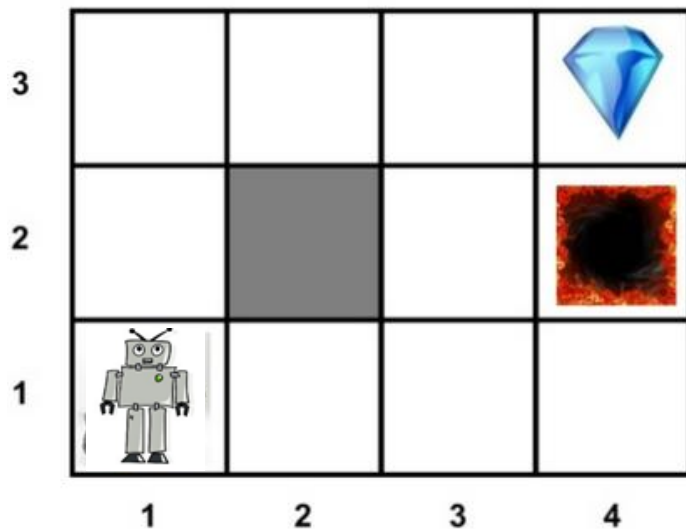
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Generation 3: **Model-Based** and **Model-free** Analyses

Reinforcement Learning (RL)

- **Model-based RL**

 - Step 1: learn the model (T, R)

 - Step 2: use the model to derive the optimal policy

- **Model-free RL**

 - derive the optimal policy without learning the model

Generation 3: **Model-Based** and **Model-free** Analyses

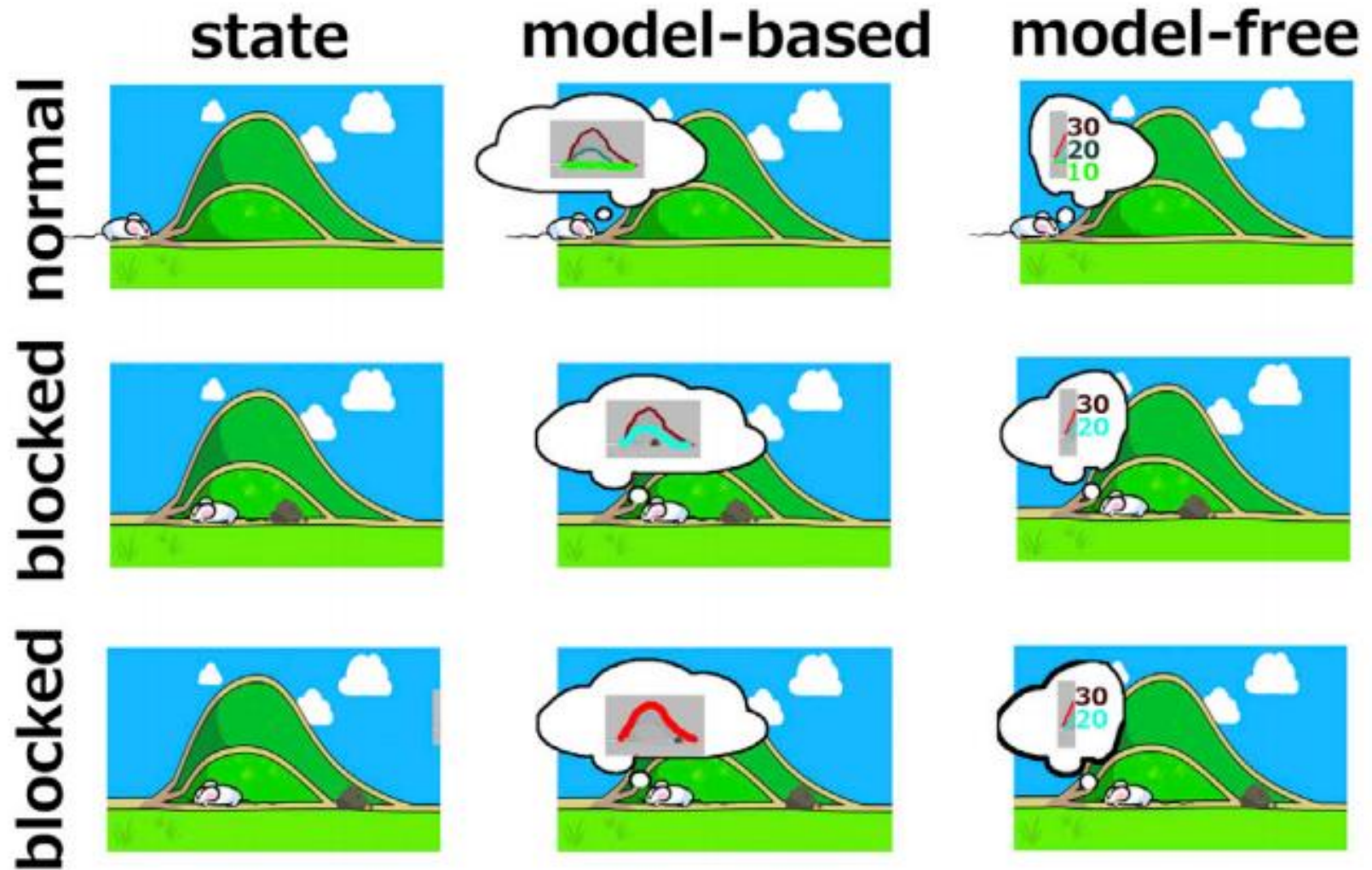
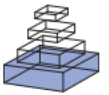


Figure 1. Schematic of the Tolman Detour Task

Cooperation and competition between two systems

- There has been anatomical and pharmacological insight into the balance of influence between the two systems.



The Mixed Instrumental Controller: using Value of Information to combine habitual choice and mental simulation

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Psychopathology

- **Overdominance of a model-based system**
 - Psychotic states, such as paranoia, delusions, and hallucinations. These can be seen as arising when the sort of processes that are associated with building and evaluating a model become sufficiently detached from external input from the world.
 - Boosting dopamine boosts the impact and control of such model-based influences
- **Overdominance of a model-free system**
 - Obsessive-compulsive disorder(OCD), drug addiction