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Basic Concepts and Definitions

Did you know that

- learning can result in either an increase or a decrease in responding?
- learning may not be readily apparent in the actions of an organism? Special test procedures may be required to see evidence of learning.
- learning may be investigated at the level of behavior, neural circuits and neurotransmitter systems, or individual neurons and their synapses?
- learning is a cause of behavior change? Therefore, learning can only be investigated with experimental methods that identify causal variables.
- control procedures are as important in studies of learning as training or experimental procedures?

Learning is of great interest because it is the primary means by which human beings and other animals take advantage of their experience to become more successful in interacting with the world in which they live. Learning requires flexibility in how one responds to the environment and therefore was considered evidence of intelligence by Darwin and other early comparative psychologists (Darwin, 1897; Romanes, 1882). Contemporary scientists study learning to gain insights into how the mechanisms of behavior are altered by experience. Learning procedures are often employed in studies of clinical, developmental, and cognitive psychology, as well as behavioral neuroscience and psychopharmacology.

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The Essentials of Conditioning and Learning, Fifth Edition, by M. Domjan and A. R. Delamater

Learning is a pervasive feature of human behavior and is evident in many other animal species as well. It has been found in creatures as diverse as fruit flies, sea slugs, bees, frogs, rodents, birds, and monkeys. How organisms learn has fascinated scientists for more than a century and continues to be a core topic in psychology and related disciplines.

FUNDAMENTAL FEATURES OF LEARNING

People learn to recognize friends as different from strangers. People also learn to anticipate when it might rain and when it is safe to walk home at night. They learn how to operate a new app on a smart phone and where to find games and video clips they may enjoy. People also learn to swim, ride a bicycle, and avoid stepping in puddles when it's raining. In all these cases, learning is identified by a change in behavior. An experienced swimmer or cyclist behaves very differently than someone who has not learned to swim or ride a bike.

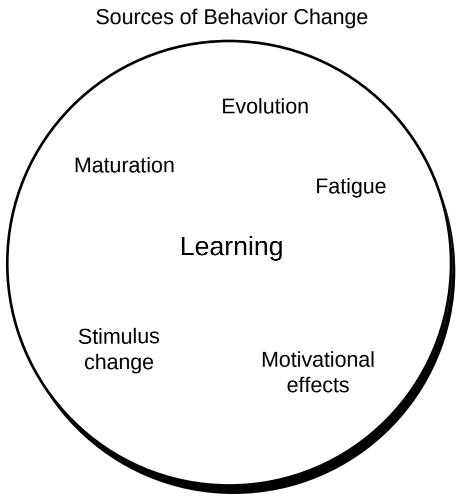
Learning to swim or ride a bicycle involves learning new hand, leg, and body movements and coordinating these movements to achieve balance and forward locomotion. Many, but not all, instances of learning involve the acquisition of new responses. We also learn *not* to do certain things. Children learn to keep quiet in church, to hold still when being examined by a doctor, and not to run into the street without first looking to see if it is safe. Learning to inhibit or suppress behavior is often as important as learning new responses. Riding a bicycle, for example, requires learning to pedal as well as learning not to lean too much to one side or the other. Thus, the change in behavior that is used to identify learning can be either an increase or a decrease in a particular response.

Learning and Other Forms of Behavior Change

Although all learning is identified by some kind of change in behavior, not all instances in which behavior is modified are instances of learning (see Figure 1.1). Therefore, it is important to distinguish learning from other sources of behavior change.

A major feature of learning that makes it different from other forms of behavior change is that learning is relatively long-lasting. This serves to distinguish learning from various short-term or temporary changes in behavior. For example, **fatigue** is a temporary decrease in behavior caused by repeated or excessive use of the muscles involved to perform the behavior. Fatigue and drowsiness can cause widespread and large changes in behavior (many of your actions become slower and less vigorous). However, such changes are temporary and can be reversed by a good rest. Major short-term changes in behavior can also be caused by changes in **motivation**, which is a hypothetical state that increases the probability of a coordinated set of activities or activates a system of behaviors that functions to satisfy a goal, such as feeding, predatory defense, infant care, or copulation. For example, people are much more reactive to stimuli related to food when they are hungry than after a hearty meal.

FIGURE 1.1. Possible Mechanisms That Can Result in Changes in Behavior



Note. Learning is only one of several possible sources of behavior change.

Changes in stimulus conditions can also cause widespread but short-term changes in behavior. If you get a stone in your shoe, the discomfort is likely to change the way you walk and may encourage you to stop and empty your shoe. But the disruption is likely to be short-lasting; you will resume your usual gait once the stone is removed. Learning, by contrast, involves longer term changes. The assumption is that once something is learned, it will be remembered for a substantial period of time. For example, you are not considered to have learned a new concept discussed in class if you cannot remember it the next day.

Although learning involves enduring changes in behavior, not all long-term changes are due to learning. Long-term changes in behavior can also be produced by physical or psychological development, a phenomenon known as **maturation**. Children become better at lifting heavy objects and reaching a cookie jar on a high shelf as they get older. These changes result from physical growth and maturation rather than learning.

Behavioral changes due to learning and changes due to maturation can be interrelated and difficult to distinguish. As a child becomes stronger and taller with age, these maturational changes facilitate the learning of new skills. However, one important difference between learning and maturation is that you don't have to specifically practice the things that you are able to do because of maturation. **Practice** is the repetition of a response or behavior, usually with the intent of improving performance.

Practice is obviously necessary to learn a skill such as swimming or riding a bicycle. One cannot become an expert bicycle rider without extensive practice in pedaling, steering, and balancing. Other things can be learned very quickly. A child will learn not to touch a burning log in a fireplace after just one painful encounter. Regardless of the amount of practice involved, all learning requires some practice or experience specifically related to the acquired behavior.

Another difference between maturation and learning is that the same maturational process can produce behavioral changes in a variety of situations. As a child grows taller, she will be able to reach higher shelves, climb taller trees, and catch butterflies that are flying higher off the ground. In contrast, behavior changes due to learning are more limited to the practiced response. Learning to operate a kitchen stove will help you cook indoors but will not improve your skill in building a fire for cooking on a camping trip. This is not to say that learning about one thing cannot help you do something else. Some generalization of learning does occur. However, generalization of learning tends to be limited. What you learn in one situation only generalizes to other similar situations. For example, learning to operate a particular gas stove will improve your ability to work other similar stoves but may not help if you are trying to cook with a microwave oven.

Another type of long-term change that has to be distinguished from learning is change due to evolution. **Evolution** is change in a physical or behavioral trait that occurs across successive generations because of differential reproductive success. Evolution can change not only the physical attributes of organisms but also their behavior. Furthermore, evolutionary changes, like learning, are a result of interactions with the environment. However, evolutionary changes occur across generations. In contrast, learning creates changes in behavior much more quickly within the lifetime of an individual. To function successfully, individuals have to learn about that causal structure of their environment and what to do in specific situations.

Although learning is clearly distinguishable from evolution, it is no doubt the product of evolutionary processes. Considering how pervasive learning is in the animal kingdom, it is safe to assume that it has evolved in particular environmental niches because organisms with the ability to learn are more successful in producing offspring in those environments. The greater reproductive fitness of individuals with the ability to learn increases the likelihood that their genes (and the genetic bases of learning) will be passed on to future generations (Krause et al., 2022). This evolutionary process produces changes in the mechanisms of behavior from one generation to the next. Learning, in contrast, involves changes in behavior (and its underlying mechanisms) during an individual's own lifetime.

Learning, Performance, and Levels of Analysis

That learning has occurred can only be determined by observing a change in behavior; the change, however, may only be evident under special circumstances. A physics student, for example, may not be able to provide an adequate definition of a quark, suggesting that they have not learned the concept. However, the same student may be able to pick out the correct definition from a list of alternative possibilities. Children can learn many things about driving a car by watching their parents drive. They can learn what the steering wheel does and what are the functions of the accelerator and the brake pedals. However, they may show no evidence of this knowledge until they are old enough to take driving lessons. These examples illustrate that learning can be behaviorally silent—having no visible behavioral manifestation. In such cases, special procedures must be used to determine what the individual has learned.

Learning may not be evident in the actions of an organism for a variety of reasons. One possibility is that what is learned is a relationship between stimuli or events in the environment rather than a particular response. For example, we may learn to associate the color red with ripe strawberries. The learning of an association between two stimuli is called **stimulus–stimulus learning**, or **S–S learning**. A learned association between red and ripeness will not be reflected in what we do unless we are given a special task, such as picking out the best tasting strawberries. S–S learning is usually not evident in the actions of an organism unless special test procedures are used.

The things an individual does—a person's observable actions—are collectively referred to as **performance**. Performance depends on many things, including motivation and the stimulus conditions or behavioral opportunities provided by the environment. Learning is just one of the many factors that determine performance. You may be an excellent flute player, but if you do not have the opportunity or the inclination to play the flute, no one will be able to tell what an accomplished musician you are.

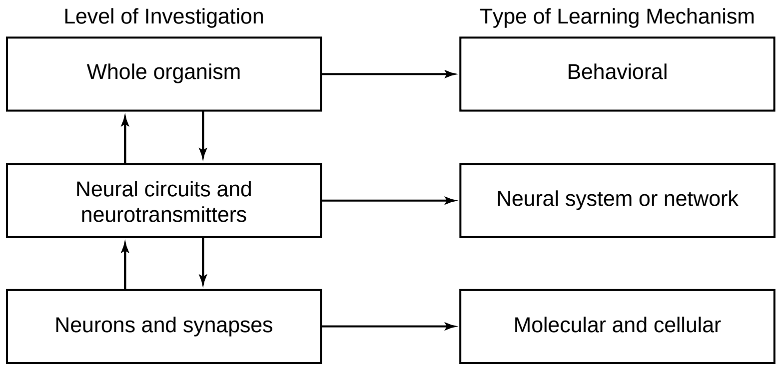
We consider a number of behaviorally silent forms of conditioning and learning in the following chapters. Examples of behaviorally silent learning suggest that learning cannot be equated with a change in behavior. Rather, learning involves a change in the potential for doing something.

Where does the change in the potential for action reside? Behavior is the product of the nervous system. Therefore, learning involves long-lasting changes in the neural mechanisms of behavior. In fact, early neuroscientists, such as Ivan Pavlov, considered behavioral studies of learning to be studies of how the nervous system works. Pavlov considered learning procedures to be techniques for the investigation of neural function.

Because learning involves changes in several systems, or levels, learning may be investigated at a variety of levels of analysis (see Figure 1.2). We may study learning at the level of molecular changes in nerve cells (or neurons), and their connections (or synapses). We may also study learning at the level of neural systems, such as neurotransmitter systems and neural circuits. Finally, we may study learning at the level of changes in the behavior of intact organisms.

Historically, studies of learning began at the level of the intact organism, and learning has been investigated most extensively at the behavioral level. However, with recent advances in the neurosciences, concepts and terms that have been developed for the behavioral analysis of learning have also been applied to investigations at the level of neural circuits and neurotransmitter systems, as well as at the cellular and molecular levels. In fact, studies of the

FIGURE 1.2. Levels of Analysis of Learning



Note. Learning mechanisms may be investigated at the organismic level, at the level of neural circuits and transmitter systems, and at the level of nerve cells or neurons.

neural mechanisms of learning represent one of the largest areas of contemporary research in learning. A major challenge in the coming years will be to integrate knowledge from studies of learning that concentrate on different levels of analysis. Understanding how learning occurs at the behavioral level is critical for this integration (Delamater & Lattal, 2014). This book describes the behavioral analysis of learning, and we feel that more integration of behavioral concepts with the other levels of analysis will be critical for a healthy development of the discipline.

A Definition of Learning

We identified a number of characteristics of learning in the preceding discussion. Learning involves a change in the potential or neural mechanisms of behavior. This change is relatively long-lasting and is the result of experience with environmental events specifically related to the behavior in question. These characteristics are combined in the following definition:

> ***Learning*** is a relatively enduring change in the mechanisms of behavior resulting from experience with environmental events specifically related to that behavior.

NATURALISTIC VERSUS EXPERIMENTAL OBSERVATIONS

Behavior occurs in many ways and in many situations, but there are just two basic ways to study behavior: naturalistic observations and experimental observations. **Naturalistic observations** involve observing and measuring behavior as it occurs under natural conditions, in the absence of interventions or manipulations introduced by the investigator. In contrast, **experimental observations** involve measuring behavior under conditions specifically designed by scientists to test particular factors or variables that might influence learning and its expression in behavioral performance.

Consider, for example, activities involved in foraging for food by tree squirrels. Foraging can be investigated using naturalistic observations. One could watch squirrels in a park, for example, and count how often they picked up a seed, how often they ate the seed right away, and how often they buried the seed for later retrieval. Making such observations throughout the day and across seasons would provide detailed information about the foraging behavior of the squirrels in that park. However, such observations would not reveal why the squirrels did what they did. Observing squirrels undisturbed cannot tell us why they select one type of seed instead of another, why they devote more effort to foraging during one part of the day than another, or why they eat some seeds right away and bury others to eat later. Naturalistic observations cannot provide answers to questions that probe the causes of behavior. They may help us formulate questions or hypotheses about why animals do certain things, but naturalistic observations cannot identify causal variables.

The causes of behavior can only be discovered using experimental methods. Experimental observations require the investigator to manipulate the environment in special ways that facilitate reaching a causal conclusion. Using naturalistic observations, you may find that squirrels bury more seeds in the fall than in the winter. What might cause this outcome? One possibility is that more seeds are available in the fall than in the winter. We could test this possibility by comparing squirrels under two conditions. Under one condition, the squirrels would be provided with excess food by spreading lots of peanuts in the observation area. Under the second condition, the squirrels would not be provided with extra peanuts. In all other relevant respects, the test conditions would be the same. Temperature, changes in daylight from day to day, and the extent of foliage in the trees would be identical. Given these identical conditions, if the squirrels buried more seeds when food was plentiful than when food was scarce, we could conclude that excess food, independent of seasonal changes, encourages or causes the storing of seeds.

Although experimental observations permit us to draw conclusions about the causes of behavior, it is important to realize that the causes of behavior cannot be observed directly. Rather, causes must be inferred from differences in behavior observed under different experimental conditions. When we conclude that excess food causes seed burying, we are not describing something we have actually observed. What we saw in our hypothetical experiment is that squirrels bury more seeds when food is plentiful than when food is scarce. The conclusion that excess food causes seed burying is an inference arrived at by comparing the two experimental conditions. Causal conclusions are inferences based on a comparison of two (or more) experimental conditions.

Uncontrolled naturalistic observations can provide a wealth of descriptive information about behavior. We have learned a great deal from naturalistic observations about foraging for food, courtship and sexual behavior, maternal behavior, parental behavior, and defensive and territorial behavior. Considering that learning is ultimately also evident in the behavior of human and other animals, one might suppose that observational techniques can also be useful in the study of learning. In fact, some have advocated that detailed investigations of learning should begin with naturalistic observations of learning phenomena (D. B. Miller, 1985). However, naturalistic observations are inherently unsuitable for studies of learning because they cannot identify causal variables.

THE FUNDAMENTAL LEARNING EXPERIMENT

A critical aspect of the definition developed in this chapter is that learning is a result of past experiences. As such, learning is a causal variable, one that involves past experience with relevant environmental events. To conclude that learning has occurred, we have to be sure that the change in behavior we observe is caused by the training experience we provided.

As we noted earlier, causes cannot be observed directly. Rather, they have to be inferred from experimental observations. This idea has profound implications for the study of learning. Because learning is a causal variable, it cannot be observed directly. Learning can only be investigated by means of experimental manipulations that isolate a specific training experience as the cause of a change in behavior.

To conclude that a change in behavior is due to a specific training experience, one has to compare individuals with and without that experience under otherwise identical circumstances. The specific training experience is the independent variable, and the resultant change in behavior is the dependent variable. The **independent variable** is specifically manipulated before the **dependent variable**, or outcome variable, to assess the effect of the independent variable. Consider, for example, the fact that most 8-year-old children can ride a bicycle proficiently, whereas 3-year-olds cannot. A reasonable interpretation is that the older children are expert riders because they had more time to practice riding. That is, the change in behavior from 3 to 8 years of age may be caused by experience with bicycles. To support this conclusion, it is not enough to point to the fact that 8-year-olds are better riders than 3-year-olds. Such a difference could be due to physical growth and maturation. It is also not compelling to point out that 8-year-olds spend more time riding bicycles than 3-year-olds, because this may be an effect rather than a cause of the greater skill of 8-year-olds. Some kind of experiment has to be carried out to prove that proficient riding is a result of past experience or learning.

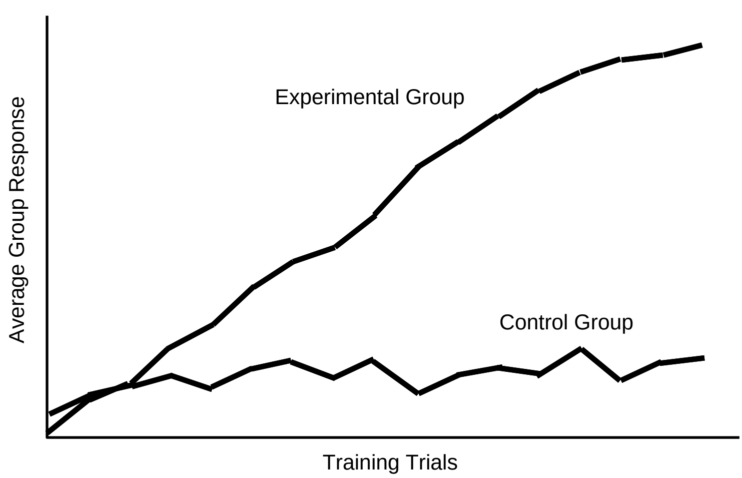
To conclude that a behavior change is a result of learning, we have to compare the behavior of individuals under two conditions. In the **experimental condition**, participants are provided with the relevant environmental experience or training. In the **control condition**, participants do not receive the relevant training but are treated identically in all other respects. The occurrence of learning is inferred from a comparison between the two conditions. One cannot conclude that learning has occurred by observing only individuals who have acquired the skill of interest. Rather, conclusions about learning require a comparison between the experimental and control conditions. In addition, the conditions of testing for learning should be the same for the experimental and control groups (Rescorla, 1988).

One way to prove that bicycle riding is a learned skill would be to conduct an experiment with 3-year-old children who have never ridden a bicycle. We could assign the children randomly to one of two treatment groups: an experimental group and a control group. The experimental group would receive three 1-hour lessons in riding a bicycle. This would be the independent variable. The control group would also receive three 1-hour lessons through which they would become familiar with bicycles. However, the control group would not be taught to ride. Rather, they would be told about the various parts of a bicycle and how the parts fit together. At the end of the lessons, both groups of children would be tested for their skill in riding. Proficiency in bicycle riding would be the dependent variable. If proficient riding is learned through relevant practice, then the children in the experimental group should be more proficient than the children in the control group. This example illustrates the fundamental learning experiment (see Figure 1.3).

The Control Problem in Studies of Learning

Are there any special consequences because learning can only be inferred from a comparison between individuals with a particular training history and others who lack that history? Yes, indeed. One important consequence is that learning cannot be investigated using naturalistic observations. Under natural circumstances, individuals with a particular training history often differ in a number of respects from individuals who do not have the same history. Therefore, the requirements of the fundamental learning experiment are not satisfied under entirely natural circumstances.

FIGURE 1.3. The Fundamental Learning Experiment



Note. In the fundamental learning experiment, the training procedure is provided for participants in the experimental group but not for participants in the control group. The results are presented in terms of the average performance of each group. A difference between the two groups is evidence that learning has occurred.

A second important consequence is that the control procedure in a learning experiment must be designed with as much care as the experimental procedure. In fact, some landmark contributions to the study of learning have come not from analyses of training procedures but from analyses of control procedures (e.g., Church, 1964; Rescorla, 1967; see also Papini & Bitterman, 1990). Different training procedures require different control procedures. We will discuss this issue in greater detail in the consideration of various types of learning in the following chapters. For now, suffice it to say that the design of a control procedure is dictated by the particular aspect of past experience one wishes to isolate as being responsible for the behavioral change of interest.

A third important consequence of the fact that learning can only be inferred from a comparison between experimental and control conditions is that learning is usually investigated with at least two groups of participants. An experimental plan that involves comparing two separate groups of participants is called a **between-group experimental design**.

Single-Case Experimental Designs

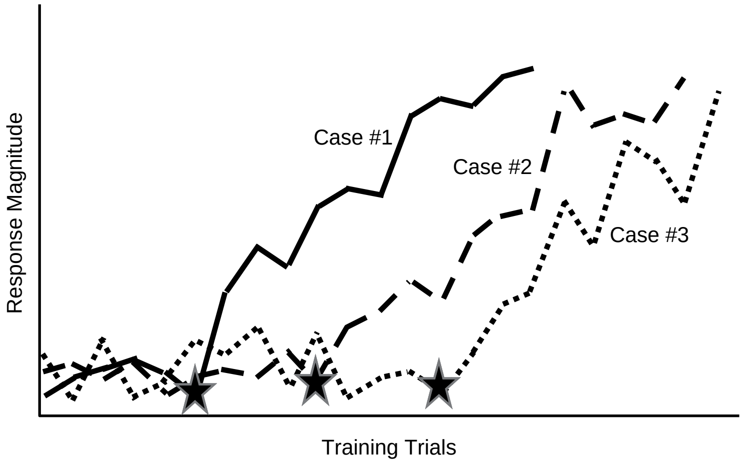
An important alternative to the traditional between-group experimental design was developed in the Skinnerian tradition of learning research. Skinner advocated focusing on the performance of individuals rather than on the average of a group of research participants. This led to the development of **single-case experiment** designs (Sidman, 1960), which are now used extensively in research on applied behavior analysis. The term *single case* is a bit misleading because often several individuals are examined in a "single-case" research study. However, the results are presented separately for each participant rather than averaged together. The study does not include an explicit control group. In place of the control group, the behavior of the individual participants is examined over time before a training procedure is introduced to document in detail what each participant does without training. This **baseline data**, an observation of a participant's response before the experimental intervention, is then used to evaluate the impact of the training procedure. The assumption is that without training, the performance of each individual would have remained at the baseline level (see Figure 1.4).

Historically, single-case experimental designs and between-group designs were used by psychologists who worked in different intellectual traditions and focused on different research questions. However, there is growing interest in integrating and reconciling these two contrasting research traditions (Kazdin, 2021). Single-case research designs are especially useful in translational research, where the goal is to develop effective protocols to treat various clinical problems. Clinicians typically treat individual clients or patients. Therefore, research that elucidates the effectiveness of training procedures at the level of the individual person can be translated into clinical practice more easily.

The General-Process Approach to the Study of Learning

In addition to relying on experimental techniques, investigators of learning typically employ a **general-process approach**. Such an approach assumes

FIGURE 1.4. Single-Case Research Design



Note. In this hypothetical single-case learning experiment, the behavior of three individuals (or cases) was observed during a baseline period of varying durations. The learning procedure was introduced at different points for each individual, as indicated by the stars. Notice that no matter when the learning procedure was introduced, responding quickly increased with training. The assumption is that each individual's performance would have remained at baseline levels if the training procedure had not been introduced.

that learning phenomena are the products of fundamental or basic processes that operate in much the same way in different learning situations.

The general-process approach is common in science and engineering. For example, in designing cars, engineers assume that the basic principles of how an internal combustion engine operates are pretty much the same whether the engine is used to propel a small four-door sedan or a large sport utility vehicle. In an analogous fashion, the basic principles involved in learning are assumed to be the same whether children are learning to operate a computer tablet or rats are learning to navigate a maze to obtain food. The general-process approach focuses on underlying commonalities across learning situations, with the goal of identifying universal learning principles.

The assumption that universal, basic laws of association are responsible for learning phenomena does not deny the diversity of stimuli different animals may learn about, the diversity of responses they may learn to perform, and species differences in rates of learning. The generality is assumed to exist in the rules or processes of learning, not in the contents or speed of learning.

If we assume that universal rules of learning exist, then we should be able to discover those rules in any situation in which learning occurs. Thus, an important methodological implication of the general-process approach is that general rules of learning may be discovered by studying any species or response system that exhibits learning. The general process approach to learning has been challenged by discoveries of various "biological constraints" that have encouraged a more ecological approach to the analysis of animal learning. However, even contemporary studies that incorporate an ecological perspective have sought to identify general principles that are applicable across species and learning situations (Domjan & Krause, 2017).

The Use of Nonhuman Participants in Research on Learning

Many of the basic principles of learning that we describe in this book were first established in research with nonhuman animal participants and were only later extended to humans. Studying learning in laboratory animals offers many advantages. These include (a) better knowledge and control of the prior learning experiences of the research participants, (b) greater precision and control over the learning environment and administration of the learning procedures, (c) the ability to observe the same individuals under precisely the same conditions over repeated training and test trials, (d) knowledge of and ability to control the genetics of the participants, (e) greater control over motivational variables that might affect learning, (f) better chance to minimize the role of language, and (g) better chance to minimize efforts by the participants to please or displease the experimenter. Without the use of laboratory animals such as rats and mice, scientists would also be unable to develop behavioral tasks and tests that are critical to the study of the neurobiology and neuropharmacology of learning and memory. Such studies are important to develop treatments for serious maladies such as Alzheimer's disease and post-traumatic stress disorder.

Although nonhuman laboratory animals provide numerous advantages for the study of learning, some have argued in favor of alternatives. Four common alternatives have been proposed: (a) observational research, (b) studying plants, (c) studying tissue cultures, and (d) studying computer simulations. As pointed out previously, observational techniques do not involve the kind of precise experimental manipulations that are critical for studies of learning. Studying plants is not a viable alternative because plants do not have a nervous system, which is critical for learning. Tissue cultures can be useful in isolating the operation of specific cellular processes. However, without behavioral research involving intact organisms, one cannot determine the importance of a particular cellular process for the behavioral changes that characterize learning at the level of an intact organism. Finally, computer simulations cannot replace experimental research because we first have to figure out how learning occurs in live organisms before we can build a computer simulation of that type of learning.

SUMMARY

Although learning is a common human experience, what it is and how it should be investigated are not obvious. Learning is evident in a change in behavior—either the acquisition of a new response or the suppression of an existing response. However, not all instances of altered behavior involve learning, and not all instances of learning produce immediately observable changes in behavior. The term *learning* refers to cases in which there is an enduring change in the mechanisms of behavior that results from prior experience with environmental events specifically related to that behavior.

Learning mechanisms may be examined at the level of intact organisms, the level of neural circuits or systems, or the level of neurons and their synapses. However, because learning is a causal variable, it can be investigated only with experimental methods. Naturalistic observations may provide suggestions about learning but cannot provide definitive evidence. The basic learning experiment involves comparing an experimental and a control condition, using either between- or within-subject experimental designs. The experimental condition includes the training procedure or experience whose effects are being tested. The control condition is similar but omits the relevant training experience. Learning is inferred from a difference in outcomes between the experimental and control conditions. For this reason, control procedures are as important for studies of learning as are experimental procedures.

Studies of learning have been based on a general-process approach, which assumes that diverse learning phenomena reflect the operation of universal elemental processes, such as those in which organisms learn about the causal structure of their environment. This general-process approach and other conceptual and methodological considerations have encouraged the use of nonhuman animal subjects in learning experiments. Given the nature of learning phenomena, alternatives to the study of intact organisms are not viable.

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TECHNICAL TERMS

fatigue, page 4
motivation, page 4
maturation, page 5
practice, page 5

evolution, page 6
stimulus–stimulus learning, page 7
S–S learning, page 7
performance, page 7
level of analysis, page 7
learning, page 8
naturalistic observation, page 8
experimental observation, page 8
independent variable, page 10
dependent variable, page 10
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