# 2 Introduction to Operant Conditioning

## Edward Thorndike

The research that led to the study of what today we call operant conditioning began a little over 100 years ago with the work of Edward Thorndike. Impressed by William James's classic textbook, *Principles of Psychology* (James, 1890), Thorndike enrolled at Harvard University and took courses with James. At Harvard, Thorndike began the first experimental study of learning in animals. At the time, there was no formal psychological laboratory at Harvard and very little money to support Thorndike's work. His first laboratory was in his home.

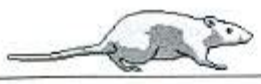
Thorndike (1898) described his early animal learning experiments in a classic monograph. In these experiments, Thorndike studied the way cats learned to escape from an apparatus that he called a **puzzle box**. The cats were locked inside the box and had to manipulate a mechanical device to open the box and escape. Initially, the cats behaved in many different ways, most of which did not lead to escape. However, gradually by trial and error, the cats found the behaviors that led to escape. Thorndike recorded how long it took each cat to escape on each trial and found that the average time gradually decreased from several minutes to a few seconds. As the escape speeds increased, the cats were learning to eliminate useless behaviors, while retaining the much smaller number of successful behaviors. The form of learning that Thorndike studied is often called **instrumental conditioning**, because the animal's behavior is instrumental in producing certain consequences. Thorndike summarized the mechanism that strengthens and selects successful behaviors by stating what he called the **law of effect**:

> Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond. (quoted in Kimble, 1961, p. 10)

Thorndike's experiments showed that the effect—the consequence—of a behavior determines whether the behavior will be strengthened or weakened. Hitting the right combination of levers in Thorndike's puzzle box had the positive effect of opening the door and letting the cat out of the box. As with most pioneers, Thorndike's models of instrumental conditioning and his statement of the law of effect have been subject to many changes. However, they remain an important cornerstone of our understanding of the learning process.

## B. F. Skinner

B. F. Skinner formulated the methods and procedures that describe a variant of Thorndike's instrumental conditioning that Skinner called **operant conditioning**. In Thorndike's work with puzzle boxes and subsequently in his studies of animals learning to run mazes, the learning tasks involved apparatus and procedures in which animals had the opportunity to make a correct response only at certain well-defined times called **trials**. Skinner developed a learning situation in which an animal is confined during training in a cage called an **operant chamber**, which contains a device on which responses can be made as well as a mechanism, called the **magazine**, for the delivery of food. In an operant chamber, animals are trained in an experimental situation in which the opportunity to perform some response is continuously available. Like Thorndike, Skinner was interested in how the consequences of behaviors influence the frequency with which those behaviors are repeated. Skinner's work with operant conditioning is thus an extension of Thorndike's work with instrumental conditioning. Moreover, the same principles of learning seem to apply both when the animal has the opportunity to make a correct response only at certain times (as in



Thorndike's puzzle boxes and mazes) and when the animal is able to respond at any time (as in Skinner's operant chamber).

Skinner (1938) made three fundamental assumptions about behavior:

- Animals are frequently active, a fact that means that organisms are continually **emitting** various behaviors.
- These emitted behaviors frequently have consequences that influence the frequency with which the behaviors are repeated in the future.
- The effects of the consequences are influenced by the animal's motivational state as well as by the physical and social environment. For example, the effect of presenting food as a consequence of performing some behavior depends upon whether the animal has been deprived of food.

Skinner studied animal learning, but he believed that it was possible to apply his findings to design more effective human institutions in which the planned, systematic application of reinforcement would make people happier and more productive (Skinner, 1953). Skinner not only called for the objective study of behavior, he also posited that behavior is often caused by events in the environment that can be discovered and manipulated to change behavior. In other words, he attempted to create a philosophical framework based on his findings; and this effort generated a lot of excitement and controversy (Skinner, 1971).

Traditionally, people have believed that mental events cause many aspects of human behavior. In contrast, Skinner (1953, 1971) asserted that it is more useful to view feelings, thoughts, emotions, and most other mental events as covert behaviors. In Skinner's view, both overt behaviors and the mental events that accompany them occur because of current and past conditions of reinforcement; and both are subject to the same behavioral laws.

Although he recognized that behavior is produced by the interaction of genetic and environmental factors, Skinner and his followers have concerned themselves almost exclusively with environmental effects. The historical reasons for this emphasis on the environment are complex; but one important reason is that environmental factors are easier to manipulate than genetic factors, especially in human beings, in which genetic manipulations are usually considered to be unethical. For example, a child's genes and the environment in which the child grows up jointly determine how tall the child will grow to be.

However, although nothing can be done about a child's tallness genes once the embryo has been conceived, the diet that the child eats—an environmental factor—can significantly affect adult height.

Skinner (1938, 1953) stated that psychologists should be concerned with discovering the laws of behavior and emphasized the importance of relating environmental causes to behavioral effects. In addition, he believed it is often possible to discover behavioral laws without understanding what goes on inside the organism. Many psychologists have employed the metaphor of a black box to characterize this aspect of Skinner's approach to psychology. The box, which represents the organism, is opaque. The inside is invisible, and we don't need to know what goes on inside the box. Understanding the rules that govern the box's behavior and controlling its actions do not require opening it. In fact, trying to understand what goes on inside the box may be confusing and misleading.

We can understand this "black box" view of the individual by considering the behavior of a television set. Few of us can produce or understand a circuit diagram that explains how a TV set works, but we can still operate one. We know that we must plug the set into an electric outlet. We know that when we manipulate the channel selector, the stations change. We know that a second control adjusts the volume, and other controls change the colors. The picture and sound are the behaviors that we want to predict and change, and we can predict and change these behaviors. If the set is not working properly, we also know that sometimes a sharp rap on the side of the case will improve the picture. None of this knowledge about how to change the behavior of a TV set requires understanding its internal workings. Skinner believed we can predict and change the behavior of organisms, including ourselves, in a similar way without needing to understand the internal workings of the body.

Skinner (1938) proposed that psychologists should seek to discover relationships between the environment and behavior without speculating about what goes on inside the organism. However, this "agnostic" approach to the workings of the organism was one of the most controversial aspects of Skinner's approach to psychology. A great many psychologists in Skinner's day (such as Guthrie, 1960; Hull, 1943, 1952; Tolman, 1932) believed, and a majority of present-day psychologists still maintain, that understanding behavior requires understanding the psychological and/or physiological processes that go on inside the organism. This computer program manual is not the place to debate these profound issues in the philosophy of science. Suffice it to say that in designing a virtual animal that simulates the behavior of a real

rat in an operant chamber, we had to endow Sniffy with certain psychological processes in order to reproduce the results that Skinner and others have obtained. Sniffy's psychological processes are modeled after those discussed in many contemporary textbooks on the psychology of learning (for example, Domjan, 1998; Mazur, 1998; Tarpy, 1997). Nevertheless, there is no way of knowing how closely Sniffy's psychological processes resemble those of real rats. All we can say is that Sniffy's psychological processes, which we display in the various mind windows, illustrate the kinds of processes that many psychologists believe are characteristics of real rats.

Skinner (1935, 1938, 1953) distinguished between elicited and emitted behaviors. An elicited behavior is the specific result of presenting a particular stimulus. Examples of elicited behavior include blowing compressed air into the eye to elicit an eyeblink or placing food on the tongue to elicit salivation. You will study how learning can affect elicited behaviors in experiments on classical conditioning. In contrast, emitted behaviors are responses that occur without any readily identifiable eliciting stimulus. For example, there is no stimulus that will reliably elicit grooming movements or barking from all normal dogs in the same way that placing food on a dog's tongue will elicit salivation.

Many of the behaviors that psychologists are interested in understanding are emitted, not elicited. Consider the behavior of students during class. Students not only listen to the instructor and take notes, they also scratch, yawn, read newspapers, wiggle around in their seats, and exhibit a wealth of other behaviors. Almost all these behaviors are emitted in the sense that no single stimulus exists whose presentation will reliably elicit any of these behaviors from everyone.

The scientific question to which Skinner sought experimental answers was, What controls the frequency of emitted behaviors? To address this question, Skinner developed the operant chamber, a very simple environment in which he thought it would be possible to discover how the environment determines the frequency with which animals and people produce emitted behaviors.

## The Operant Chamber

Sniffy's operant chamber resembles those found in laboratories where psychologists do research on operant conditioning. A look at Sniffy's operant chamber reveals three particularly important objects on the back wall: a lever, or so-called **bar**, that you will train Sniffy to press, a

water spout, and a food hopper. As in all operant conditioning situations, the bar is continuously available for Sniffy to press. The hopper is the device that you will use to provide a positive consequence, or **reinforcement,** when Sniffy does something that you want him to do more often. You can program the operant chamber to deliver food pellets automatically when Sniffy presses the bar, or you can dispense pellets manually by hitting the space bar on your computer keyboard or clicking your computer's (left) mouse button while pointing at the bar. Other devices in Sniffy's operant chamber permit you to present other kinds of stimuli. These include a speaker through which sounds can be played, a light that can be turned on and off, and the parallel metal bars that form the floor through which electric shocks can be delivered.


In this restricted environment, a real rat performs a limited subset of species-typical behaviors. As with a real rat, you can expect to see Sniffy rearing up, grooming himself, and exploring the chamber. You can observe and manually record any of Sniffy's behaviors. However, the response that psychologists generally study in an operant chamber is bar pressing. In research laboratories, psychologists use computers to control the presentation of food and other stimuli and to record bar presses, and the Sniffy Pro program simulates these functions.

## Reinforcement and Punishment

Skinner (1938) defined **reinforcement** as a procedure that makes a behavior pattern, or **response**, more likely to be repeated under similar circumstances in the future. In operant conditioning, the term *reinforcement* refers to the procedure of presenting or removing a stimulus (called a **reinforcer**) as a consequence of performing a response. A **positive reinforcer** is a stimulus whose presentation as a consequence of a behavior causes that behavior to occur more frequently under similar circumstances in the future. The term **positive reinforcement** refers to the procedure of presenting a positive reinforcer as a consequence of a behavior pattern. You will use food as a positive reinforcer to train Sniffy to press the bar in the operant chamber. A **negative reinforcer** is a stimulus whose removal or termination as a consequence of a behavior makes that behavior more likely to occur under similar circumstances in the future. The term **negative reinforcement** refers to the procedure of removing a negative reinforcer as a consequence of a behavior. Uncomfortable environmental conditions (temperature extremes, rain) are examples of negative reinforcers, stimuli whose termination can strengthen behaviors. As the saying goes, most people are smart enough to learn to come in out of the rain. Both positive and negative reinforcement have the effect of increasing the rate (the number of times per minute or hour) at which the reinforced response will occur under similar circumstances in the future.

Skinner (1953, 1971) decried the fact that much of our society is controlled by negative reinforcement. When we have a noisy next-door neighbor, we often bang on the wall to make the noise stop. Termination of the annoyance is negative reinforcement for wall banging under similar circumstances in the future. Children do homework to avoid parental nagging, a woman visits her mother to escape her husband's abusive behavior, a worker shows up for work on time to avoid unemployment. Skinner believed that this heavy reliance on negative reinforcement is a sign of a poorly planned society. He wrote several books and articles describing how society might be better organized based on knowledge of operant principles and extensive use of positive reinforcement.

Operant conditioning also defines two procedures for punishing behavior. **Punishment** is the mirror image of reinforcement. Whereas reinforcement causes behaviors to be repeated more often, punishment causes behaviors to occur less often. A **positive punisher** is a stimulus

whose presentation following the occurrence of a response makes that response occur less often in the future. **Positive punishment** is the name of the procedure involved in presenting a positive punisher as a behavioral consequence. If you hit your puppy with a rolled-up newspaper after it has a toilet accident in the house, you are employing positive punishment. A **negative punisher** is a stimulus whose removal following a response causes that response to occur less often in the future. **Negative punishment** is the procedure involved in removing a negative punisher to make a behavior occur less often. If your daughter misbehaves while watching her favorite television program and you send her to her room (thereby terminating access to the television program), you are employing negative punishment.

Note that the terms *negative* and *positive* have the same meaning when applied to punishment that they have when applied to reinforcement. Both positive reinforcers and positive punishers have their effects respectively of strengthening or weakening behaviors when you apply or turn on the stimuli following a behavior pattern. Both negative reinforcers and negative punishers have their respective effects when the stimuli are removed or terminated. But remember: Both positive and negative reinforcement cause behaviors to occur more often, whereas both positive and negative punishment cause behaviors to occur less often.

Another dimension that applies to both reinforcers and punishers concerns whether or not the reinforcing or punishing power of the stimulus is intrinsic or learned. Food is a good example of a stimulus whose reinforcing power is intrinsic in the sense that animals require no special training in order for food to acquire the capacity to act as a positive reinforcer. Similarly, presenting electric shock is an intrinsic positive punisher, and terminating shock is an intrinsic negative reinforcer. Stimuli whose effectiveness as reinforcers or punishers requires no special training are said to be **primary reinforcers** or **punishers**. Other stimuli that lack intrinsic reinforcing or punishing power can acquire the capacity to act as reinforcers or punishers if they are paired with primary reinforcers or punishers. Money is a good example of a stimulus whose reinforcing power has been acquired in this way. There is nothing intrinsically reinforcing about money; it's just pieces of paper and metal disks. However, people learn to treat money as a powerful positive reinforcer because of its pairing with primary reinforcers such as food and drink. Stimuli that acquire reinforcing or punishing power as a result of pairing with primary reinforcers or punishers are called **secondary**, or **conditioned**, **reinforcers** or **punishers**.

In operant conditioning, subjects learn that particular behaviors produce particular consequences in particular situations. In more technical terms, many psychologists believe that operant conditioning involves learning a three-part association among a situation, a response, and a reinforcing or punishing consequence (Domjan, 1998; Mazur, 1998; Schwartz & Reisberg, 1991; Tarpy, 1997). The effect of reinforcement is to select for the reinforced behavior at the expense of other unreinforced behaviors. In other words, the effect of reinforcement is to make the reinforced behavior occur more often; and a side effect of reinforcement is that many unreinforced behaviors occur less often because the subject comes to perform the reinforced behavior so frequently that less time is available to do other things. The effect of punishment is just the opposite of that of reinforcement. Punishment selects against the punished behavior, thereby making it occur less often and, as a side effect, making other, unpunished behaviors occur somewhat more often. An animal's **behavioral repertoire** is a list of all the behaviors that the animal would ever produce. The effect of operant conditioning is always to modify the relative frequencies with which different behaviors in the behavioral repertoire occur.

Skinner argued that punishment, in either of its forms, is undesirable for several reasons. Apart from ethical considerations, perhaps the most important of these reasons is that punishment is a less effective training tool than reinforcement because punishment conveys less information. When you punish an animal or child for doing something, you are in effect teaching the subject not to perform one particular item in its behavioral repertoire in the situation where the punishment occurred, but punishment provides no information about which other behaviors are appropriate. Reinforcement is a more powerful training tool because reinforcement specifically teaches the organism what to do.