Neurological Basis of Instrumental Conditioning

by Richard H. Hall, 1998

Prototype

The prototype **instrumental** (also called "operant") **conditioning** experiment is illustrated by the "**Skinner box**", named after the legendary behaviorist psychologist, B. F. Skinner. In a typical Skinner box, there is a lever that a rat can press and a food pellet is delivered. The rat learns to press the lever as a result of being reinforced. This basic paradigm can be generalized to explain virtually all learning that is more complex than an instinctive response. The basic idea, of course, is that behavior that is followed by positive events will continue and strengthen, while behavior followed by negative events, will decline and eventually fade away. In operant conditioning, there are three basic variables. First, of course are the **behavior** (e.g. lever pressing) and the **consequence** (e.g. food pellet). A, third, equally important, but perhaps not so obvious variable is the **discriminative stimulus**, which signals that the behavior and reinforcement contingency is in effect (the sight of the bar, the context of the box, etc.) We all learn that most contingencies only occur within the context of given environments, such as the child who learns it's bad to take cookies without asking, when the parents are watching. Parents in this case would be an example of a discriminative stimulus. Figure 1 depicts the prototype Skinner box experiment, along with a hypothetical neurological circuit. Note that the sensory system detects a discriminative stimulus, and due to the reinforcer, the discriminative stimulus is associated with a given behavior. Thus, learning in the case of instrumental conditioning is the association of a stimulus with a behavior.

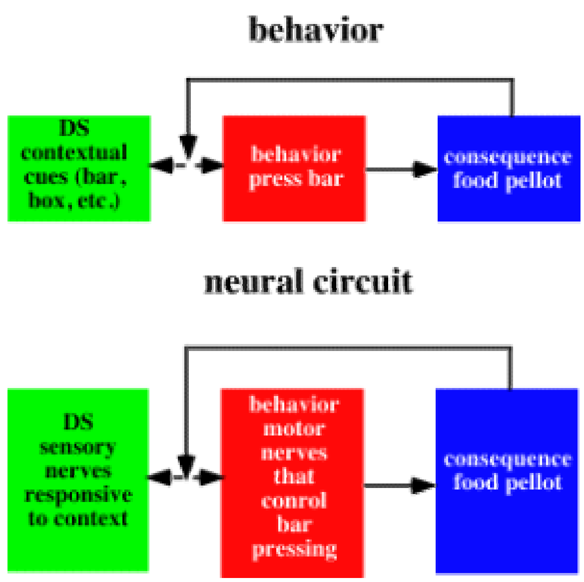

Figure 1. Prototypical “Skinner Box” Instrumental Conditioning Experiment

Dopamine and Reinforcement

Over forty years ago, two researchers, Olds and Milner, stumbled on a neurological discovery, which had a profound impact on our understanding of the role of the brain in reinforcement. Contrary to what they expected, they discovered that stimulation of certain areas of a rats brain was reinforcing to the rat. They introduced electrical stimulation into a rat's brain every time the rat went to a certain area of a cage, and, surprisingly, the rat began to return to this area of the cage in an obvious effort to receive more stimulation. Since the time of this important experimental accident, many neuroscientists have demonstrated the reinforcing effects of electrical stimulation of certain brain areas using a **self stimulation** paradigm. In a self stimulation experiment, a rat can provide stimulation to their own brain by pressing a lever, which activates an electrode in certain areas of their own brain.

This research indicates that one area, the **medial forebrain bundle (MFB)**, and one neurotransmitter, **dopamine (DA)**, are particularly important in this self stimulation effect. When the electrodes are put into the medial forebrain bundle, which is a pathway that travels from the midbrain to the basal forebrain, the effects are dramatic, with rats self stimulating as many as 1000s of times an hour. The neurotransmitter dopamine is thought to be important in this effect, too, for a number of reasons. First, the MFB is rich in DA neurons. Second, drugs that block DA's effect will decrease or eliminate the self stimulation effect. Third, drugs that are reinforcing (e.g., cocaine) are powerful dopamine agonists. Fourth, behaviors that are reinforcing (e.g., sexual behavior and feeding) have been linked to an increase in dopamine in various areas of the brain.

Instrumental Conditioning: Cellular and Structural Factors

One of the most interesting experiments, which serves as a model for illustrating the effect of DA neurons on instrumental conditioning, involves the "training" of individual cells. In this experiment researchers measured the firing rate of individual dopamine neurons as a base line. They then introduced dopamine directly onto the cells immediately after the cell fired. In this miniature instrumental conditioning experiment, the environment the cell was in represented the discriminative stimulus, firing represented the behavior, and the introduction of dopamine represented the consequence. In fact, the cells increased their firing rate in response to the introduction of the dopamine. Also, this increase in firing was not just a response to the dopamine independent of the cell's "behavior"; rather it only occurred when the dopamine was presented right after the cell fired. Thus, just as in instrumental conditioning with an organism, instrumental conditioning can only occur if a behavior is performed first.

Figure 4. Cellular Instrumental Conditioning of Dopamine Neurons

In terms of the brain structure, research indicates that the nucleus accumbens, in the basal forebrain, is particularly important in instrumental conditioning. Drugs that block dopamine receptors in the nucleus accumbens inhibit the acquisition of an instrumental response. There is some evidence that dopamine in this brain area may play a particularly important role in motivation. For example, animals with dopamine blockers injected into the nucleus accumbens are less willing to work (press a lever) for preferred food, and will settle for food they prefer less that is readily available, and rats won't climb a barrier to get twice as much food, but will settle for a smaller amount they don't have to climb for. Rats in these same experiments with normal DA inputs to their nucleus accumbens, on the other hand, will readily press a bar for preferred food, and climb a barrier for extra food.