# Caught in a Do-Loop: Malfunction in a Primitive Brain System to Model Compulsive Behavior

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## Introduction

Behaviors such as checking, counting, arranging, cleaning, and washing become intrusive on normal daily activity when one regularly has an uncontrollable urge to repeat these behaviors. One goal of learning why a person is compelled to do these activities is to gain a greater understanding of how we incorporate our desires and needs into the process of choosing our actions. Desires are that internal urge to do or have something. Needs are the basic necessities of healthy living - including eating and sleeping. Sometimes our desires and needs align, such as being hungry and wanting to eat a healthy meal. Other times they are at opposition, such as when wanting to watch a movie but too tired to stay awake. While cognitive processes play a critical role in the action selection process, the focus of the model presented here is more primitive brain mechanisms that are likely out of our cognitive control.

Presented here is a review of the neurological studies relating brain regions and systems to compulsive behavior. Then I describe a computational model that shows when an imbalance is created, compulsive behavior emerges and regular patterns are disrupted.

## Neurological Background

Many brain regions are likely involved in compulsive behaviors, from the prefrontal cortex to plan the behavior to mesolimbic structures involved in learning and reinforcement. However, the model described below focuses on even more basic brain functions. In particular I look at primal brain mechanisms related to foraging and exploration.

The dopamine system has been associated with addiction in humans (Wise, 2002) and compulsive behaviors in humans and lower mammals (Panksepp, 1998, 2001). Since we are mostly concerned with primitive mechanisms that influence behavior, we can leverage research in animal behavior. In particular I base the model on the SEEKING system as it has been reported in studies on lower mammals (Panksepp, 1998). An example of the compulsive behavior modeled is when a rat is presented with a lever that controls self-stimulation to the lateral hypothalamus. Stimulated rats exhibit excited and vigorous behavior and will continue to self-stimulate for an extended period. Eventually the rat will become physically exhausted and collapse. While many compulsive behaviors in humans do not reach the point of physical exhaustion, this extreme example is used to demonstrate the effect of an uncontrollable urge to persistently conduct a behavior.

While the dopamine system is often referred to as the reward system, as Panksepp (1998) points out, these compulsive behaviors (whether in self-stimulation in rats or OCD behaviors of humans) are often highly aroused activities performed with great vigor. This is in sharp contrast to the calming behavior seen in consuming rewards. Thus I base this model on the assumption that the compulsive behaviors are the result of a difference in the expectation for reward (as a result of activation of the SEEKING system) and the rewards received.

The SEEKING system is one of seven primary processes identified by Panksepp, the others being FEAR, RAGE, LUST, CARE, PANIC, and PLAY (Panksepp, 1998). The SEEKING process is perhaps the most basic process. It is the innate mechanism that motivates foraging and exploring of the environment to find resources. This process of seeking and exploring is rewarded and feeds into mechanisms for reinforcement learning. It is this reward, this satisfaction, that the rats cannot stop desiring but never achieve. Similarly, I speculate that many compulsive behaviors in people with OCD are in part the result of overstimulation of reward seeking mechanisms.

It is far from a new idea that the dopamine system is associated with compulsive behaviors. The SEEKING system has previously been linked to emotional disorders such as obsessive compulsive and paranoid schizophrenia (Panksepp, 1998, 2001). Additionally, addiction - which is a compulsion to engage in a particular behavior - has also been shown to be related to the dopamine system (Wise, 2002). However, no known model has provided a plausible explanation of how a malfunction in this system produces compulsive behavior. Since dopamine is related to reward functions of the brain, one could propose a model of learned behavior, and learning definitely plays a significant role in the behavior. However, this would not explain the uncontrollable urge to engage in the learned behavior. The model presented here is intended to simulate the mechanisms that produce this urge and precede the selection of a particular learned behavior.

## Computational Model

To demostrate how a mismatch in expectation and reward can result in uncontrollable urges to perform compulsive behavior, the model presented here is used to simulate the selection of a seeking, resting, or sleeping activity in response to the creation of expectations and the consumption of rewards. When normal functionality is achieved, a regular pattern of sleeping and seeking emerges. However, too little reward (or over activation of expectations) results in highly irregular cycles.

To simulate the effect of the activation of the SEEKING system and the creation of expectation to be rewarded, I represent the *desire* for some X as D(X), which increases at the rate of d(D(X)). The reward for finding or consuming X is represented as R(X) (which similarly has a rate of achievement of d(R(X)). The difference between these is the *deficit* E(X) in reward. I make the assumption that acquiring a reward without first having some expectation has no effect. Thus, the equation for deficit is the following:

$$E(X) = max(D(X) - R(X), 0) \tag{1}$$

Expectations for multiple rewards may be generated simultaneously. I represent the total deficit in rewards as the *urge* to seek. I calculate urge U in the following way:

$$U = \sum_i E(X_i) \tag{2}$$

SEEKING is not a passive task and thus requires and consumes energy. As a result, I track the amount of *Energy* the agent has. Energy is depleted at a constant rate when SEEKING is active. I acknowledge that not all SEEKING activities require an equal amount of energy but make this simplifying assumption for the initial version of the model.

To balance the energy depletion, the model includes two activities to replenish energy: SLEEP and REST. Both regenerate energy at a constant rate, with SLEEP providing more energy than REST. The rules for selecting SLEEP, REST or SEEK are as follows and processed in this order:

| **Condition** | **Activity** |
|---|---|
| previous activity is SLEEP and Energy <SLEEP_THRESHOLD | SLEEP |
| previous activity is SLEEP and continuous sleep <MIN_HOURS_SLEEP | SLEEP |
| U >0 and Energy >MIN_SEEKING_ENERGY | SEEK |
| U >UNCONTROLLABLE_URGE and Energy >0 | SEEK |
| Energy <MIN_SEEKING_ENERGY | SLEEP |
| Else | REST |

When the rates $d(R(X)) \geq d(D(X))$ there is an emergent pattern of regular SLEEP/SEEK cycles. However, when $d(R(X) < d(D(X)$ irregular patterns emerge. The less frequency of the rewards creates an increasing urge to SEEK, eventually crossing the threshold for an uncontrollable urge to seek. The uncontrollable urge will be maintained until either sufficient reward is achieved to satisfy the desires or energy has been fully depleted and the agent is completely physically exhausted. This full consumption of energy brought about by an incessant need to seek simulates the behavior seen in rats when the SEEKING system is activated through self-stimulation.

An interesting behavior intentionally depicted in this model is the effect of one object of desire being rewarded but not the other. The total urge to seek in this case is positive and thus the selected activity is SEEK (provided sufficient energy). While one reward continues to be found even though it has a zero deficit, the other object of desire is not being regularly or sufficiently rewarded. The intent here is to simulate a particular pattern seen in some compulsive behaviors. Let us use washing as an example. Assume there are two possible desires: one is to be clean and the other is to eat. The clean desire is easily rewarded with the washing of the hands, but the desire to eat is still unsatisfied. The total deficit (or urge) would be positive in this model, and the SEEK activity would be selected. The conditioned response to the SEEK activity in this case is to wash the hands. Thus the person gets caught in a "do-loop" of continuously washing hands.

This behavior is similar to that seen in other animals. Researchers found that when an animal is "stimulus-bound" to a particular activity - such as eating, drinking, or gnawing - and the preferred goal object is taken away, after an extended period of electrical stimulation to the brain the animal acquired a new goal and persisted in the new behavior even when the original object is returned (Valenstein, 1973). In this example, the animal may have the dopamine system activated as the result of being hungry (or electrical stimulation) but eating does not occur despite the presence of food. Instead it continues the unsatisfying and unrewarding activity of eating or gnawing and literally starves its hunger desire.

## Conclusion

This computational model provides a plausible explanation for how the SEEKING system is related to compulsive behavior. The model presented here allows us to compare normal activity selection to compulsive behavior as a result of an over-activity of reward seeking mechanisms. When the rate of reward is insufficient but the expectation for reward persists, an urge to incessantly seek is generated. This insatiable urge results in prolonged seeking behavior to the point of physical exhaustion. In contrast, when reward matches expectations, simulations show a regular pattern of sleeping and seeking.

## References


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