

Innate Behavior Patterns and Habituation

LEARNING OBJECTIVES

After reading this chapter, you should be able to

- describe the major concepts of control systems theory, and apply the concepts to both living and nonliving examples of goal-directed behavior
- describe four different types of innate behavior patterns, and explain how they differ
- describe some human abilities and predispositions that may be inborn
- define habituation, and list the general principles of habituation that are found in all animal species
- discuss what is known about the physiological mechanisms of habituation
- describe opponent-process theory, and diagram the typical pattern of an emotional response to a new stimulus and to a stimulus that has been repeated many times

When any animal is born, it is already endowed with a variety of complex abilities. Its immediate survival depends on the ability to breathe and to pump blood through its veins. If it is a mammal, it has the ability to regulate its temperature within narrow limits. If its survival depends on the ability to flee from predators, it may start to walk and run within minutes after birth. Newborn animals are also equipped with a range of sensory capacities. As Hubel and Wiesel (1963) have shown, kittens have inborn visual cells responsive to colors, edges, and probably other aspects of the visual world.

Such innate sensory structures are by no means limited to kittens, nor to the visual system.

One major purpose of this chapter is to provide examples of the types of behavioral abilities that an animal may already possess as it enters the world. There are good reasons for examining innate behavior patterns in a book about learning. First, many learned behaviors are derivatives, extensions, or variations of innate behaviors. Second, many of the features of learned behaviors (e.g., their control by environmental stimuli, their mechanisms of temporal sequencing) have parallels in inborn

behavior patterns. Another purpose of this chapter is to examine the phenomenon of habituation, which is often said to be the simplest type of learning.

Most of the examples of innate behavior patterns described in this chapter are based on the work of **ethologists**—scientists who study how animals behave in their natural environments. Although both ethologists and psychologists in the field of learning study animal behavior, their purposes and strategies are different. The testing environments of learning psychologists tend to be barren and artificial, for their goal is to discover general principles of learning that do not depend on specific types of stimuli. Ethologists usually conduct their experiments in the animal's natural habitat or in a seminaturalistic setting, because their purpose is to determine how an animal's behavior helps it to survive in its environment. Ethologists are interested in both learned and innate behaviors, and many of the behavior patterns they have studied in detail are species specific (unique to a single species). In recent years, psychologists who study learning have shown increasing interest in innate behaviors and species-specific behaviors. As a result, the work of ethologists is having greater impact on both research and theory in the field of learning.

One characteristic that is common to many behaviors, both learned and unlearned, is that they appear to be purposive, or goal directed. As we will see, this is true of some of our most primitive reflexes as well as our most complex

skills. For this reason, it will be useful to begin this chapter with some concepts from **control systems theory**, a branch of science that deals with goal-directed behaviors in both living creatures and inanimate objects.

CHARACTERISTICS OF GOAL-DIRECTED SYSTEMS

Control systems theory provides a general framework for analyzing a wide range of goal-directed systems. The terminology used here is based on the work of McFarland (1971). A relatively simple example of an inanimate goal-directed system is a house's heating system. The goal of the heating system is to keep the house temperature above some minimum level, say 65°F. If the house temperature drops below 65°F, the heating system "spontaneously" springs into action, starting the furnace. Once the temperature goal is reached, the activity of the heating system ceases. Of course, we know there is nothing magical about this process. The activity of the heating system is controlled by the thermostat, which relies on the fact that metals expand when heated and contract when cooled. The cooling of the metals in the thermostat causes them to bend and close an electrical switch, thus starting the furnace. Heating of the metals opens the switch and stops the furnace.

The thermostat is an example of a fundamental concept in control systems theory, the **comparator**. As shown in Figure 3-1, a comparator

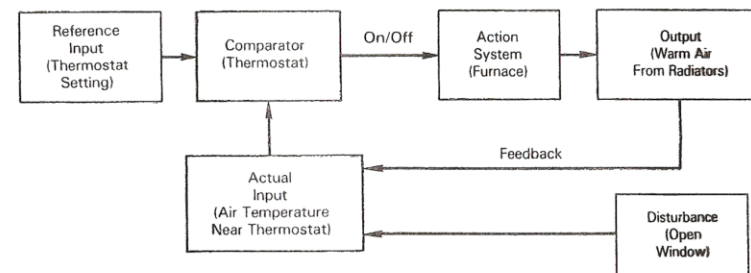


FIGURE 3-1 Concepts of control systems theory as applied to a home's heating system.

receives two types of input, called the *reference input* and the *actual input*. The reference input is often not a physical entity but a conceptual one (the temperature that, when reached, will be just enough to open the switch and stop the furnace). On the other hand, the actual input measures some actual physical characteristic of the present environment, in this case, the air temperature in the vicinity of the thermostat.

Any comparator has rules that it follows to determine, based on the current actual input and reference input, what its output will be. In the case of a thermostat, the output is an on/off command to the furnace, which is an example of an *action system*. The rules that the thermostat follows might be these: (1) If the furnace is off and the air temperature becomes one degree lower than the reference input, turn on the furnace. (2) If the furnace is on and the air temperature becomes one degree higher than the reference input, turn off the furnace. With a setting of 65°F, these rules would keep the air temperature between 64°F and 66°F.

The product of the action system is simply called the *output*—the entry of warm air from the radiators in this example. As Figure 3-1 shows, the output of the action system feeds back and affects the actual input to the comparator. For this reason, such a goal-directed system is frequently called a *feedback system* or a *closed-loop system*. The output of the action system (warm air) and the actual input to the comparator (air temperature) seem closely related, and you may wonder why two separate terms are needed to describe them. The reason is that a close relationship does not always exist between the output of the action system and the actual input; other factors can affect the actual input. One example is the *disturbance* depicted in Figure 3-1. A window open on a cold day, will also affect the air temperature near the thermostat, which may then be quite different from the temperature of the air coming out of the radiators.

This example illustrates six of the most important concepts of control systems theory: comparator, reference input, actual input, action system, output, and disturbance. We will encounter many examples of goal-directed

behaviors in this book, and it will often be useful to try to identify the different components of the feedback loop in these examples. The next section is the first of many in this text that will make use of the concepts of control systems theory.

REFLEXES

A **reflex** is a stereotyped pattern of movement of a part of the body that can be reliably elicited by presenting the appropriate stimulus. You are probably familiar with the patellar (knee-jerk) reflex: If a person's leg is supported so that the foot is off the ground and the lower leg can swing freely, a light tap of a hammer just below the kneecap will evoke a small kicking motion from the leg. As with all reflexes, the patellar reflex involves an innate connection between a stimulus and a response. The stimulus in this example is the tapping of the tendon below the kneecap, and the response is the kicking motion.

A normal newborn child displays a variety of reflexes. A nipple placed in the child's mouth will elicit a sucking response. If the sole of the foot is pricked with a pin, the child's knees will flex, pulling the feet away from the painful stimulus. If an adult places a finger in the child's palm, the child's fingers will close around it in a grasping reflex. Some of the newborn's reflexes disappear with age. Others, such as the dilation of the pupils and the closing of the eyes in response to a bright light, or coughing in response to a throat irritation, persist throughout life.

If you ever accidentally placed your hand on a hot stove, you probably exhibited a flexion reflex—a rapid withdrawal of the hand caused by a bending of the arm at the elbow. The response is very rapid because the association between sensory and motor neurons occurs directly in the spinal cord. Figure 3-2 depicts a cross section of the spinal cord and some of the neural machinery involved in this reflex. The hand contains sensory neurons sensitive to pain, and their lengthy axons travel all the way into the spinal cord before synapsing with other neurons. In the flexion reflex, one or more small neurons, called **interneurons**,

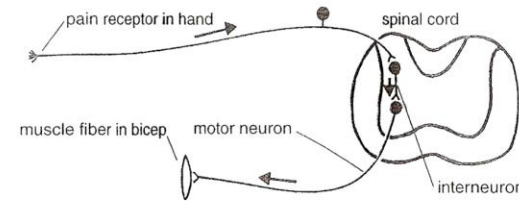


FIGURE 3-2 A cross section of the spinal cord, along with the components of the spinal withdrawal reflex.

separate the sensory neurons from motor neurons. The motor neurons have cell bodies within the spinal cord, and their axons exit through the front of the spinal cord, travel back down the arm, and synapse with individual muscle fibers in the arm. When excited, the muscle fibers contract, thereby producing the response. The physiology of this reflex is sometimes called the **spinal reflex arc**, after the shape of the path of neural excitation shown in Figure 3-2. Not one but many of such sensory neurons, interneurons, and motor neurons are involved in producing the reflexive response.

This description of the chain of connections in the spinal reflex arc is consistent with the standard definition of a reflex, that is, a stimulus elicits a response. There is more to the story of the spinal reflex arc, however, so now let us see how this reflex can be viewed as a feedback system. Within the muscles of the arm are structures called *stretch receptors*, which serve as the comparators of the feedback system. We will not go into detail about how this happens, but the stretch receptors compare (1) the goal or reference input—the commands sent from the motor neurons to the muscle fibers telling them to contract, and (2) the actual amount that the muscles have contracted. Notice that just because some motor neurons have sent their commands to the muscle, this does not guarantee that the arm is safely withdrawn from the dangerous object. There might be a disturbance—an obstruction that impedes the movement of the arm. Or the muscles may be in a state of fatigue and therefore fail to respond sufficiently to the commands of the motor neurons. If the muscles have not contracted sufficiently for any such

reason, the stretch receptors begin to stimulate the motor neurons (which in turn stimulate the muscle fibers more vigorously), and this stimulation continues until the contraction is completed. In short, the comparators (the stretch receptors) continue to stimulate the action system (the motor neurons and muscle fibers) until the goal (a successful muscle contraction) is achieved. This analysis of the spinal reflex arc shows that feedback can play a crucial role in even the simplest reflexive behaviors.

TROPISMS AND ORIENTATION

Whereas a reflex is the stereotyped movement of a part of the body, a **tropism** is a movement or change in orientation of the entire animal. The first to study tropisms was Jacques Loeb (1900), who called tropisms *forced movements* to suggest that no intelligence, will, or choice was involved. Later researchers (e.g., Fraenkel & Gunn, 1940) grouped tropisms into two major categories: kinesis (plural of *kinesis*) and taxis (plural of *taxis*).

Kinesis

A frequently cited example of a kinesis is the humidity-seeking behavior of the wood louse. This creature, though actually a small crustacean, resembles an insect, and it spends most of its time under a rock or a log in the forest. The wood louse must remain in humid areas in order to survive; if the air is too dry, it will die of dehydration in a matter of hours. Fortunately for the wood louse, nature has provided it with a simple yet effective technique for finding and remaining in moist areas. To study the wood louse's strategy, Fraenkel

and Gunn (1940) placed several wood lice in the center of a chamber in which the air was moist at one end and dry at the other. They found that the wood lice usually kept walking when they were in the dry end of the chamber, but they frequently stopped for long periods of time in the moist end. As a result, they tended to congregate in the moist end of the chamber.

What distinguishes a kinesis from a taxis is that in a kinesis the *direction* of the movement is random in relation to a stimulus. The wood louse does not head directly toward a moist area or away from a dry one, because it has no means of sensing the humidity of a distant location—it can only sense the humidity of its present location. Nevertheless, its tendency to keep moving when in a dry area and stop when in a moist area is generally successful in keeping the creature alive.

The wood louse's humidity-seeking behavior is another example of a feedback system. Although we do not know exactly how the wood louse measures humidity, its behavior tells us that it must have a comparator that can detect the actual input (current humidity) and compare it to the reference input (the goal of high humidity). The action system in this case is the creature's locomotion system, that is, the motor neurons, muscles, and legs that allow it to move about. Locomotion is, of course, the output of this action system, but there is no guarantee that locomotion will lead to the goal of high humidity. The wood louse may move about incessantly if it finds itself in a dry location, but if there are no humid areas nearby, the goal of high humidity will not be achieved as a result of this locomotion.

Taxes

Unlike kineses, in a taxis the direction of movement bears some relationship to the location of the stimulus. One example of a taxis is a maggot's movement away from any bright light source. If a bright light is turned on to the maggot's right, it will promptly turn to the left and move in a fairly straight line away from the light. The maggot accomplishes this directional movement by using a light-sensitive receptor at its head end. As the maggot moves,

its head repeatedly swings left and right, and this oscillating movement allows it to compare the brightness of light in various directions and to move toward the direction where the light is less intense.

The maggot's taxis is primitive, for it can only point the organism in a single direction—away from the light. A more sophisticated taxis is exhibited by the ant, which can use the sun as a navigational aid when traveling to or from its home. On a journey away from home, the ant travels in a straight path by keeping the sun at a constant angle to its direction of motion. To return home, the ant changes the angle by 180 degrees. The ant's reliance on the sun can be demonstrated by providing it with an artificial sun that the experimenter can control. If this light source is gradually moved, the ant's direction of travel will change to keep its orientation, with respect to the light, constant (Schneirla, 1933).

SEQUENCES OF BEHAVIOR

So far we have discussed innate behaviors that consist of either a brief movement or a continuous series of adjustments. The innate behavior patterns we will now examine are more complex, for they consist of a series of different movements performed in an orderly sequence.

Fixed Action Patterns

The ethological term **fixed action pattern** has been used to describe some behavioral sequences. Although some ethologists (Eibl-Eibesfeldt, 1975) include simple reflexes in the broader category of fixed action patterns, this category also encompasses more elaborate sequences of behavior. A fixed action pattern has the following characteristics: (1) It is a part of the repertoire of all members of a species, and it may be unique to that species; (2) suitable experiments have confirmed that the animal's ability to perform the behavior is not a result of prior learning experiences; and (3) in a sequence of behaviors, the behaviors occur in a rigid order regardless of whether they are appropriate in a particular context; that is, once a fixed action pattern is initiated, it will continue

to completion without further support from environmental stimuli.

As an example of a fixed action pattern, Eibl-Eibesfeldt (1975) described the nut-burying behavior of a particular species of squirrel:

The squirrel *Sciurus vulgaris* L. buries nuts in the ground each fall, employing a quite stereotyped sequence of movement. It picks a nut, climbs down to the ground, and searches for a place at the bottom of a tree trunk or a large boulder. At the base of such a conspicuous landmark it will scratch a hole by means of alternating movements of the forelimbs and place the nut in it. Then the nut is rammed into place with rapid thrusts of its snout, covered with dirt by sweeping motions and tamped down with the forepaws. (p. 23)

Although all members of the species exhibit this behavior pattern, this does not prove that the behavior is innate. Each squirrel may learn how to bury nuts by watching its parents early in life. To determine whether the behavior pattern is innate, Eibl-Eibesfeldt conducted a deprivation experiment in which all possible means of learning the behavior were removed. A squirrel was separated from its parents at birth and raised in isolation so that it had no opportunity to observe other squirrels burying nuts (or doing anything else, for that matter). In addition, the squirrel received only liquid food and it lived on a solid floor, so it had no experience in handling food or in digging or burying objects in the ground. The animal was kept well fed so that it had little chance of discovering that storing away food for a time of need is a good strategy. When the squirrel was full-grown, Eibl-Eibesfeldt finally gave it some nuts, one at a time. At first the squirrel ate the nuts until apparently satiated. When given additional nuts, it did not drop them but carried them around in its mouth as it searched about the cage. It seemed to be attracted by vertical objects, such as a corner of the cage, where it might drop the nut. Obviously, it could not dig a hole in the floor, but it would scratch at the floor with its forepaws, push the nut into the corner with its snout, and make the same covering and tamping-down motions seen in the burying sequence of a wild squirrel. This careful experiment demonstrates conclusively

that the squirrel's nut-burying repertoire is innate. The caged squirrel's scratching, covering, and tamping-down motions in the absence of dirt show how the components of a fixed action pattern will occur in their usual place in the sequence even when they serve no function.

As with simple reflexes, it usually takes a fairly specific stimulus, which ethologists call a **sign stimulus**, to initiate a fixed action pattern. In the case of the squirrel, the sign stimulus is clearly the nut, but without further experiments we cannot tell which features—its size, shape, color, and so on—are essential ingredients for eliciting the response. For other fixed action patterns, systematic investigation has revealed which features of a stimulus are important and which are irrelevant. In humans, Provine (1989) has found evidence that contagious yawning (the tendency to yawn when someone else yawns) is a fixed action pattern that may occur if we see the entire face of a yawning person. Seeing only the yawner's eyes or only the mouth is not enough to elicit contagious yawning.

Another example of a fixed action pattern is the territorial defense response of the male three-spined stickleback (Tinbergen, 1951). During the mating season, this fish will fiercely defend its territory against intrusion by other male sticklebacks (female sticklebacks are allowed to enter). The male's stereotyped threat behaviors are elicited by the sight of a red patch on the underside of the intruding male. If the intruding male stickleback does not have a red patch (which can only happen if the spot has been painted over by a devious experimenter), it will not be attacked. On the other hand, the defending male will attack pie-shaped or cigar-shaped pieces of wood that are placed in its territory if the objects have a red patch on the bottom. This example shows that the sign stimulus is often a simple specific detail; as a result, a seemingly poor imitation of the natural sign stimulus can elicit a fixed action pattern.

A more surprising finding is that sometimes an unrealistic model can elicit a stronger response than the actual sign stimulus itself. One example is provided by the oyster catcher, a bird that lays white eggs with brown spots. If



FIGURE 3-3 An oyster catcher attempts to roll a supernormal egg back to its nest. (After Tinbergen, 1951)

one of its eggs rolls out of its nest, the bird will retrieve it with stereotyped head and neck movements. However, if given a choice between one of its own eggs and a replica that is four times as large, it prefers this supernormal stimulus to the normal one and strains to bring this “egg” to its nest (Figure 3-3). In a similar way, Rowland (1989) found that female sticklebacks were strongly attracted to models of male sticklebacks that were larger than any males they had ever seen.

Reaction Chains

Ethologists distinguish between fixed action patterns and what are sometimes called **reaction chains**. Whereas fixed action patterns continue until completion once started, in a reaction chain the progression from one behavior to the next depends on the presence of the appropriate external stimulus. If the stimulus is not present, the chain of behaviors will be interrupted. On the other hand, if a stimulus for a behavior in the middle of a chain is presented at the outset, the earlier behaviors will be omitted.

An interesting example of such a sequence of behaviors, all innate, is provided by the hermit crab. The hermit crab has no shell of its own; instead, it lives in the empty shells of gastropods (mollusks). Frequently during its life,

the hermit crab grows too large for its present shell and must find a larger one. Reese (1963) identified at least eight separate fixed action patterns that usually occur in a sequence as this creature searches for and selects a new shell. A crab with no shell or with an inadequate shell exhibits a high level of locomotion. Eventually during its travels, the crab spots a shell visually, at which point it approaches the shell and touches it. The crab grasps the shell with its two front legs, then climbs on top of it. Its cheliped (claw) is used to feel the texture of the surface—a rough texture is preferred. The crab then climbs down and rotates the shell in its legs, exploring the external surface. When the aperture of the shell is located, this too is explored by inserting the cheliped as far as possible. If there is sand or other debris in the aperture, it is removed. Once the aperture is clear, the crab turns around and inserts its abdomen deeply into the shell and then withdraws it, evidently to determine whether the size of the interior is acceptable. If the shell is suitable, the crab turns the shell upright, enters it once again, then goes on its way.

The behaviors in this sequence and the stimuli that prompt them are diagrammed in Figure 3-4, which helps to emphasize the distinguishing characteristic of reaction chains; namely, the performance of one behavior usually produces the stimulus that elicits the next behavior in the chain. For instance, the first behavior of the chain, locomotion, eventually results in visual contact with a shell, which is the stimulus for the second response, approach. The response of approach brings the crab into close proximity with the shell, which is the stimulus for the third response, lifting, and so on. Unlike the behaviors of a fixed action pattern, those of a reaction chain do not always occur in this complete sequence. The sequence can stop at any point if the stimulus required for the next step is not forthcoming. For example, Reese (1963) found that shells filled with plastic were similar enough to usable shells to elicit the first six behaviors of Figure 3-4. However, since the aperture was not open, the seventh behavior did not occur, and the crab would eventually walk away. On the other hand, the initial steps of the

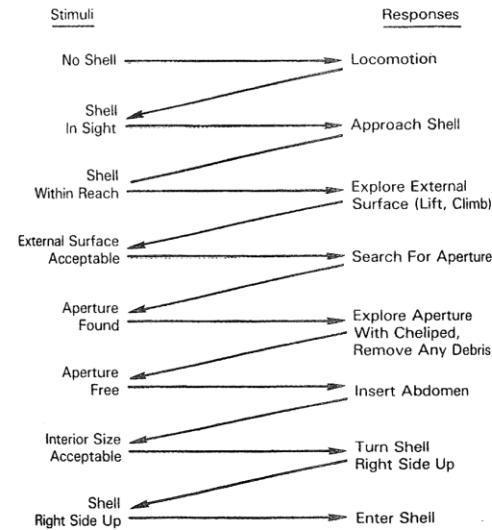



FIGURE 3-4 The hermit crab’s reaction chain of shell searching and selecting behaviors. The behaviors form a chain because each successive behavior usually leads to the stimulus for the next behavior in the chain.

sequence may be omitted if the stimulus for a behavior in the middle of the sequence occurs. When crabs were presented with a suitable shell with the aperture directly in front of them, they would often omit the first five behaviors and proceed with the last four behaviors of the sequence. This dependence on external stimulus support makes the behaviors of a reaction chain more variable, but at the same time more adaptable, than those of a fixed action pattern.

INNATE HUMAN ABILITIES AND PREDISPOSITIONS

Although human beings have a variety of reflexes, plus a few fixed action patterns and other inborn behaviors, these innate responses certainly constitute a very small portion of what we do. As noted in Chapter 1, almost all of our daily behaviors are products of our learning experiences. Because learning plays such a large role in human behavior, some philosophers, such as the British Empiricists (Chapter 2), have maintained that all human behavior is based on prior learning. (Recall John Locke’s statement that the mind of a child at birth is a *tabula rasa*, or blank slate.) This viewpoint about the all-important role of experience was shared by many psychologists, including the behaviorist John B. Watson (1925), whose bold statement about the importance of upbringing is often quoted:

Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I’ll guarantee to take any one at random and train him to become any type of specialist I



The Web site of the Animal Behavior Society provides information about research in animal behavior, including career opportunities: <http://www.animalbehavior.org>. You can find information on applied ethology that focuses on domesticated animals at <http://www.usask.ca/wcvm/herdmed/applied-ethology>.

might select—doctor, lawyer, artist, merchant-chief, and yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors. I am going beyond the facts and I admit it, but so have advocates of the contrary, and they have been doing it for thousands of years. (p. 82)

Watson believed that the environment could play such a dominant role in determining what type of adult a child will become because he thought heredity had little or nothing to do with how people behave. In *The Blank Slate*, Steven Pinker (2002) argues that this point of view, though widely held in modern society, is incorrect, and that heredity plays a much larger role than is commonly assumed. Pinker reviews evidence from various areas of scientific research, including neurophysiology, genetics, psychology, and anthropology, to support his contention that all human beings have in common a large set of inborn abilities, tendencies, and predispositions, which collectively might be called “human nature.” He argues that the human brain is not simply a batch of uniform, undifferentiated neurons that are waiting to be shaped by whatever the environment presents. He reviews evidence that neurons in different parts of the brain are specialized to perform certain functions or to respond to the environment in certain preestablished ways.

We have already seen a bit of this evidence. Chapter 2 showed that our sensory receptors are specialized neurons that respond to specific colors, tastes, sounds, smells, and so on. This sort of specialization does not end with sensory neurons. For example, it is well known that certain parts of the human brain play a critical role in our ability to use language. A section of the cerebral cortex called Wernicke’s area is essential for language comprehension: If this area is damaged through accident or illness, a person cannot understand spoken language. Another area of the cerebral cortex, Broca’s area, is necessary for speech production, and if this area is damaged a person loses the ability to speak in coherent sentences. Pinker maintains that the presence of neurons specifically designed to respond to human speech is what allows young children to learn

language so easily. As will be shown in Chapter 11, chimpanzees, dolphins, and a few other species can be taught to use human-like language to a certain degree, but no other species comes close to what young children can do.

A strategy used by Pinker (and by other scientists) to support the claim that a particular characteristic of human beings is innate is to demonstrate that this characteristic is found in people everywhere on Earth. We cannot conduct deprivation experiments with people as Eibl-Eibesfeldt (1975) did with a squirrel, but we can demonstrate that people living in vastly different cultures and environments all exhibit a particular characteristic. There are many different languages on Earth, but all human societies have verbal language, and all human languages have nouns, verbs, adjectives, and adverbs. Although different languages use different word orders, there are certain commonalities in the way sentences are structured (Baker, 2001). Children of all cultures babble before they learn to speak, and even deaf children babble at an early age (Lenneberg, 1967), although the nature of their babbling is different from that of children with normal hearing (Oller & Eilers, 1988). These and many other cross-cultural universals have been used as evidence for an innate human ability to acquire language.

Another aspect of human behavior that may be innate is the range of emotions people experience, how emotions are reflected in their facial expressions, and how others interpret these facial expressions. Charles Darwin (1872) first proposed that different emotions may have evolved because they helped creatures survive, and that gestures and facial expressions of emotion are important means of social communication among members of a species. Since the 1970s, the psychologist Paul Ekman (1973, 2003) has conducted research showing that facial expressions can be understood by people from cultures around the world. For instance, Ekman showed people from many different cultures photographs of faces that depicted six different emotions (happiness, disgust, surprise, sadness, anger, and fear) and asked them to classify the emotion of the person in the photograph. Regardless of

where they lived, people showed a high degree of accuracy in classifying the emotions shown in the photographs. Some of Ekman’s hypotheses remain controversial, but many psychologists now agree that there is cross-cultural uniformity in how people express emotions and interpret facial expressions. However, learning is also involved, because some types of facial expressions are culture specific. For example, in China, sticking out your tongue is a way of showing surprise, and this is not so, of course, in Western societies.

The anthropologist Donald E. Brown (1991) has compiled a list of **human universals**—abilities or behaviors that are found in all known human cultures. The list contains about 400 items, and it includes some very specific behaviors such as dance, music, death rituals, hygienic care, jokes, and folklore, as well as some major characteristics of human life, such as marriage, inheritance rules, tool making and tool use, government, sanctions for crimes, and division of labor. Learning and experience clearly affect just about every item on Brown’s list: Dance, music, and folklore vary tremendously from culture to culture. So do a society’s type of government, what is considered a crime and how people are punished, what types of tools people make, and how labor is divided among individuals. However, Brown’s point is that every human society has *some* type of dance, *some* type of government, *some* type of division of labor, and so on. He maintains that because these characteristics of human existence are found in all cultures, even those that are completely isolated from the modern world, they most likely reflect innate human tendencies.

Deciding that a particular behavioral tendency or characteristic is innate is not an easy matter. The fact that a behavioral characteristic is found in all human cultures does not, by itself, constitute proof that the characteristic is innate. Another possibility is that the behavior is seen in people everywhere because the environment places similar constraints on people everywhere. For example, one could argue that division of labor is advantageous in all environments because it is more efficient for an individual to become an expert in one line of

PRACTICE QUIZ

1. In control systems theory, the **comparator** compares the _____ and the _____, and if they do not match, the comparator signals the _____.
2. In the flexion reflex, **pain receptors** in the hand have **synaptic connections** with _____, which in turn have synapses with _____.
3. A **kinesis** is a _____ movement in response to a stimulus, and a **taxis** is a _____ movement in response to a stimulus.
4. The main difference between **fixed action patterns** and **reaction chains** is that _____.
5. Abilities or behaviors that are found in all known human cultures are called _____.

Answers

1. actual input, reference input, action system
2. interneurons, motor neurons
3. random, directional
4. the behavior sequence occurs in a rigid order in fixed action patterns, but it is more flexible in reaction chains
5. human universals

work than to try to master dozens of different skills. Perhaps future research on human genetics will help to sort out **which** of these universal human characteristics are hereditary, which are the product of **similar environments**, and which are a combination of the two. Whatever the case may be, Brown’s list of human universals is interesting to contemplate because it shows, in a world full of people with vastly different lifestyles, interests, beliefs, and personalities, how much the **human species** has in common.

HABITUATION

Habituation is defined as a decrease in the strength of a response after repeated presentation of a stimulus that elicits the response. In principle, any elicited response can exhibit habituation, but in practice, **habituation** is most evident in the body’s automatic responses to

new and sudden stimuli. Here is a typical example. For his vacation, Dick has rented a cottage on a picturesque lake deep in the woods. The owner of the cottage has advised Dick that although the area is usually very quiet, members of the fish and game club just down the shore often engage in target practice for a few hours during the evening. Despite this forewarning, the first loud rifle shot elicits a startle reaction from Dick—he practically jumps out of his chair, his heart beats rapidly and he breathes heavily for several seconds. After about half a minute, Dick has fully recovered and is just returning to his novel when he is again startled by a second gunshot. This time, the startle reaction is not as great: Dick's body does not jerk quite as dramatically, and there is not so large an increase in heart rate. With additional gunshots, Dick's startle response decreases until it has disappeared completely, that is, the noise no longer disrupts his concentration on his novel.

Another behavior that often displays habituation is the **orienting response**. If a new sight or sound is presented to a dog or other animal, the animal may stop its current activity, lift its ears and its head, and turn in the direction of the stimulus. If the stimulus is presented repeatedly but is of no consequence, the orienting response will disappear. Similarly, if an infant is played a tape recording of an adult's voice, the infant will turn its head in the direction of the sound. If, however, the same word is played over and over, the infant will soon stop turning toward the sound. Therefore, both animals and humans will typically exhibit an orienting response to a novel stimulus, and they will both exhibit habituation of the orienting response if the same stimulus is presented many times.

An important characteristic of habituation (which distinguishes it from both sensory adaptation and muscular fatigue) is that it is *stimulus specific*. Thus, after Dick's startle reaction to the sound of gunfire has habituated, he should still exhibit such a reaction if the back door slams. An infant that has stopped turning its head toward a speaker playing the same word over and over will again turn toward the speaker if a different word is played. In this

way, psychologists can tell that even infants just a few months old can distinguish subtle differences in human speech sounds (Polka & Werker, 1994).

The function that habituation serves for the individual should be clear. In its everyday activities a creature encounters many stimuli, some potentially beneficial, some potentially dangerous, and many neither helpful nor harmful. It is to the creature's advantage to be able to ignore the many insignificant stimuli it repeatedly encounters. To be continually startled or distracted by such stimuli would be a waste of the creature's time and energy. A study by Dielenberg and McGregor (1999) shows how animals can habituate to a fear-provoking stimulus if the stimulus repeatedly proves to be insignificant. Rats were presented with a cat collar that contained a cat's odor, and the response of the rats was to run into a hiding place and remain there for quite a while. However, Figure 3-5 shows that after several presentations of the cat collar, the rats' hiding times decreased and came close to those of the control group (rats that were exposed to a cat collar that had no cat odor on it).

A creature that was unable to habituate to insignificant stimuli would probably have a difficult time attending to more important stimuli. In fact, there is some evidence that the rate of habituation in human infants is correlated with mental abilities later in life. Laucht, Esser, and Schmidt (1994) found that infants who displayed faster habituation to repetitive stimuli at 3 months of age obtained, on average, slightly higher scores on intelligence tests when they were 4½ years old. Another study found that adolescents who showed very slow habituation to repetitive stimuli had a higher risk of developing the severe psychiatric disorder schizophrenia later in life (Hollister, Mednick, Brennan, & Cannon, 1994). These are correlational studies, not experiments, so it would be a mistake to try to draw any conclusions about cause and effect from them. Nevertheless, this research does suggest that the ability to habituate to repetitive, unimportant stimuli early in life may be one predictor of later mental abilities and mental health.

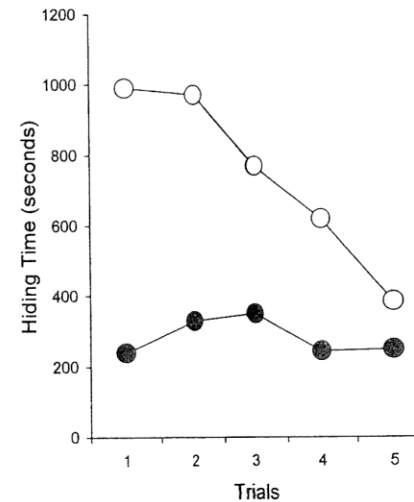


FIGURE 3-5 The amount of time rats spent hiding when exposed to a cat collar with cat odor exhibits habituation over successive days of exposure. The filled circles are from a control group of rats exposed to a cat collar that had no cat odor. (From Dielenberg & McGregor, 1999)

The usefulness of habituation is witnessed by its universality throughout the animal kingdom. Even before birth, the human fetus exhibits habituation to such stimuli as vibration or sounds (van Heteren, Boekkooi, Jongasma, & Nijhuis, 2001). Habituation can also be seen in hydra, whose diffuse network of neurons are among the most primitive nervous systems found on our planet (Rushford, Burnett, & Maynard, 1963). There have even been reports of habituation in protozoa (one-celled organisms). In one study, Wood (1973) found a decline in the contraction response of the protozoan *Stentor coeruleus* with repeated presentations of a tactile stimulus. At the same time, the responsiveness of *Stentor coeruleus* to another stimulus, a light, was undiminished.

General Principles of Habituation

Anyone who questions the feasibility of discovering general principles of learning applicable to a wide range of species should read the extensive literature on habituation. We have seen that habituation occurs in species as different as *Stentor coeruleus* and *Homo sapiens*. Furthermore, it is not just the existence of

habituation that is shared by such diverse species. In a frequently cited article, Thompson and Spencer (1966) listed some of the most salient properties of habituation, properties that have been observed in human beings, other mammals, and invertebrates. Several of Thompson and Spencer's principles are described next.

1. *Course of Habituation.* Habituation of a response occurs whenever a stimulus is repeatedly presented. The decrements in responding from trial to trial are large at first but get progressively smaller as habituation proceeds.

2. *Effects of Time.* If after habituation the stimulus is withheld for some period of time, the response will recover. The amount of recovery depends on the amount of time that elapses. To draw a parallel to Ebbinghaus's findings, we might say that habituation is "forgotten" as time passes. Suppose that after Dick's startle response to the gunshots has habituated, there are no more gunshots for 30 minutes, but then they begin again. Dick is likely to exhibit a weak startle reaction to the first sound of gunshot after the break. (Thus, there is some savings over time, but also some forgetting.) In comparison, if there were no

further shooting until the following evening, Dick's startle reaction after this longer time interval would be larger.

3. *Relearning Effects.* Whereas habituation may disappear over a long time interval, it should proceed more rapidly in a second series of stimulus presentations. In further series of stimulus presentations, habituation should occur progressively more quickly. To use Ebbinghaus's term, there are savings from the previous periods of habituation. For example, although Dick's initial startle response to the sound of gunfire on the second evening of his vacation might be almost as large as on the first evening, the response should disappear more quickly the second time.

4. *Effects of Stimulus Intensity.* We have already seen that a reflexive response is frequently stronger with a more intense stimulus. Such a response is also more resistant to habituation. Habituation proceeds more rapidly with weak stimuli, and if a stimulus is very intense, there may be no habituation at all.

5. *Effects of Overlearning.* As in Ebbinghaus's experiments, further learning can occur at a time when there is no longer any change in observable behavior. Thompson and Spencer called this *below-zero habituation* because it occurs at a time when there is no observable response to the stimulus. Suppose that after 20 gunshots, Dick's startle response has completely disappeared. After a 24-hour interval, however, he might show little savings from the previous day's experience. If there were 100 gunshots on the first evening, Dick would probably show less of a startle response on the

second evening. In other words, although the additional 80 gunshots produced no additional changes in Dick's behavior at the time, they did increase his long-term retention of the habituation.

6. *Stimulus Generalization.* The transfer of habituation from one stimulus to new but similar stimuli is called **generalization**. For example, if on the third evening the sounds of the gunshots are somewhat different (perhaps because different types of guns are being used), Dick may have little difficulty ignoring these sounds. The amount of generalization depends on the degree of similarity between the stimuli, and it is always the subject, not the experimenter, who is the ultimate judge of similarity. For this reason, psychologists can use habituation as a tool to determine exactly which stimuli an individual finds similar. For example, S. P. Johnson and Aslin (1995) presented 2-month-old infants with a display that featured a dark rod moving from side to side behind a white box (Figure 3-6). At first, the infants would look at this display for many seconds, but after repeated presentations, this orienting response habituated. Then, the infants were tested with two new stimuli: a solid rod moving back and forth with no box in front and a broken rod moving back and forth. Which new stimulus would the infants find more similar to the original display? Evidently, they found the solid rod more similar, because they spent less time looking at the solid rod than at the broken rod. In other words, the infants showed more generalization of habituation to the solid rod than to the broken rod. Based on this finding, Johnson

and Aslin inferred that these young infants treated the original stimulus as a solid rod (not a broken rod) moving behind the box, even though the middle part of the rod could not be seen.

Many experiments have used similar procedures to examine a wide range of skills in human infants, including their ability to perceive faces (Easterbrook, Kisilevsky, Muir, & Laplante, 1999), to use perspective cues to perceive depth in two-dimensional images (Durand, Lecuyer, & Frichtel, 2003), and to analyze cause and effect in a chain of events (Cohen, Rundell, Spellman, & Cashon, 1999). This strategy of using habituation to measure surprise or changes in attention has proven to be a valuable technique for studying the perceptual and mental abilities of infants, even those less than a month old.

Physiological Mechanisms of Habituation

Research with a Simple Creature. Because the principles of habituation are common to a wide range of creatures, simple and complex, some psychologists have speculated that the physiological mechanisms of habituation may also be similar in different species. Of course, this speculation could be wrong, because it is certainly conceivable that two species that exhibit similar patterns of habituation from a behavioral perspective might have very different physiological mechanisms producing this habituation. Nevertheless, this possibility has not deterred some researchers from investigating the physiological changes accompanying habituation in fairly primitive creatures. The strategy of studying fairly primitive creatures, which have nervous systems that are smaller and less complex, is known as the **simple systems approach**. A good example is the work of Eric Kandel.

Kandel and colleagues (Antonov, Kandel, & Hawkins, 1999; Castellucci, Pinsker, Kupfermann, & Kandel, 1970; Kandel & Schwartz, 1982) have spent several decades studying both the behavior and the nervous system of *Aplysia*, a large marine snail (see Figure 3-7a). They chose to study this animal because its nervous

system is relatively simple—it contains only a few thousand neurons, compared to the billions in a mammal's nervous system. Kandel and his co-workers investigated the process of habituation in one of *Aplysia's* reflexes, the gill-withdrawal reflex. If the creature's siphon (described as a "fleshy spout") is touched lightly, its gill contracts and is drawn inside the mantle for a few seconds. The neural mechanisms that control this reflex are well understood. The siphon contains 24 sensory neurons that respond to tactile stimulation. Six motor neurons control the gill-withdrawal response. Each of the 24 sensory neurons has a *monosynaptic* connection (i.e., a direct connection that involves just one synapse) with each of the six motor neurons. In addition, other axons from the sensory neurons are involved in *polysynaptic* connections (indirect connections mediated by one or more interneurons) with these same motor neurons. Figure 3-7b depicts a small portion of this neural circuitry.

If the siphon is stimulated about once every minute for 10 or 15 trials, the gill-withdrawal reflex habituates. Complete habituation lasts for about an hour, and partial habituation may be observed for as long as 24 hours. If such trials are given on three or four successive days, long-term habituation (lasting several weeks) can be observed. What changes at the physiological level are responsible for this habituation? Through a series of elaborate tests, Kandel's group was able to determine that during habituation, a decrease in excitatory conduction always occurred at the synapses involving the axons of the sensory neurons (the points marked by arrows in Figure 3-7b). These researchers also found that there was no change in the postsynaptic neuron's sensitivity to the transmitter. What had changed was the amount of transmitter released by the presynaptic (sensory) neurons: With repeated stimulus presentations, less transmitter was released into the synapse. Kandel (1979) noted that this mechanism of habituation is not unique to *Aplysia*. Physiological investigations of habituation in two other species (the crayfish and the cat) also found decreases in the amount of transmitter released by the sensory neurons.

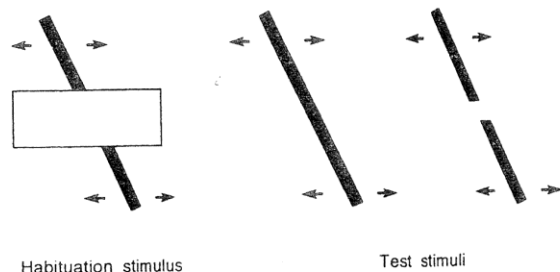


FIGURE 3-6 In the study of Johnson and Aslin (1995), infants were repeatedly shown the stimulus on the left until their orienting responses to the stimulus habituated. They were then tested for generalization, using each of the two stimuli on the right.

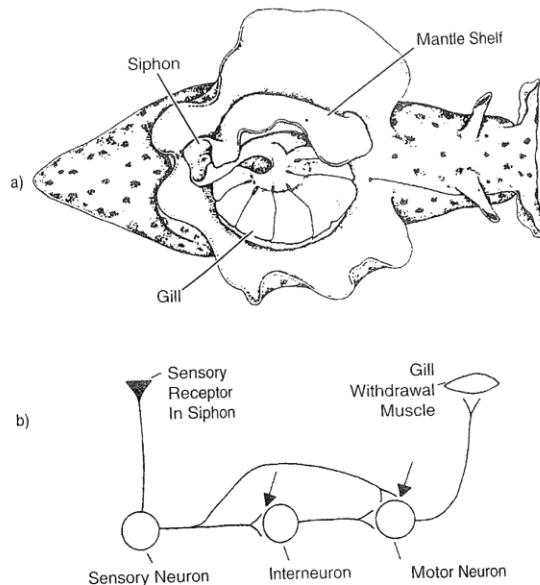


FIGURE 3-7 (a) The marine snail *Aplysia*. (b) A small portion of the neural circuitry involved in the gill-withdrawal reflex. The sensory receptors in the siphon synapse either directly with a gill motor neuron or with an interneuron. In either case, Kandel and associates found that habituation occurs in the first synapse of the chain, as indicated by the arrows. (From Kandel, 1979)

Having determined exactly which neurons underwent changes during the habituation of the gill-withdrawal reflex, Kandel proceeded to ask questions at a deeper level: What chemical mechanisms are responsible for the depressed transmitter release of the sensory neurons? Each time a neuron fires, there is an influx of calcium ions into the axon terminals, and this calcium current is thought to cause the release of transmitter into the synapse. Perhaps this calcium current into the axon terminals becomes progressively weaker with repeated stimulation of the sensory neuron. Kandel's studies supported this idea: The calcium current grew weaker during habituation, and in the recovery period after habituation, both the calcium current and the response of the postsynaptic (motor) neuron increased at the same rate (Klein, Shapiro, & Kandel, 1980). The experimenters concluded that a decrease in the calcium current causes a decrease in the amount of transmitter released into the synapse, which in turn decreases the excitation

of the motor neuron, producing a weakened gill-withdrawal response.

The work of Kandel and associates nicely illustrates the potential advantages of the simple systems strategy in physiological research on learning. Because of the comparative simplicity of *Aplysia's* neural networks, researchers have been able to pinpoint the neural changes responsible for habituation and to begin examining the chemical processes involved as well. This research shows that, at least in some cases, learning depends on changes at very specific neural locations, not on widespread changes in many parts of the nervous system. Furthermore, this learning involved no anatomical changes, such as the growth of new axons, but merely changes in the effectiveness of already established connections between neurons.

Research with Mammals, Including Humans. Because the nervous system of a typical mammal is so much more complex than

that of *Aplysia*, it is much more difficult to identify the individual neurons that undergo change during habituation to a stimulus. Nevertheless, substantial progress has been made in locating the brain locations involved in habituation, at least in certain specific cases. Michael Davis (1989) has conducted extensive research on one such specific case: a rat's startle response to a sudden loud noise. The startle response is measured by testing a rat in a chamber that sits on springs, so that the rat's movement when it is startled shakes the chamber slightly, and this movement is measured by a sensor. As with humans, the rat's startle reaction will habituate if the same loud noise is presented many times. Davis wanted to know what parts of the rat's nervous system were responsible for this habituation.

To begin, Davis had to determine which parts of the nervous system were involved in the startle reaction in the first place. Through many careful studies, Davis and colleagues were able to trace the entire circuit through the nervous system (Davis, Gendelman, Tischler, & Gendelman, 1982). The circuit began in the auditory nerve, then worked its way through auditory pathways to the brainstem, then went to motor pathways that controlled the muscles involved in the startle response. Further research indicated that the changes during habituation took place in the early portions of this circuit (i.e., in the auditory pathways). Although the exact neurons responsible for the habituation have not been identified, Davis's findings are similar to those from *Aplysia* in two respects. First, the neurons that undergo change during habituation are on the sensory side of the circuit. Second, the changes take place within the reflex circuit itself, rather than being the result of new inputs from neurons elsewhere in the nervous system.

Other studies with mammals extend but also complicate the physiological picture of habituation. In some cases of habituation, higher sections of the brain seem to be involved, including the auditory cortex, which is located on both sides of the brain, in the area of the temples. Using guinea pigs, Condon and Weinberger (1991) found that if the same tone was presented repeatedly, individual cells in

the auditory cortex "habituated"; that is, they decreased their sensitivity to this tone, but not to tones of higher or lower pitch.

With modern brain imaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), it has become possible to identify brain areas that are involved in habituation in humans. With fMRI, researchers can measure the activity of different parts of the brain in real time, as a person performs some task or is presented with some stimulus. For instance, one study using fMRI found habituation in many different parts of the brain, including the cerebral cortex and the hippocampus, when people were repeatedly shown the same pictures of human faces (Fischer, Wright, Whalen, McNerney, Shin, & Rauch, 2003). Other brain areas show habituation when people are presented with auditory stimuli (Kiehl & Liddle, 2003). PET scans have displayed changes in the cerebellum as a person's startle response to a loud noise habituates (Timmann et al., 1998). There is growing evidence that many different areas of the brain and nervous system display habituation (a decrease in responsiveness) when the same stimulus is repeatedly presented.

Neurophysiologists use the term **plasticity** to refer to the nervous system's ability to change as a result of experience or stimulation. All in all, the physiological studies of habituation demonstrate that plasticity is possible in many different levels of the nervous system, and that this plasticity sometimes results from chemical changes in existing synapses rather than from the growth of new synapses.

Habituation in Emotional Responses: The Opponent-Process Theory

Richard Solomon and John Corbit (1974) proposed a theory of emotion that has attracted a good deal of attention. The theory is meant to apply to a wide range of emotional reactions. The type of learning they propose is quite similar to the examples of habituation we have already examined: In both types of learning, a subject's response to a stimulus changes

simply as a result of repeated presentations of that stimulus. Opinions about their **opponent-process theory** differ greatly, and as you read this section you might want to form your own opinion about the theory's scientific merit, using the criteria for scientific theories discussed in Chapter 1.

The Temporal Pattern of an Emotional Response. Imagine that you are a premedical student taking a course in organic chemistry. You received a C+ on the midterm, and your performance in laboratory exercises was fair. You studied hard for the final exam, but there were some parts of the exam that you could not answer. While leaving the examination room, you overheard a number of students say that it was a difficult test. A few weeks later you receive your grades for the semester, and you learn to your surprise that your grade in organic chemistry was an A-! You are instantly ecstatic and you tell the good news to everyone you see. You are too excited to do

any serious work, but as you run some errands, none of the minor irritations of a typical day (long lines, impolite salespeople) bother you. By evening, however, your excitement has settled down, and you experience a state of contentment. The next morning you receive a call from the registrar's office. There has been a clerical error in reporting the grades, and it turns out that your actual grade in organic chemistry was B-. This news provokes immediate feelings of dejection and despair. You reevaluate your plans about where you will apply to medical school, and you wonder whether you will go at all. Over the course of a few hours, however, your emotional state gradually recovers and returns to normal.

This example illustrates all of the major features of a typical emotional episode as proposed by opponent-process theory. Figure 3-8 presents a graph of your emotional states during this imaginary episode. The solid bar at the bottom marks the time during which some emotion-eliciting stimulus is present. In this

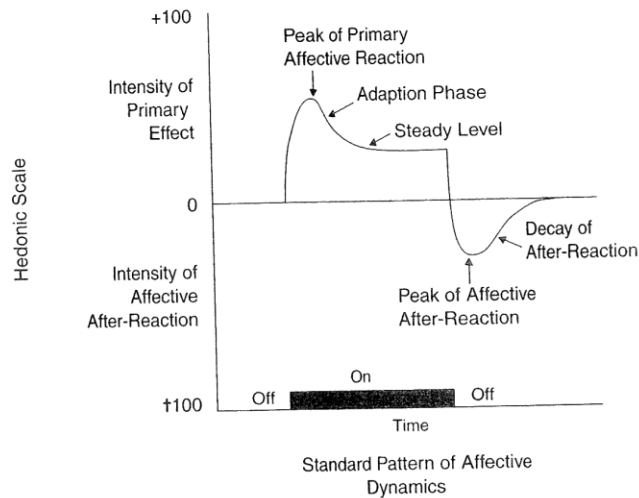


FIGURE 3-8 The typical pattern of an emotional response according to the opponent-process theory. The solid bar shows the time during which an emotion-eliciting stimulus is present. (From Solomon & Corbit, 1974)

example, it refers to the time when you believed your grade was an A-. The y-axis depicts the strength of an individual's emotional reactions both while the stimulus is present and afterward. (Solomon and Corbit always plot the response to the stimulus itself in the positive direction, regardless of whether we would call the emotion "pleasant" or "unpleasant.") According to the theory, the onset of such a stimulus produces the sudden appearance of an emotional reaction, which quickly reaches a peak of intensity (the initial ecstasy in this example). This response then gradually declines to a somewhat lower level, or plateau (your contentment during the evening). With the offset of the stimulus (the telephone call), there is a sudden switch to an emotional after-reaction that is in some sense the opposite of the initial emotion (the dejection and despair). This after-reaction gradually declines, and the individual's emotional state returns to a neutral state.

To strengthen their arguments, Solomon and Corbit reviewed some experimental data from a situation where the initial emotional response was decidedly negative, but where heart rate was used as an objective measure of a subject's emotional reaction. In this experiment (Church, LoLordo, Overmier, Solomon, & Turner, 1966), dogs were restrained in harnesses and received a number of 10-second shocks. During the first few shocks, a dog's overt responses were typically those of terror—it might shriek, pull on the harness, urinate or defecate, and its hair might stand on end. At the termination of the shock, a typical dog's behavior was characterized as "stealthy, hesitant, and unfriendly" (1966, p. 121). Intuitively, we might not feel that these after-reactions are the "opposite" of terror, but they are certainly different from the initial reaction. After a short time, the stealthiness would disappear and the dog's disposition would return to normal—"active, alert, and socially responsive" (1966, p. 121). Heart-rate measures provided more compelling support for the pattern in Figure 3-8: During the shock, heart rate rose rapidly from a resting state of about 120 beats/minute to a maximum of about 200 beats/minute, then began to decline. At

shock termination, a rebound effect occurred in which heart rate dropped to about 90 beats/minute, then returned to normal after 30 or 60 seconds.

The a-process and b-process. Solomon and Corbit (1974) describe several other examples of emotional episodes, but let us now turn to the intervening variables of their theory, that is, the internal processes that, they propose, underlie an individual's observable emotional responses. They hypothesize that the pattern shown in Figure 3-8 is the result of two antagonistic internal processes that they call the **a-process** and the **b-process**. The a-process is largely responsible for the initial emotional response, and the b-process is totally responsible for the after-reaction. The left half of Figure 3-9 shows how these two processes supposedly combine to produce the pattern of Figure 3-8. Solomon and Corbit describe the a-process as a fast-acting response to a stimulus that rises to a maximum and remains there as long as the stimulus is present. When the stimulus ends, the a-process decays very quickly (see the middle left graph in Figure 3-9). In the heart-rate study, the a-process would be some hypothetical internal mechanism (perhaps the flow of adrenaline) that produces, among other responses, an increase in heart rate. The antagonistic b-process is supposedly activated only in response to the activity of the a-process, and it is supposedly more sluggish both to rise and to decay. The middle left graph in Figure 3-9 also shows the more gradual increase and decrease in the b-process. In the heart-rate example, the b-process would be some internal mechanism causing a decrease in heart rate.

Note in Figure 3-9 that the b-process begins to rise while the stimulus (the shock) is still present. Solomon and Corbit propose that when both the a-process and the b-process are active to some degree, the resulting emotional response can be predicted by simple subtraction. That is, the action of the a-process will be countered to some extent by the action of the b-process, and the emotional response will be weaker. According to the theory, it is the rise in the b-process that causes the drop in the initial emotional reaction from the peak to

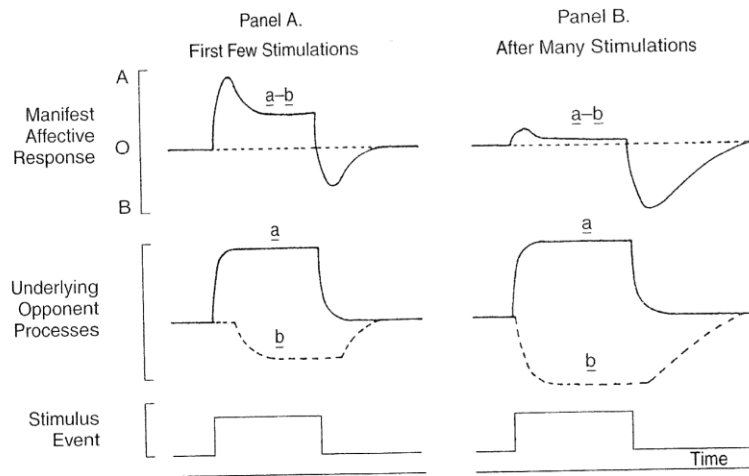


FIGURE 3-9 According to opponent-process theory, a person's emotional reaction (or "manifest affective response") is jointly determined by the underlying a- and b-processes. The proposed time course of these processes during the first few presentations of an emotion-eliciting stimulus is shown on the left. The right side shows the predicted patterns after many repetitions of the same stimulus. (From Solomon & Corbit, 1974)

the plateau. When the stimulus ends and the a-process quickly decays, all that remains is the b-process, which produces the emotional after-reaction. Before reading further, make sure you see how the two processes in the middle left graph of Figure 3-9 combine to produce the pattern in the upper left graph.

The Effects of Repeated Stimulation. Up to now the discussion has been restricted to an individual's first encounter with a new stimulus. However, a crucial feature of the opponent-process theory is its predictions about how the pattern of an emotional response changes with repeated presentations of the same stimulus. To put it simply, the theory states that with repeated exposures to a stimulus, the primary emotional response exhibits a sort of habituation—it becomes progressively smaller—while at the same time there is a marked increase in the size and duration of the after-reaction. The top right graph in

Figure 3-9 shows the predicted pattern of an emotional response after many stimulations. The middle right graph shows that, according to the theory, this change is the result of an increase in the size of the b-process. Solomon and Corbit propose that whereas the a-process does not change, the b-process is strengthened with use and weakened with disuse. With repeated stimulations, the b-process rises more quickly, reaches a higher maximum, and is slower to decay after the stimulus is terminated.

Solomon and Corbit supported these predictions by describing the pattern of responding after dogs received a number of shocks in the study by Church and colleagues (1966). After several sessions, there was little if any increase in heart rate during the shock. However, after shock termination, heart rate decreased by as much as 60 beats/minute, and it took from 2 to 5 minutes (instead of 1 minute or less) for heart rate to return to normal. The

dogs' overt behaviors also exhibited changes with experience:

During shocks, the signs of terror disappeared. Instead, the dog appeared pained, annoyed, anxious, but not terrified. For example, it whined rather than shrieked, and showed no further urination, defecation, or struggling. Then, when released suddenly at the end of the session, the dog rushed about, jumped up on people, wagged its tail, in what we called at the time "a fit of joy." Finally, several minutes later, the dog was its normal self: friendly, but not racing about. (Solomon & Corbit, 1974, p. 122)

In short, with extended experience the dog's overt behaviors paralleled its heart-rate response: The reaction to the shock was smaller than before, but the after-reaction was larger and of longer duration.

Other Examples of Emotional Reactions.

Solomon and Corbit (1974) claim that opponent-process theory describes the temporal dynamics of many different types of emotional experiences, and a few more of their examples will give some indication of the generality of the theory. They discuss the emotional responses of parachutists on their initial jumps and on later jumps, as reported by S. M. Epstein (1967). Overall, the emotional experiences of parachutists resemble those of the dogs in the heart-rate study. Novice parachutists appear terrified during a jump; after the jump, they look stunned for a few minutes, then return to normal. Experienced parachutists appear only moderately anxious during a jump, but afterward they report feelings of exhilaration and euphoria that can last for hours. They claim that this feeling of euphoria is one of the main reasons they continue to jump.

A graphic example involving a pleasurable initial reaction followed by an aversive after-reaction deals with the use of opiates. After a person's first opiate injection, an intense feeling of pleasure (a "rush") is experienced. This peak of emotion declines to a less intense state of pleasure. As the effect of the drug wears off, however, the aversive after-reactions set in—nausea, insomnia, irritability, anxiety, inability to eat, and other physical problems, along with

feelings of craving for the drug. The withdrawal symptoms can last for hours or a few days.

For an experienced opiate user, the pattern changes. The injection no longer brings an initial rush, but only mild feelings of pleasure, if any. This decrease in the effects of a drug with repeated use is called **tolerance**, and it is observed with many drugs besides opiates. Some theorists have suggested that drug tolerance is a good example of habituation (e.g., Baker & Tiffany, 1985). According to the opponent-process theory, however, tolerance is the product of a strengthened b-process. The stronger b-process also explains why, with repeated opiate use, the withdrawal symptoms become more severe, and they may last for weeks or longer. At this stage, the individual does not take the opiate for pleasure but for temporary relief from the withdrawal symptoms. In terms of the opponent-process theory, each injection reinstates the a-process, which counteracts the withdrawal symptoms produced by the b-process. Unfortunately, each injection also further strengthens the b-process, so the individual is caught in a vicious cycle. Solomon and Corbit propose that their theory provides a framework for understanding not only opiate use, but all addictive behaviors (such as smoking, alcoholism, and the use of barbiturates and amphetamines). We will see in Chapter 5, however, that other researchers who study drug use disagree with the details of the opponent-process theory.

Why is it that many emotional reactions include both an a-process and an antagonistic b-process? Solomon and Corbit suggest that the b-process is the body's mechanism, albeit imperfect, of avoiding prolonged, intense emotions. Extremes of emotion, whether positive or negative, tax the body's resources, so when any a-process persists for some time, the corresponding b-process is evoked to counteract it, at least in part. If this is indeed the function of the b-process, then the examples of addictive behaviors clearly demonstrate that this mechanism is imperfect.

A Brief Evaluation. As discussed in Chapter 1, two characteristics of good scientific theories are that they make testable predictions and that these predictions are found to be

consistent with experimental results. Opponent-process theory does make specific predictions about the pattern of emotional responses that have been tested in quite a few experiments. In many cases, the theory's predictions have been supported (e.g., Glover, 1992; R. L. Solomon, 1980), but in some cases they have not (Fanselow, DeCola, & Young, 1993; Newton, Kalechstein, Tervo, & Ling, 2003). Another characteristic of good theories is fruitfulness—the ability to stimulate new ideas and new research. Opponent-process theory can definitely be classified as a fruitful theory. It has been followed by a number of related theories that use the basic opponent-process idea in somewhat different ways (some of which are discussed in Chapter 5). It has been applied to a diverse range of human behaviors, including food preferences (Zellner, 1991), the effects of exercise (Lochbaum, 1999), and leisure travel by retired persons (Staats & Pierfelice, 2003).

Despite its successes, a common criticism of opponent-process theory is that there is little concrete evidence about the actual physiological mechanisms that might correspond to the hypothetical a- and b-processes. Of course, this situation could be remedied if researchers find physiological processes that behave as the theory predicts. For example, one study with rats has found a section of the brain (known as the *nucleus accumbens*) that appears to be involved in both the initial positive reaction to opiates and the negative after-reactions (Koob, Caine, Parsons, Markou, & Weiss, 1997). Further research on this or other brain areas might well unearth clues about why the positive reaction is weakened and the after-reaction is strengthened with repeated opiate use.

Critics also point out that the different examples used by Solomon and Corbit exhibit vastly different time courses. In the heart-rate studies with dogs, the b-process lasts only seconds or a few minutes. In an addiction, the b-process may continue for months. Is it likely that the same physiological mechanisms are involved in emotional events whose durations differ by a factor of 10,000 or more? Critics have argued that there may be nothing more than a superficial resemblance among the different examples Solomon and Corbit present.

In defense of opponent-process theory, we might assert that as long as emotional responses conform to the predictions of the theory, it does not matter whether these patterns are based on a single physiological mechanism or on a dozen different ones. On a strictly descriptive level, the major characteristics of emotional episodes emphasized by opponent-process theory (the peak, the plateau, the after-effect, the changes with repeated stimulation) appear to be fairly well documented by case histories, systematic observations, and experiments. Whether or not these patterns share a common physiological mechanism, the data suggest that the theory captures some characteristics of emotional responses that are quite general. Though it has been called a weakness, the theory's ambitious attempt to unite diverse emotional situations in a single framework may actually be its greatest virtue. The broad viewpoint provided by opponent-process theory allows us to see commonalities among our emotions that would probably go unnoticed in a more myopic analysis of individual emotional responses.

PRACTICE QUIZ

- The second time a stimulus undergoes habituation, the time course of habituation is _____.
- More intense stimuli habituate _____ than weaker stimuli.
- Research with *Aplysia* has found that habituation involves _____ changes in the _____ neurons.
- In opponent-process theory, with repeated stimulation, the _____ does not change, but the _____ starts earlier, becomes stronger, and lasts longer.
- In drug addiction, the b-process appears as _____, whereas in parachute jumping, the b-process appears as _____.

Answers

1. more rapid 2. more slowly
3. chemical, sensory 4. a-process, b-process
5. craving and withdrawal symptoms, euphoria

SUMMARY

One of the simplest types of innate behaviors is the reflex, which is a simple response to a specific stimulus, such as blinking when a bright light is shined in the eye. Kineses are random movements in response to a specific stimulus, whereas taxes are directed movements (such as a fish using the sun as a compass). Fixed action patterns are sequences of behavior that always occur in a rigid order, whereas reaction chains are more flexible sequences that can be adapted to current circumstances. The concepts of control systems theory, which describe a comparison between the actual state of the world and a goal state, are helpful in analyzing these innate behavior patterns. Few innate behavior patterns have been found in humans, but there is evidence that humans may have quite a few innate abilities and predispositions, including language skills, how emotions are displayed in facial expressions, and a variety of other social behaviors.

Habituation is the decline and eventual disappearance of a reflexive response when the same stimulus is repeatedly presented. Habituation gives a creature the ability to ignore unimportant, repetitive events. In both simple and complex creatures, habituation exhibits the same set of properties, such as forgetting, overlearning, and stimulus generalization. Research with simple creatures such as the snail *Aplysia*, as well as with mammals, has traced the physiological and chemical changes that occur in the brain during habituation and specific brain structures involved in habituation in a few cases.

The opponent-process theory of Solomon and Corbit states that many emotional reactions consist of an initial response called the a-process and a later, opposing response called

the b-process. Repeated presentations of the same stimulus strengthen the b-process, so that the initial reaction grows weaker and the after-reaction grows stronger and lasts longer. This theory has been applied to a wide variety of emotional reactions, including drug addiction, the emotions involved in parachute jumping, and responses to painful or aversive stimuli.

REVIEW QUESTIONS

- Describe an example of each of the following innate behavior patterns: reflex, kinesis, taxis, fixed action pattern, and reaction chain. Select one of these examples and show how it can be analyzed using the concepts of control systems theory.
- What types of evidence do scientists use to support claims that human beings are born with certain abilities and predispositions? Which examples of innate human predispositions do you find most convincing, and which do you find less convincing? Explain your reasoning.
- If you bought a clock for your room that made a loud ticking sound, you would probably soon habituate to the sound. Use this example to illustrate the general principles of habituation. Why is this simple type of learning useful?
- How can habituation be studied in human infants?
- Why have researchers devoted so much study to habituation in the snail *Aplysia*? What has been learned about the neural and chemical mechanisms of habituation in the gill-withdrawal reflex in this creature?
- Draw a diagram that shows the pattern of a typical emotional response to a new stimulus, according to opponent-process theory. Now diagram the changed pattern that occurs in response to a stimulus that has been frequently repeated. Use a specific example, such as drug addiction or smoking, to explain the diagrams.