*e* eBook Collection

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**Summary**

Students who take a course in the psychology of learning are usually pretty knowledgeable

about learning by the time they have reached this point. Through instruction and on-the-job

training, they have already picked up numerous everyday, commonsense principles about

how to learn. Students can readily tell their instructors that it is better to spread studying

over several days rather than to cram it all into one day (what psychologists call *the spaced*

*versus massed practice effect*), and that temporary forgetting for otherwise well-known

information occurs, especially on exam days (what we otherwise call *retrieval failure*).

Students are aware of what psychologists call *context-dependent learning*, that it is better to

study in the place in which you will take the test. These practical principles are accurate as

broad generalities, but they are also only partially true. They are half-truths. This is a book

full of half-truths.

Let me quickly explain what I mean. There are numerous facts, laws, and principles

of learning that have been uncovered over the past 120 years that psychology has formally

been in existence. However, these principles are more complex than the simple statements

we popularly use to describe them (e.g., spaced practice is better than massed practice).

Statements of these principles almost always require qualifiers; they are true under certain

conditions. In this book, I will attempt to tell both halves, and thus in the end something

closer to the truth as we know it now.

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1The standard format for noting sources in psychology is to cite the last names of the authors and the year of

publication. Complete source information is provided in the References at the end of the book, where the citations

are listed alphabetically and by year.

Take some well-known popular generalizations. Spaced practice produces better

learning than does massed practice. Well, yes, usually. But much depends on what we are

attempting to learn and how long we will have to retain it, just two of several possible qualifiers

we might add here. Actually, one line of research on remembering people’s names suggests

that it is better to mass repetitions of a given name at first, and then gradually lengthen

the interval between successive presentations (Landauer & Bjork, 1978).1 Repeat the new

name immediately; repeat it again after a little while; and keep increasing the interval to the

next repetition. As a second example, we all know that forgetting occurs over time. The best

you can hope for is that the memory stays stable. But under some conditions, more is remembered

later than was recalled earlier. This is the phenomenon of reminiscence, or hypermnesia,

and is the opposite of forgetting. Finally, common sense seems to say that feedback is

more effective when it is given immediately and consistently after each performance of a

behavior. Yet, again, this is not always so. Skilled movements are sometimes learned better

with delayed or only occasional feedback (see Chapter 11).

Other forms of learning pose questions that have alternative correct answers. Do subliminal

learning tapes, such as those that are supposed to induce self-control or weight loss,

work? Both yes and no answers can be defended. Some data indicate they are effective, but

more probably due to placebo or expectancy effects rather than to any effects on our subconscious.

Does this mean that there is no such thing as subliminal learning? No, learning

can occur at many levels of awareness or consciousness. Does sleep learning occur? Instead

of buying the hard-copy version of this text, should you get the audio book version and play

the tapes throughout the night? The answer depends on what you mean by *learning.*

Research conducted in sleep labs indicates that factual information may not be acquired if

we are truly asleep when the tapes are played, but possibly some other forms of learning

(such as conditioning of the Pavlov variety) might occur.

The point of these examples is to give a sample of what real principles of learning

look like. The goal of this book is to present a scientifically accurate and sophisticated view

of the principles of learning. And this includes the qualifying statements: when a given principle

holds and when exceptions occur. As Einstein said, “Everything should be made as

simple as possible, but not simpler.”

**The Origins of the Study of Learning**

The field of scientific research broadly described as learning has the same origins as

psychology itself, beginning just over a hundred years ago. They are both outgrowths of

philosophy and science. In particular, the philosophical movements of empiricism and rationalism

in the seventeenth and eighteenth centuries, and the development of evolution theory

within biology in the nineteenth century, fostered an interest in the scientific investigation of

learning. These movements are still active influences in contemporary psychology.

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**Philosophy of Epistemology**

The nature–nurture question, which asks how we are affected by biology on the one hand

(i.e., nature) and by environment on the other (i.e., nurture), has long been a source of literary,

political, and scientific speculation. If a child were raised in isolation from others,

what would that child know? Would language develop, and, if so, what sort of language

would it be? Would the child grow to be morally pure, or cruel and beastlike? The French

philosopher Rousseau thought that there existed a “noble savage” who would be discovered

living beyond the reach of the degrading influences of civilization. However, the discovery

of what were called feral children, living apart from other humans and supposedly

reared by wild animals, revealed a sad plight (Candland, 1993). These children were not

only intellectually deprived, but also emotionally devastated.

The nature–nurture issue crystallized in the area of philosophy known as *epistemology*,

the study of how we come to have knowledge. This is the central question for the field of

learning. The philosopher Descartes, while not denying that we learn, suggested that there

were other sources of knowledge that did not depend on experience. Some knowledge

is innately given, for example, our ideas of God, infinity, or perfection. This idea is known

as *nativism.* Other knowledge is derived by a reasoning, logical, and intuiting mind, as illustrated

by the derivation of geometric axioms and algebraic logic. This latter source of knowledge

is known as *rationalism.* In each case, knowledge is present independent of particular

experiences with the world (Descartes, 1641/1960).

By contrast, the British philosopher John Locke (1690/1956) suggested that the origin

of knowledge is in experience, as provided to the mind through the senses. This is the notion

of *empiricism.* For instance, our notion of causation derives from our frequent experiences

in which some event in the world (which we later label a *cause*) is typically followed by

some other event (the *effect*).

An example of the empiricists’ view of knowledge is their treatment of associations

among ideas. What are the origins of our associations of STOP to GO or of TABLE to

CHAIR? Locke, following Aristotle’s writings, suggested these associations derive from our

experience in which the two objects are contiguous: They are close together in time or

space. Therefore, the mental representations of the objects, their ideas, are also contiguous

in our minds. This associative principle of contiguity was supplemented by the principles

of frequency (we associate ideas that are often contiguous), similarity (ideas that are similar),

and contrast (ideas that are opposite). Locke allowed that new knowledge could be

derived within the mind by *reflection*, or thinking and reasoning with previously learned

ideas. This mental chemistry approach of combining existing knowledge to produce new

ideas is similar to Descartes’ rationalism, except that the source of the initial ideas differs

in the two philosophies.

The two epistemological positions represented by Descartes and Locke were certainly

known to the first generation of psychologists, who were well versed in philosophy. (The

Ph.D. is literally a doctor of philosophy degree, and for some early psychologists theirs were

obtained for a dissertation in philosophy.) The influence from empiricism led researchers to

investigate how we acquire knowledge through environmental experiences. A background in

associationism made these first psychologists receptive to scientific methods of investigating

association learning, such as Pavlov’s and Thorndike’s conditioning procedures and

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Ebbinghaus’s method of verbal learning (Kendler, 1987). For example, how could a dog

come to associate two stimuli? By using Pavlovian conditioning, an experimenter would present

a tone followed with food several times, and then look for changes in the dog’s reactions

to the tone. Here we see the associative principles of contiguity and frequency.

Rationalism and nativism were also influential to the field of learning, usually

addressing somewhat different questions. For instance, early psychologists were asking

whether various perceptual capacities, such as depth perception, were innate or acquired.

**Evolution**

Nineteenth-century advances in the sciences would also influence the field of learning, particularly

the ideas of using controlled laboratory experiments, quantifying or measuring outcomes,

and reducing complex phenomena to simpler processes. A more specific influence

from biology, coming nearer the beginnings of psychology itself as a discipline, was Darwin’s

*On the Origin of Species*, published in 1859. In it, Darwin presented his theory of *evolution* to

describe how organisms change over generations in order to better adapt to the environment

to which they are exposed. Darwin first noted that there were individual differences among

members of a species; not all individuals were identical. Some of these differences could

increase the likelihood of survival and reproduction. If these differences were inherited, then

the evolution of adaptive specializations would occur across generations.

The capacity to learn evolved as an adaptive specialization. Whereas evolution theory

at first stressed anatomical changes over time as a means of adapting to the environment, psychologists

would emphasize learning as a means of adapting within the organism’s lifetime.

In addition, the belief that different species were related through a common evolutionary

history suggested there was a continuity of mind across species. Thus, animals other than

humans could be studied, with generalizations proceeding in either direction along the phylogenetic

scale.

**Contemporary Influences**

This discussion of philosophy and biology may seem to be of historical interest at best, but

each has had a continuous influence on the field of learning during the last hundred years.

The contemporary influence of nativism is present in theories that suggest that there are

innate predispositions for acquiring language, for developing phobias to only certain stimuli,

or to comprehending the principles of number and cause and effect (Pinker, 1994;

Spelke et al., 1992). In one modern example, the ideas of nativism, empiricism, and evolution

are represented in a theory of *biological preparedness* for learning. The prime example

of preparedness is the human capacity for language. Language is said to be a biologically

prepared form of learning, something we learn quickly and readily due to our evolutionary

history. This is shown by several aspects of human language: its universality; its common

developmental progression in children across cultures; the fact that it is readily acquired

even in language-poor environments; the possibility that there is a critical period for learning

language; and that certain areas of the brain seem dedicated to language (Pinker, 1994).

Environment is also obviously essential to language development, determining the particular

language we learn and the specific rules of our native language. But the fact that we even

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learn a language, as complex as this is and as intellectually immature as we are as infants,

suggests the existence of a biological predisposition.

Another example of nature–nurture interaction is the theory that evolution has produced

several memory systems through which organisms can learn. There may be specialized

learning systems, such as one for song learning in birds or phobia learning in humans.

Other systems might accommodate incremental learning of habitual behaviors, versus the

memory for individual events that so characterizes human memory (Sherry & Schacter,

1987). Certainly, there is disagreement among learning theorists who advocate stronger

versus weaker contributions of innate predispositions. The point I am making here is that

contemporary theory reflects the nativism of Descartes, the empiricism of Locke, and the

evolution theory of Darwin.

**The Definition of Learning**

Learning is the acquisition of knowledge. Just as the philosophers of epistemology are interested

in the nature and origin of knowledge, so also are psychologists. However, psychologists

have defined learning both broadly and in a manner amenable to scientific study.

Knowledge must be broadly defined to include not just verbal knowledge, but also habits

and skills, attitudes, and knowledge or behavior outside conscious awareness. The everyday

meaning of the word *knowledge* implies a level of conscious awareness and verbalizable

recall that is not present in many instances of learning. For instance, the learning displayed

by nonhuman animals is sometimes better identified by terms such as conditioning rather

than by knowledge. In some cases, I would not be comfortable in saying that a mouse

“knows” what a stimulus means, although I am comfortable in saying the mouse has learned

a conditioned reaction to the tone. The same reasoning applies to much of our knowledge.

So in addition to an intuitive definition of learning, scientific study requires a precise, operational

definition of what can be observed as indicators that learning has occurred. Thus, the

study of learning is guided formally by an objective definition, as well as informally by the

actual practices and interests of the researchers (see Table 1.1).

*Learning may be defined as a relatively permanent change in behavior, or behavioral*

*repertoire, that occurs as a result of experience.* This formal definition specifies what is

included under the rubric of learning, and, just as important, what is to be excluded. This

definition has several components.

First, learning involves an observed *change in behavior.* The point here is that the

detection of learning requires some objective evidence. Psychology is a science because it

is objective and quantifiable. Learning and memory themselves are not observed directly;

they are processes that occur in the nervous system. As much as we may be interested in

the inner workings of the brain (or mind), we need to observe the organism’s behavior in

order to validate our hypotheses about what is going on inside.

Certainly, researchers are coming closer to detecting the neural basis of learning.

Changes in the synaptic processes of a sea snail, the *Aplysia*, have been found during conditioning

(Kennedy, Hawkins, & Kandel, 1992); the circuit for eyeblink conditioning in

the rabbit has been mapped (Thompson et al., 1987); and PET scans show which brain

regions in humans are active when we retrieve word meanings (Raichle, 1994). But most

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**TABLE 1.1 The Breadth of Learning**

The everyday use of the term *learning* does not describe all of the diverse phenomena that

psychologists study in the field of learning. Hillner (1978, pp. 1–2) presented a list of some

of what is included by the term:

**1.** Learning encompasses both animal and human behavior. It is applicable to the behavior of

intact or whole organisms, and even to the adaptive behavior of inanimate model systems

such as computer simulations.

**2.** Learning involves events as diverse as the acquisition of an isolated muscle twitch, a prejudice,

a symbolic concept, or a neurotic symptom.

**3.** Learning includes both the external responses of the organism and internal physiological

responses.

**4.** Learning is concerned with the original acquisition of a response or knowledge, with its

later disappearance (extinction), its retention over time (memory), and its possible value in

the acquisition of new responses (transfer of training).

**5.** Learning is related to such nonlearning phenomena as motivation, perception, development,

personality, and social and cultural factors.

**6.** Learning deals with the behavior of the average subject and with individual differences

among people.

**7.** The study of learning is associated with a long academic and scholarly tradition but also

serves as a source of practical application and technology.

**8.** The learning process is continuous with the more general linguistic, cognitive, informationprocessing,

and decision-making activities of the organism.

learning and remembering involve nervous processes that are as yet undetectable. Learning

and memory are therefore treated as intervening variables. They are hypothesized theoretical

processes that intervene between the environment (which we can manipulate) and

behavior (which we can measure).

What kinds of behaviors can we use to measure learning? Learning outcomes are

multidimensional. This means that different types of measures can be used, each of which

exhibits different aspects of what has been learned. In addition to recording the overt

behavior of organisms (e.g., maze running), we can also record physiological responses of

the internal activity of the body (e.g., heart rate) and verbal reports (e.g., recollections of

past experiences). Consider a learning experience you have had as a child: a sibling jumping

out of a darkened room or closet in order to scare you. The fear learned from such an

episode could be expressed verbally in our recollections of the event years later; physiologically

by increased heart rate in fearful anticipation of a repeat of the episode; and

behaviorally by the avoidance of entering dark hallways or rooms in the house.

The range of behaviors that we can use is illustrated by considering an application to

personnel training. For instance, say a psychologist has conducted a training workshop in an

employment setting. How do we know what the workshop participants learned? Kraiger,

Ford, and Salas (1993) suggested using three types of assessments. One outcome of training

is the factual knowledge that the participants can recall. Another outcome is skill learning,

represented by some behavior that the participants can now do quicker, more accurately, and

maybe even more automatically. Finally, affective (or emotional) measurement includes

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attitude changes. Do the participants now feel more competent, confident, or committed as

a result of training?

Learning involves changes in *behavioral repertoire*, or the stock of behaviors that

might be performed. Not all learning is immediately evidenced by overt behaviors. What

you have just learned from this text is probably not affecting your behavior now. Thus, the

definition also specifies that learning includes the potential for a change in behavior to be

demonstrated when testing conditions prompt the display of this new knowledge.

The distinction between potential and actual changes in behavior is demonstrated

nicely by a classic study of socially learned aggression. Albert Bandura and his students conducted

a series of studies showing that children will imitate aggressive behaviors that they

see adult models perform (e.g., Bandura, 1965). Children watched a videotape in which the

models punch an inflated clown doll, or BoBo doll, by kicking it, throwing it, and so on. The

children were later allowed to play with the BoBo doll. In one condition of the experiment,

the model in the tape had been praised for playing aggressively, and the children later

imitated many of the specific aggressive behaviors. In another condition, the model had been

scolded for misbehaving, and the children who had seen this version of the tape now performed

many fewer aggressive responses (see Figure 1.1). So far, we have a difference in performance

between the two experimental conditions: Children imitated the praised model and

less so the scolded model. Then the experimenter offered a reward for each aggressive

response the child could produce. The incentives increased imitation of the aggressive behavior.

For the children who had seen the scolded model, the aggressive behaviors had entered

the behavioral repertoire, even though these behaviors were not immediately displayed.

The Bandura study is also important for showing that the gender difference in

aggressive behavior disappeared when incentives were offered to demonstrate what the

model had done. The girls remembered the aggressive behaviors they had observed, but

they inhibited imitating these responses until it was acceptable to do so.

Learning occurs *as a result of experience.* This book attempts to describe what some

of these learning-producing experiences are. They may be as varied as a conditioning

0

1

2

3

4

Incentive

Offered

Model

Scolded

Model

Praised

No. of Responses

Girls Boys

**FIGURE 1.1** Mean number of different aggressive

responses imitated by children during the first phase

of testing as a function of the consequences to the

model they had observed and the number of

responses imitated when an incentive was offered

to perform.

*Source:* Bandura, 1965.

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experiment conducted in the lab, a lecture heard, a skill practiced, or an attitude developed

due to some now unrecalled event. The definition of learning excludes those changes in

behavior that are not due to experience. One such nonlearning source of behavioral change

is maturation. Organisms show some behavioral changes because of the physical, neural,

or cognitive maturation that takes place over time. For example, when sparrows reach a

certain age and at a certain time of year, they begin to sing. In some species, singing is not

dependent on particular learning experiences of having heard other birds sing. Singing,

and even the particular song, is innate. In human infants and children, walking and talking

are also dependent on maturation. Physical maturation in the muscles and the bones and

cognitive maturation of coordination allow walking to occur. When we casually talk about

children learning to walk or talk, we are wrong in thinking that they are dependent only on

learning. As we will see in what follows, however, the line between biological maturation

and learning is often blurred. The point of the *experience* phrase in the definition is to ask

us to consider what is the source of a behavior change.

Finally, learning is said to be *relatively permanent.* This may seem contrary to everyday

experiences in which we all too frequently forget facts, names, appointments, and so on. But

we may in fact remember more than we realize. Bahrick (1984a) has shown that substantial

amounts of Spanish vocabulary first learned in high school are retained even 25 years later.

After 40 years, people can still recognize 70 percent of their high school classmates’ names

and pictures, although at first, only 20 percent of their graduating class could be named

(Bahrick, Bahrick, & Wittlinger, 1975). Similarly, even though college professors seemingly

forgot their students’ names within weeks of the semester’s end, the professors did recognize

former students’ pictures and could match names and faces years later (Bahrick, 1984b). Thus,

much more was learned than was apparent on tests of the ability to recall names.

The purpose of the “relatively permanent” phrase is to exclude transient changes in

behavior, changes that are not due to learning. Responding could temporarily fluctuate due

to increases or decreases in, as examples, arousal, fatigue, or motivation. In these cases, the

change in responding is not learning-induced. For example, rats run faster in a maze if they

are hungrier or if given caffeine. This does not mean they suddenly “know more” about the

maze’s route. They are simply more motivated or energized. Knowledge of the maze’s layout

will be present even after hunger or arousal has returned to normal levels. We have to

be careful to separate the transient effects of variables such as arousal and motivation from

their permanent effects on learning (Kimble, 1967).

**Some Caveats**

Although there is a well-specified definition of learning, the study of learning includes phenomena

that do not fit precisely within the formal definition. There are gray areas. Two such

areas are distinctions between maturation and learning and between biology and environment.

The attribution of behavioral changes to either environment or biology is sometimes a

false dichotomy. There is an inseparable interplay between the two, and the line between

learning and other experientially based changes is not always clear. For instance, we say

learning is based on experience. Yet experience affects the development of the brain, too.

Exposing immature rat pups to an enriched environment, one with toys and other rats,

enhances development of one area of the brain important for learning, the hippocampus.

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Both the number of nerve cells and the number of connections among them are increased

(Rampon et al., 2000). These rats will be better at learning certain tasks (such as recognizing

new objects or smells) than rats from more standard environments (Kemperman, Kuhn, &

Gage, 1997). So, there can be a permanent change in behavioral repertoire as a result of experience

that we would not attribute to learning, even though some phrases of the definition of

learning certainly fit.

Another gray area with respect to our definition is the separation between learning

and maturation. The problem here is that the two often coexist and interact with one

another. How can we tell where one leaves off and the other begins?

At one extreme, there are some human behaviors that are substantially influenced

by maturation. Infant development of sitting upright, standing, and eventually walking are

primary examples. Gesell and Thompson (1929) conducted a classic experiment in which

one infant twin of a pair received several weeks of practice at stair climbing. The other twin,

denied this explicit practice, later took only a week to equal the proficiency the practiced sibling

had achieved in four weeks. Similarly, Lenneberg (1967) describes a child who had been

prevented from practicing language sounds for several months by a tracheal tube. When the

tube was removed the child showed age-appropriate prelanguage development, progressing

through the stages of cooing, babbling, and so on. In Gesell’s case, early practice gave little

benefit, and in Lenneberg’s case, the absence of practice produced little decrement.

Other behaviors clearly illustrate the interaction of experience and maturation.

Marler’s (1970) study of white-crowned sparrows is especially instructive here. These

birds have a repertoire of about seven sounds, six of which are essentially uniform across

geographic regions. However, the male song during breeding season shows variability,

known as dialect variation. Marler raised some birds in isolation from others of their type.

When singing began several months after hatching (the timing of which is maturationally

determined), the birds sang a song that was, in outline, the appropriate song for the whitecrowned

sparrows. However, in detail, the song was significantly different or abnormal.

Exposing the birds to a song of their own type during the period from 10 to 50 days after

hatching leads to normal song development, which itself is manifested months later.

Curiously, the local dialect needs to be heard to be acquired, but exposure to a different

dialect will not cause it to be acquired. Thus, song is determined by the interaction of

maturation (an innate predisposition) and learning (experience with specific songs). (See

Ball & Hulse, 1998, for a recent review of research on the development of birdsong.)

An interesting case of song learning was noticed in New York’s Central Park. Birders

there were puzzled to hear a warbler singing weeks before this bird’s usual migration back

north. The mystery was solved by the observance of a white-throated sparrow that alternately

sang the warbler’s song and its own, thereby confusing the birders (National Public

Radio, 04/09/01).

**The Learning/Performance Distinction**

Earlier, we noted that learning itself is not directly observed. This process occurs in the

mind or the brain, which is beyond direct observation. Instead, we infer that learning has

occurred based on some behavior of the organism. However, these behavioral measures are

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sometimes imperfect and indirect. There is not always a one-to-one correspondence

between what the organism knows and what the organism does.

Sometimes no behavioral change is observed even though (we realize later) learning

has occurred. The classic example of this is Tolman and Honzik’s (1930) study of *latent*

*learning.* Rats were placed in a maze but were not given food or any other explicit reward

in the goal box. Not surprisingly, the rats persisted in entering the blind alleys across several

days of this training. (Other rats who were fed in the goal box learned to run directly

to the goal box.) When food was suddenly offered in the goal box, there was an immediate

improvement in performance. The animals now made few wrong turns on their way to the

goal box. The rats had indeed learned the layout of the maze in those previous trials without

food reward, but this knowledge remained *latent*, or hidden, until the subjects were

motivated to complete the maze quickly. Similarly, your knowledge of this chapter may

remain latent until an exam is given. This absence of performance has been aptly referred

to as the “problem of behavioral silence” (Dickinson, 1980). If an experience does not produce

a change from the previous behavior, we really do not know whether learning has not

occurred or learning has occurred and is hidden.

Test anxiety may be one too-familiar illustration of the learning–performance distinction.

Students who truly know the material can perform poorly on the exam because of excessive

anxiety. Performance does not accurately assess the underlying learning that is present.

(To cite one extreme case, Capretta and Berkun [1962] noted that soldiers crossing an unstable

rope bridge over a deep ravine performed worse on a digit span task than when tested

under nonstress conditions.) Interestingly, Naveh-Benjamin (1991) has dissociated two sorts

of anxious students. There are those who study but get anxious taking exams. These students

benefit from training in anxiety management. And there are students who haven’t learned the

material and therefore have good reason to be anxious. These latter students benefit more

from study-skills training. This example shows that there can be alternate interpretations for

poor performance. It may sometimes indicate poor learning, but it may also indicate the presence

of factors, such as anxiety, that inhibit expression of learning.

The phenomenon of stereotype threat demonstrates that actual performance does not

always match underlying knowledge. There are certain negative stereotypes about the academic

abilities of certain groups, for example that women have trouble with math, or that the

elderly are forgetful. Reminding someone who is a member of that group of the stereotype

can negatively affect their performance. Thus, instructions to a senior citizen participating

in a study that “we are going to test your memory” and “we are interested in how good your

memory is” can prime the aging-forgetfulness stereotype. Older adults might then perform

more poorly than younger adults on an actual test of remembering. If neutral instructions

had been given, the age difference would have been smaller or absent altogether (Rahhal,

Hasher, & Colcombe, 2001). Thus the stereotype threat affected performance.

**Learning: A Recapitulation**

Let’s review the key ideas of the previous sections. Research on learning is guided by a formal

definition that makes our study more objective: Learning is a relatively permanent

change in behavior, or behavioral repertoire, that is due to experience. This definition

excludes changes in behavior that are transient, and are thus likely to reflect behavioral

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changes due to fluctuations in attention, motivation, or arousal level. The study of learning

intersects with studies of innate or maturationally determined behaviors. Although our formal

definition emphasizes changed behavior as an indicant of learning, we also acknowledge

that behavioral performance can be a misleading indicator of what has been learned.

**The Relationship between the Terms**

***Learning* and *Memory***

The words *learning* and *memory* in everyday language have related but distinct uses. The

same holds for the technical meanings within psychology. The distinctions psychologists

make are both ones of denotation (or exact meanings) and of connotation (suggested or

implied meanings). Thus, in the past, learning was used to refer to conditioning and reinforcement

tasks, to (nonhuman) animal subjects, or to skills requiring repeated trials for

acquisition. Memory was used in reference to verbal recall tasks, to studies of human subjects,

and to material presented for study just once. Historically, learning was associated

with a behavioral tradition that emphasized the unconscious conditioning of specific

behaviors, and memory with the cognitive approach that studied the conscious recollection

of previous experiences (the behavioral and cognitive approaches are described later). All

of the preceding represent the connotative meanings of learning and memory: what the

terms have usually implied. There are numerous exceptions to each of these rules, especially

in contemporary research, such that each distinction (e.g., animal versus human)

does not perfectly correspond with a distinction between learning versus memory.

A more exact distinction is to say that learning refers to acquiring knowledge

or behavior, whereas memory refers to retaining and recalling the knowledge or behavior.

As a researcher or student, one could primarily be interested in the *acquisition*, or encoding,

of new information: learning associations among stimuli, learning skills, or learning facts.

Or, after these things have been learned, one could be interested in the *retention*, or retrieval,

of the associations, skills, or facts. Essentially, we make a distinction between two phases

and attempt to study each separately.

For instance, in studying learning, one might consider those factors that affect

acquisition, such as the amount of reinforcement, the spacing of study trials, or the presence

of individuals who model certain behaviors. We would measure the development or

progression of learning, as illustrated by a *learning curve.* This would be a graphic plot

of some measure of behavior on the *Y*, or vertical, axis (e.g., number or size of the correct

responses) as a function of the number of trials given shown on the *X*, or horizontal, axis

(see Box 1.1). Such a study might make minimal demands on memory by testing learning

after short intervals of time. On the other hand, in studying memory, one might consider

those factors that affect the retention or retrieval of the previously learned material, such as

the length of the retention interval, or the presence of distracting activities during that

interval. We could measure the course of memory by a *forgetting* curve. This would be a

plot of the measure of behavior (again, the number or size of the correct responses) as a

function of time or events since learning was completed. Sometimes minimal demands are

made on the learning portion of the study by presenting easily acquired material that can

be immediately remembered.

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**12** C H A P T E R 1

**B O X 1.1**

**The Learning Curve**

The phrase *learning curve* has entered everyday

language, often used as a metaphor in comparing

individuals. One person is said to be farther along

the learning curve than another, for instance. An

advertisement for computer software claims it will

put you farther ahead of your competitors on

the learning curve. There is even an accounting–

management textbook titled *Learning Curve* (Riahi-

Belkaoui, 1986). What exactly is the learning curve?

The phrase refers to a particular shape of the

curve that develops over training trials, particularly

as described by Clark Hull, a prominent Yale learning

theorist of the 1940s (Hull, 1943). He said the

basic learning curve is a negatively accelerated

curve. This means that learning (or rather performance,

which is what is actually measured) starts off

with a period of very rapid growth, in which each

trial produces large increments in performance.

These increments get smaller and smaller on later trials,

which is what negative acceleration means.

There is a point of diminishing returns, such that

continued practice has smaller benefits. Figure 1.2

shows the hypothetical increments across successive

trials as Hull depicted them.

We could make an analogy to learning how

to play tennis. At first, the improvements with each

lesson may be fairly large. With yet more practice,

improvements seem smaller. Performance may

eventually reach an asymptote, or plateau, after

which little or no further improvement is seen.

Learning curves are not always negatively

accelerated. Sometimes performance improves only

0 1 2 3 4 5 6 7 8 9 101112131415161718192021222324252627282930

100

80

60

40

20

0

Units of Habit Strength (*SHR*)

Succesive Reinforcements (*N*)

**FIGURE 1.2 Hull’s Theoretical Learning Curve.** Notice that the increases in

height in the curve are smaller and smaller across trials. This is a negatively

accelerated learning curve.

*Source:* From *Principles of Behavior* (pp. 108, 116, 117), by C. L. Hull, 1943, New York:

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very slowly at first, and then the negatively accelerated

process kicks in. This produces an S-shaped

curve: small increments at the start of training, large

increments in the middle, and a return to slow growth

at the end. So, to say that you are farther along the

learning curve may mean that you are in the phase of

rapid acceleration or have passed through it, whereas

someone else is still stuck in that early phase of slow

growth.

This prototypical learning curve has been

documented in many situations, and is incorporated

in contemporary theories of learning (e.g., the

Rescorla-Wagner theory; see Chapter 3). Although

the learning curve may be an accurate description of

what we do observe, its interpretation can be challenged.

By averaging over subjects whose individual

performances vary, we can produce a curve that may

not be an accurate representation of any one subject.

Other contemporary theorists suggest that

the rate of growth is better described by a power

curve rather than by a negatively accelerated curve

(Newell & Rosenbloom, 1981). This means that

the *trials* variable is expressed in log numbers

rather than ordinal numbers, which compresses the

larger numbers and produces a straight line rather

than a curve.

The opposite of the learning curve is the

*forgetting curve*. Here we would plot the amount

remembered at different intervals of time after

learning has been completed. Over time there

would be a decline in what can be recalled, the

opposite of the learning curve. Is forgetting rapid

or gradual? Is the rate of loss constant or does it

vary? Forgetting curves often parallel the negatively

accelerated learning curve. Just as the increments

in learning are larger across the first trials,

the losses in memory are larger at the start of the

retention period. After a while, the rate of loss

slows down. (A forgetting curve is shown in

Figure 6.1, Chapter 6.)

This learning–memory distinction can be illustrated by considering the role of the

spacing of study trials. The well-known generalization is that spaced practice is better, but

does spacing facilitate learning or does it aid retention after learning? A more complete

answer to this question will be presented in a later chapter, but, for now, consider a study

by Keppel (1964). His college student subjects (or *participants*, as we now call them)

learned a list of paired items, such that the first item would be a cue to recall the second.

For example, asking subjects to remember that TABLE is paired with SHOE. One group of

subjects studied and attempted to recall the list eight times in a single session. This is the

massed-practice group, because the study trials came one right after another. A second

group received two study and test trials on each of four days. This is the spaced-practice

condition. Keppel’s results are shown in the left panel of Figure 1.3, which is a learning

curve showing the number of correctly recalled associated words across practice trials.

Acquisition seems to be better with massed practice than with spaced practice. The spacedpractice

group took additional study trials to reach the level of correct recall attained with

massed practice.

Once the lists are learned, which condition produces better memory? The right panel

shows the retention for the massed and spaced groups when tested 1 day or 7 days after the

last training trial. This is a forgetting curve. Here, the spaced-practice group seemed to

remember more after a longer interval.

In this example, learning is studied in the first phase, involving the acquisition of the

TABLE–SHOE associations. Memory is studied in the second phase, involving the retention

of the associations. You might argue (validly) that the learning phase of the spaced group

also tested memory by requiring recall from one day to the next. Logically, this argument

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could also be applied to the massed group, but on a shorter scale of minutes, because it also

had to remember from one trial to the next. Indeed, some psychologists assert that any test

of learning also involves a test of memory (e.g., Spear & Riccio, 1994). Therefore, maybe

this study is not a good example of the distinction between learning and memory. But this

is exactly the point. To label a study as being one of learning versus memory is often based

on convention and consensus.

So how do we decide whether any variable is better or worse if different results are

found in acquisition versus retention studies, as shown before in Keppel’s experiment?

Such discrepancies extend beyond individual experiments. Schmidt and Bjork (1992)

have summarized the situation: “because learning and retention are thought to be different

phenomena, they tend to be studied with separate methods, by different scientists,

and even in different laboratories.” They go further to make the important point that

“Rather than viewing learning and posttraining retention as separable . . . we argue that

the effectiveness of learning is revealed by . . . the level of retention shown” (p. 209).

Their preference is to emphasize longer-term retention and transfer of learning to new

situations.

**Basic and Applied Research**

One might expect a textbook on learning to include detailed information on how to learn the

material in the book. Instead, the processes of learning are illustrated by preparations such

as eyeblink conditioning or word-list memorizing, sometimes with participants other than

humans. This discrepancy reflects the different purposes of research, these being an interest

0

2

1

4

3

5

8

7

6

1–2 3–4 5–6 7–8

Mean Correct Responses

Trials

Distributed

Massed

0

2

1

4

3

5

8

7

6

0 1 2 3 4 5 6 7 8

Mean Correct Responses

Massed

Distributed

Retention Interval Days

**FIGURE 1.3** The left panel shows the acquisition of paired associates as a function of massed versus

spaced practice. The eight trials were blocked in a single session, or spaced over 4 days. The right

panel shows associates recalled when testing occurred immediately after learning, or 1 or 8 days later.

*Source:* From “Facilitation in Short- and Long-Term Retention of Paired Associates Following Distributed

Practice in Learning,” by G. Keppel, 1964, *Journal of Verbal Learning and Verbal Behavior, 3*, pp. 96 and 97.

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Introduction **15**

in basic or in applied content areas. Within each, we are asking sometimes different and

sometimes related questions.

*Basic research* is an interest in understanding the fundamental processes of learning

and memory. It seeks to demonstrate cause-and-effect relationships between key variables.

To demonstrate the probable causality of one variable, we must control, eliminate, or hold

constant other contaminating variables that could affect behavior. This often can be accomplished

using a simple task, a simpler organism, and a highly controllable setting such

as the laboratory. For instance, if you want to discover whether synaptic changes occur in

learning, you want to study organisms that have few and large neurons, such as worms or

snails. The questions asked by basic researchers do not always have obvious and immediate

applicability to everyday learning outside of the lab.

However, it is incorrect to assert that basic research is conducted without any regard

to practical application. The stereotyped portrayal of the Ivory Tower scientist, aloof from

the concerns of everyday life, exaggerates the scientist’s disinterest. Basic researchers

believe in the potential usefulness of their research, even if they are not the ones who will

apply the findings. The applications may not be known until the research is conducted. As

one physicist put it, basic research sometimes provides a solution in search of a problem

(Lemonick, 1995). Other times, basic researchers will themselves demonstrate the practical

implications of their findings. For example, basic research on the learning of aversions to

new tastes by rats has been applied to controlling sheep poaching by coyotes (Gustavson &

Garcia, 1974), and to blocking the development of food aversions in people undergoing

chemotherapy (Bernstein, 1991).

*Applied research* is relevant to, or will apply to, solving a specific practical problem.

The distinction between basic and applied research might be better thought of as a continuum

rather than a dichotomy. (As with many of the terms encountered so far in this chapter,

we first set out a dichotomy and then suggest the truth lies somewhere in between.)

Any given piece of research falls somewhere along the basic applied continuum depending

on the relevance of the study to a specific target population, task, and/or setting to which

we wish to apply our results. Some examples may illustrate.

What is the effect of caffeine on memory? Caffeine is a known stimulant, often used

by students to boost alertness, and would logically seem to facilitate learning. Research on

maze learning by rats has shown varied results: Caffeine sometimes facilitates performance,

but also can inhibit performance (Lashley, 1917; Terry & Anthony, 1980). These studies are

obviously examples of basic research. In other experiments, college students are asked to

remember word lists. These subjects and this task have greater relevance if we are trying to

generalize to humans. Yet this study still retains aspects of basic research, in that the caffeine

is given under controlled conditions in the lab, using blind-run and placebo conditions,

and so on. The results of one such experiment were that caffeine impaired the immediate

retention of the lists (Erikson et al., 1985). One final study to consider is possibly the most

relevant to student learning: What is the relationship of caffeine intake to grade point average?

Now we are getting to the important question. Gilliland and Andress (1981) surveyed

University of Oklahoma students to determine the amount of caffeine consumed and correlated

consumption with the students’ GPAs. The results showed a negative correlation:

Higher caffeine consumption was associated with lower overall grades, and, conversely,

lower caffeine went along with higher grades. This example would seem to present the most

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**16** C H A P T E R 1

**B O X 1.2**

**Studying Everyday Memory**

In 1978, Ulric Neisser, recipient of an American

Psychological Association award for distinguished

scientific contributions, criticized experimental

psychology for its failure to study memory and

cognition as they are used in our lives. “If X is an

interesting or socially significant aspect of memory,

then psychologists have hardly ever studied

X” (Neisser, 1978, p. 4). Neisser was criticizing

psychologists for too much basic research conducted

in the laboratory and too little research on

how memory works outside the lab. Neisser’s

remarks were soon followed by a proliferation

of research on memory as it occurs in the everyday

world.

Ten years later, Banaji and Crowder (1989)

chastised researchers whose newfound interest in

everyday memory had failed to produce a body

of new scientifically valid principles of memory.

Their article was titled “The Bankruptcy of

Everyday Memory,” words equally provocative to

Neisser’s earlier remarks. Banaji and Crowder

argued that the ecological realism obtained by

studying memory in naturalistic settings does not

automatically ensure that generalizable principles

of memory will be found. These authors pointed to

an analogy to chemistry. Chemists look for general

principles of chemical interactions. No one

criticizes chemists for doing controlled lab studies

in order to isolate key variables, instead of studying

everyday compounds in the kitchen or bathroom.

Banaji and Crowder note that because certain

variables are uncontrolled in the everyday

world, a flawed research design cannot produce

valid findings from which to generalize.

For example, Banaji and Crowder present

one scenario in which eyewitnesses to a traffic accident

are questioned. But who can say which witness

is more accurate, or what conditions increase accuracy,

when so many variables are uncontrolled?

Witnesses may have observed from different perspectives

or seen different things; the first story

given to the police could contaminate that given the

researcher later; and the delay until the researcher

questions witnesses varies. How can valid results be

obtained under such poor experimental conditions?

Somewhere between the two extremes of

Neisser and of Banaji and Crowder probably lies the

truth. Several commentators pointed out that the

research setting, laboratory versus field, does itself

determine the scientific validity of the results; that

real-world research can produce generalizable

effects; and that the study of everyday memory can

provide a setting for testing the theories and principles

derived in the laboratory. The study of everyday

memory has since continued to develop, certainly

with an increase in scientific rigor (see Cohen &

Conway, 2007). Like basic research, controlled

experiments are frequently used to study ecological

memory, in addition to methods of naturalistic observation

and self-reports. Just as with basic research,

ecological research generates new questions to ask, a

criterion sometimes used to judge the usefulness of

psychological theories. Importantly, the study of

everyday memory may provide practical remedies

for real problems, such as determining the veracity of

eyewitness testimony, the validity of repressed memories,

or the remediation of memory loss produced

by injury, illness, or aging.

applicable and the most ecologically valid of the caffeine findings presented so far. Yet one

can imagine reasons other than caffeine for these results. Do procrastinating students drink

lots of coffee while cramming for exams and papers? Does self-reported caffeine consumption

accurately reflect actual consumption? By leaving the lab for the actual world, we lose

control over certain variables in our attempt to simulate naturalistic conditions. There can be

a trade-off between experimental rigor and ecological validity in research, as occurs in the

study of everyday remembering (see Box 1.2).

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The point is not that one type of research is better than the other. Basic and applied

research are each appropriate for answering certain kinds of questions. The optimal solution

is for basic and applied research to inform one another.

Our discussion of the roles of basic research raises some additional issues. First,

aren’t the effects of many of the studied variables just common sense? Second, what is the

relevance of using animals in research?

**Common Sense and Common Knowledge**

As noted at the start of this chapter, many readers already possess sophisticated knowledge

about how to learn. After all, students are professional learners. Is much of what psychologists

teach about learning already common knowledge?

Indeed, Houston (1983) presented UCLA undergraduates brief descriptions of reallife

situations in which a principle of learning applied. For example, if a child has been

feeding pigeons at her window sill for several weeks, what happens if the feedings stop?

Answering in a multiple-choice format, most students realized that the pigeons would

stop coming (what we learning psychologists refer to as *experimental extinction*). The

students also correctly predicted the outcome in 15 of 20 other situations. Houston then

tested the same questions with people he found in a park on a Sunday afternoon. They

were able to identify the expected outcomes corresponding to psychological phenomena,

answering about 75 percent of the questions correctly. Does this show that we are teaching

the obvious?

Although some beliefs about the nature of memory are shared by professionals and

the general public, there are also some particularly discrepant conceptions. Klatzky (1984)

refers to these as *memory myths.* These include distorted beliefs about amnesia, hypnosis,

aging, and forgetting in general. For example, the common conception of amnesia is that it

involves extensive forgetting of the past, particularly of personal identity, and that it occurs

frequently (judging by its frequency in afternoon television dramas). In fact, amnesia typically

does not involve loss of personal identity; it goes back for only a short time period;

and it is more likely to involve an inability to form new memories rather than a loss of old

memories (see Chapter 7).

Can memory be improved by training? If physical exercise makes the body stronger,

would mental exercise make memory stronger? A well-designed survey among a

Scandanavian population asked this very question, and found that over 90% believed that

memory exercises would improve overall memory ability (Magnussen et al., 2006).

However, the research evidence is not so supportive of the memory-as-a-muscle hypothesis.

People can indeed improve their ability to remember specific types of information

through practice. Thus, people can improve memory for names, random sequences of

the digits 0 and 1, restaurant orders, and so on, if this is what they practice remembering.

These are specific memory skills that are developed, using special techniques that aid memory

only for the specified material. Someone who can memorize pi to one-hundred decimal

places does not particularly remember other sorts of material any better than the rest of us.

One other too-common belief is that hypnosis can uncover hidden memories that are

otherwise inaccessible. The older studies of hypnosis usually contrasted two groups:

hypnotized and nonhypnotized subjects. What these simple studies failed to equate is the

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suggestibility of the subjects, their motivation to try to recall, and, importantly, the

elaborate instructions to reexperience the remembered event given the hypnosis group.

In fact, such instructions alone in nonhypnotized individuals can increase recall to that of

hypnotized levels (see Chapter 10).

A final myth worth dispelling is the belief that forgetting is a weakness. Certainly,

some of our memory failings are problematic, worrisome, embarrassing, even dangerous.

Yet total recall could pose its own problems. If every event of the same type was remembered

equally, how would you discriminate current from outdated information? Some

mundane examples include remembering my current phone number and where I parked

this morning, but not my last phone number or where I left the car yesterday. These examples

become significant for the survival of an organism. Psychologists have suggested

the radical idea that forgetting may have evolved as a positive characteristic of memory,

not a flaw.

As for the other commonsense learning principles Houston (1983) studied, they may

be generally true, but each can have important exceptions. For example, there are ways of

patterning reward that will determine how quickly the pigeons will stop coming to the window

sill. Using small amounts of food and/or infrequent feedings, rather than large and frequent

feedings, may promote more persistence of the pigeons’ visits.

**Why Animals?**

The reasons for using nonhuman animals in experiments on learning can be simply

stated. First, the experiences of animal subjects often can be more highly controlled,

obviously within the experiment itself, but also prior to the experiment in terms of the

genetic and life history of the organism. Second, given our shared evolutionary history,

there is a presumed similarity between animals and humans, and therefore an assumed

generality in the basic principles of learning. Granted, there may be exceptions to these

generalities.

A third, and controversial, reason for using animals is that procedures can be used on

animals that cannot be applied ethically to humans. This justification is controversial

because some would question why animals are not given similar protection from painful or

dangerous procedures. How prevalent is dissatisfaction with animal use in psychological

research? One survey of 1,200 psychology majors at 42 colleges found fairly strong support

for the continued use of animals (Plous, 1996). About 70 percent supported the use of

animals in psychological research and believed such research was necessary. Interestingly,

a greater number (85 percent) believed that before a proposed study is approved, the investigators

should be required to assess the degree of pain the animals will experience. This

step is required in several European countries. (Incidentally, the survey found that fewer

faculty in psychology departments are using animals than in previous years, and fewer psychology

students take lab courses using animals.)

Neal Miller, in accepting the Distinguished Professional Contribution Award from the

American Psychological Association, listed some contributions of behavioral research on

animals (1985). These include the development of behavioral therapies for psychological

disorders; applications to behavioral medicine, such as in the control of cardiovascular and

asthmatic responses; research on the effects of early experience on neural development; the

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2In this text, I will typically refer to the participant populations as human or animal, which only means a distinction

between human animals and other animals (Dess & Chapman, 1998). Strictly speaking, from an evolutionary or

biological perspective, humans are animals, too.

psychoactive effects of drugs; and benefits to animals themselves, both for those under our

care and for wildlife. The contribution of animal research in psychology is not always

acknowledged. Some introductory psychology textbooks reference certain findings to later

studies of human participants, when in fact the phenomena first emerged from animal laboratories

(Domjan & Purdy, 1995).2

**Conceptual Approaches to the Study of Learning**

When rats (who, along with college students, are psychologists’ favorite research subjects)

learn a maze, what exactly do they learn? Is it a list of specific turns, like a memorized set

of directions? Do they acquire a sort of cognitive map of the layout of the maze? Or should

we be describing the neural changes that underlie the learning of routes or maps? Does an

organism’s natural history determine which form of learning will lead to the greatest likelihood

of survival? These questions illustrate four broad approaches to studying learning

and memory. A functional approach emphasizes the necessity of learning and memory for

survival and adaptation to changing environments. A behavioral approach focuses on

the acquisition of specific behaviors and responses. A cognitive approach emphasizes the

learning of knowledge and expectancies. And finally, a neuroscience approach studies

the changes that learning produces in the brain.

These approaches, along with others, have played a major role in our understanding

of learning and memory. The several approaches are not mutually exclusive. Psychologists

sometimes adopt one perspective or another in conducting their research, although now,

questions are more commonly being asked from a combination of perspectives.

**The Functional Approach**

Animals (people included) are adapted to their environments (e.g., the freezing tundra

versus the steaming desert). In addition to the obvious physical adaptations, the capacity to

learn and remember is another adaptation. Learning evolved as a way for organisms to

adapt more quickly to the changes and inconstancies in their environment. The *functional*

*approach* studies how learning and remembering aid survival.

One focus of the functional approach is the evolution of learning across species.

Animals with a common evolutionary history would likely share certain kinds of learning

or memory abilities. For instance, all animal species have the capacity to acquire associations:

to link one stimulus to another or link behaviors and consequences. A second focus

is on the unique adaptations that differentiate species. It appears that few species can

develop personal or autobiographical memories (what we’ll call episodic memory in

Chapter 7).

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**20** C H A P T E R 1

**The Behavioral Approach**

The *behavioral approach* emphasizes the relationship among, first, observable behaviors,

second, the antecedent stimuli that precede behavior, and, third, the consequences that follow

behavior. What are the environmental stimuli and conditions that come to evoke

behavior? What are the consequences or outcomes that affect the likelihood of behavior?

And what are the behaviors themselves that are learned? The goal of behavioral psychology

is to predict and control behavior on the basis of knowledge of the antecedents, the

behavior, and its consequences.

Behaviorism takes as the basic material for its science observable stimuli and behaviors.

One version of this approach, known historically as radical behaviorism, shuns theorizing

about inferred or hypothetical (and therefore speculative) processes within the organism’s

mind. Instead, behaviorism attempts to describe the lawful relationships among stimuli,

responses, and consequences. These are called “functional” relationships. An example of a

functional statement is “the likelihood that a certain behavior will occur increases if the

response has been followed by a reinforcing stimulus in the past.” To give a specific application,

if a child’s aggressive behavior is rewarded, the likelihood of aggression in the future

will increase. If these functional relationships correctly and accurately describe behavior,

there is no need to postulate unobserved thought processes to explain the behavior (i.e., the

child has a bullying personality, or aggression is cathartic).

Historically, behavioral psychology attempted to explain learning without recourse

to mentalistic concepts such as mind or consciousness. Although initially developed to

describe the results of animal learning experiments, this approach can be readily applied to

learning by humans.

**The Cognitive Approach**

The *cognitive approach* derives from computer-influenced, information-processing

approaches to the mind. Information, or knowledge, is encoded, transformed, stored, and

retrieved. The influence from computer science is obvious: These are analogous to

processes within a computer. The basic tenet of the cognitive approach is the postulation of

an *internal representation.* That is, the organism is said to form an internal representation

that is used as the basis for further processing or for guiding behavior (Pearce, 1997).

(Cognitive researchers will often talk about this representation being in the mind, but this

does not necessarily refer to a mental mind apart from the physical representation in the

brain.) This internal representation, as well as the cognitive processes of storing it, transforming

it, retrieving it, and so forth, are all inferred on the basis of behavior, much as in

the approach of the behaviorists.

Although cognitive psychology obviously applies to humans, the generality of the

cognitive approach can be illustrated in research on animals. Here we have to depend on

behavior and not verbal report in order to infer cognitive processes. How can a researcher

determine whether a rat has acquired a cognitive map of a familiar maze? Can the rat select

a shortcut to the goal box, using a different route from the one we originally trained? If the

animal is confronted with a blocked alley, does the rat readily select an alternate route to

the goal box? We use these sorts of tests to infer the presence of an internal representation

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of the maze. Does the animal act as if it has learned a map of the maze, or instead as if it

has memorized a series of turns?

**The Neuroscience Approach**

The *neuroscience approach* has existed in parallel with both the earlier behavioral and the

newer cognitive perspectives. Taking various contemporary names that reflect different

emphases, such as neurobiology, neurophysiology, or the broader neuroscience, this

approach seeks to determine the underlying biological basis for learning and memory.

What are the changes that occur in the nervous system during learning?

Neuroscience is often combined with the other approaches. Beginning in the 1920s,

the eminent psychologist Karl Lashley attempted to find the areas of the rat’s brain necessary

for learning and memory (e.g., Lashley, 1929). He did this by systematically removing

various regions of the brain. Twenty years later, the neurosurgeon Wilder Penfield

studied memory localization by stimulating the brain of his human patients with weak

electric current (Penfield & Rasmussen, 1950). The patients, who were conscious during

this portion of the operation, sometimes reported sights and sounds that felt like memories.

A few years later, the Swedish biochemist Holger Hydén sought to find a biochemical

change that occurred in the rat’s brain when a new behavior was learned, a sort of memory

molecule (e.g., Hydén & Egyhazi, 1963). Specifically, after training his rats to balance on

a tightrope (don’t ask!), he assessed changes in the cerebellum, an area of the cortex that

is involved in movement coordination. These classic experiments illustrate the strategy of

combining approaches: behavioral (maze learning), cognitive (memory recall), and physiological

(lesioning, brain stimulation, and chemical assays).

Contemporary neuroscience uses methods such as brain scans and case studies of

brain-injured individuals. For example, positron emission tomography (or PET) and functional

magnetic resonance imagery (or fMRI) scans measure the relative levels of activity

in the brain. You have probably seen photographs of scans in which the brain is colorcoded

to show which areas are most active. We can ask an experimental subject to perform

different memory activities, and then scan the brain. For instance, I could first ask you to

remember a list of simple words, such as DOG, TABLE, GLASS, and so on. This is a memory

*encoding* task: It involves putting a list of words into memory. Later I could ask you to

recall that list. This test is a memory *retrieval* task: It involves recalling what is (maybe) in

memory. The scans made during these two tasks are compared, and several brain regions

will be active during both tasks. However, some areas are more active while encoding the

list, and other areas are more active during retrieval of the list. Figure 1.4 shows drawings

of the left and right halves of the brain, with markers showing points that were particularly

active during encoding versus during retrieval (Nyberg, Cabeza, & Tulving, 1996). As can

be seen, when learning the list, many more points in the left-front part of the brain are

active; when recalling the list, there are more points active in the right-front part. Other

research has shown differential activation while remembering faces rather than words.

Historically, there has been tension between the behavioral and cognitive approaches.

In the example that began this section, we posed the question of whether maze learning could

be best described in terms of learning a series of turns versus acquiring a cognitive map of

the maze. Research from a neural sciences approach may offer a reconciliation between

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**22** C H A P T E R 1

75

50

25

Z 0 Z

–25

–50

75

50

25

0

–25

–50

74 37 0 –37 –74 –111

Y

–74 –37 0 37 74

Encoding Activations

Retrieval Activations

Left Prefrontal Cortex Right Prefrontal Cortex

**FIGURE 1.4 Peak activation areas in the left and right hemispheres of the brain during**

**two memory tasks.** The left half of the brain shows more encoding peaks, whereas the right

half shows more retrieval peaks.

*Source:* From “PET Studies of Encoding and Retrieval: The HERA Model,” by L. Nyberg, R. Cabeza,

and E. Tulving, 1996, *Psychonomic Bulletin & Review, 3*, p. 143. Copyright © 1996 by the

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behavioral and cognitive psychologies, by showing that there are both habit learning and

cognitive learning systems in the brain (Petri & Mishkin, 1994). For example, learning that

food is always found in one particular location in the maze, day after day, is habit learning,

and this learning is impaired by damage to an area of the brain called the hippocampus.

If the food location is varied from day to day, remembering where it is today is cognitive

learning, and performance is impaired by damage to another part of the brain, the amygdala

(McDonald & White, 1993).

**Applying Neuroscience to Educational Practice**

Earlier, we distinguished between basic and applied research and suggested that each can

inform the other. Educators are keenly interested in applications of neuroscience to instruction.

Ideas such as educating both halves of the brain and identifying a critical window of

time in which the brain is ready to learn are popular. However, the gap between brain science

and education is sometimes too great for immediate application. Basic research findings may

be several steps and many years’worth of further research removed from application.

***The Mozart Effect.*** Research on the Mozart effect illustrates one extrapolation of neuroscience

to education and to public policy. In a well-publicized study, college students who

listened to 15 minutes of music by Wolfgang Amadeus Mozart showed an increase of several

points in their spatial intelligence test scores in comparison to days they did not hear Mozart

or listened to a different type of music (Rauscher, Shaw, & Ky, 1993). (*Note:* Finish reading

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this paragraph. Do not stop to download Mozart in preparation for tomorrow’s math exam.)

The publicity surrounding this finding led some to advocate Mozart’s music as an IQ

booster. It is not, however. The Mozart CDs labeled in stores as “boosting IQ” are really

boosting sales.

All of us would like to think that something like listening to Mozart (or playing chess

or learning a new language) can somehow reprogram our brains and make them more

intelligent. Unfortunately, other studies did not replicate the Mozart effect or instead found

less interesting explanations (e.g., Steele, Bass, & Crook, 1999). Was the Mozart selection

simply more exciting and stimulating, or was the control music relaxing and calming? In

one study, students did better after listening to their preferred type of music, which was

Mozart for some but jazz for others. Maybe the college student subjects figured out what

the study was about, and that influenced the outcome.

Educational implications are drawn from many other accepted facts produced by

brain research. However, sometimes we need to be cautious in generalizing findings from

one discipline to another. Brain research may be a bridge to memory research (which is the

content of this book), and memory research may be a bridge to educational innovations.

But as Bruer (1997) said, the link from brain science to educational application may be “a

bridge too far” (p. 4).

**Summary**

The point of this book is to present a scientifically accurate and sophisticated view of the

principles of learning. This includes adding qualifying statements to general principles:

specifying when a given principle holds and when exceptions occur.

**The Origins of the Study of Learning**

The philosopher Descartes suggested that some knowledge was independent of experience.

Some knowledge is innate, which is the idea of nativism. Other knowledge is derived

by a reasoning, logical, and intuiting mind; this is rationalism. By contrast, the philosopher

John Locke suggested that the origin of all knowledge is from experience, as provided to

the mind through the senses. This is empiricism.

Darwin’s theory of evolution suggested to psychologists that the ability to learn

may have evolved as an adaptive specialization. Learning is a means of adapting to the

environment within the organism’s lifetime. That different species are related through a

common evolutionary history suggests that learning by animals can offer insights into

how humans learn.

**The Definition of Learning**

Learning is defined as a relatively permanent change in behavior, or behavioral repertoire,

that occurs as a result of experience. Each phrase of the definition is significant. Because

learning itself, in the mind or in the brain, is not directly observable, behavior change is

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necessary to provide objective evidence that learning has occurred. In general, measures of

learning can be physiological, behavioral, or verbal.

The phrase *behavioral repertoire* acknowledges that not all learning is immediately

evidenced in behavior. Learning includes the potential for a change in behavior, to be

demonstrated when conditions prompt the display of this new knowledge. Learning is said

to produce relatively permanent changes in behavior, which excludes transient changes in

arousal, fatigue, or motivation.

Biologically determined maturation illustrates gray areas around the edge of our

definition of learning.

**The Learning/Performance Distinction**

There is not always a one-to-one correspondence between what an organism knows (i.e.,

learning) and what an organism does (performance). Tolman and Honzik’s study of latent

learning showed that rats learned the layout of the maze without reward, but this knowledge

remained hidden until the subjects were motivated with food to complete the maze quickly.

In an exam situation, students who have truly learned the material can still perform poorly

on the exam (maybe due to excessive anxiety, for instance).

**The Relationship between Learning and Memory**

Learning refers to the acquisition, or encoding, of knowledge or behavior. We could illustrate

its development with a learning curve, a graphic plot of a measure of behavior on the

vertical axis (e.g., number or size of the correct responses) as a function of the number of

trials given, shown on the horizontal axis. Memory refers to the retention of knowledge or

behavior that has been learned. We could illustrate the course of memory by a forgetting

curve, plotting a measure of behavior on the vertical axis, as a function of time or events

since learning was completed on the horizontal axis.

**Basic and Applied Research**

Basic research is an interest in understanding the fundamental processes of learning and

memory, by demonstrating cause-and-effect relationships between key variables. We must

often use artificial situations or tasks in order to control, eliminate, or hold constant

contaminating variables that could affect behavior. Applied research, the other end of the

continuum, is designed to be relevant to, or will apply to, answering a specific practical

problem. Each type of research is appropriate for answering certain kinds of questions.

Are most principles of learning already common knowledge? In fact, there are

discrepancies between what professionals and laypeople believe about memory. These memory

myths include distorted beliefs about amnesia, hypnosis, and forgetting in the aged.

Nonhuman animals are used in experiments on learning because their experiences

can be highly controlled and because there is a presumed similarity in learning processes

between animals and humans. Research on animals has made numerous contributions to

the welfare of both animals and people.

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**Conceptual Approaches to the Study of Learning**

There are several broad approaches to the study of learning. The functional approach

proposes that learning and remembering evolved as means for organisms to adapt to the

changes and inconstancies in their environment and thus to aid survival. A behavioral

approach focuses on the acquisition of specific responses or behaviors. It emphasizes the

relationship between these observable behaviors to the stimuli that precede behavior, and

to the consequences that follow behavior. A cognitive approach emphasizes internal

(mental or neural) cognitions and expectancies. It derives from information-processing

approaches to the mind, in which information is encoded, transformed, stored, and

retrieved. A neuroscience approach studies the changes that learning produces in the brain.

It seeks to determine the underlying biological basis of learning and memory within the

nervous system.

Those psychologists who study learning and memory can draw on basic research

conducted by neuroscientists, and learning psychologists can offer applications to educators.

However, research on topics such as the Mozart effect, critical periods in neural

development, and environmental enrichment by neuroscientists may not yet be applicable

to education.

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