CHAPTER TEN

Knowledge

I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. . . . It is a mistake to think that the little room has elastic walls and can distend to any extent. Depend upon it there comes a time when for every addition of knowledge you forget something that you knew before.

—Sherlock Holmes

The more you put in a brain, the more it will hold.

—Nero Wolfe

Knowledge refers to what you know. You probably know the capital of Canada, the number of states in the United States, your telephone number, the number of legs on an ostrich, several types of dinosaurs, the color of carrots, the texture of sandpaper, the taste of seawater, and perhaps even the air-speed velocity of an unladen European swallow. Perhaps more surprising than the number of things you know is the number of things you know that you do not know. For example, you probably know that you do not know the name of the 44th element in the periodic table (molybdenum), the name of William McKinley's first vice president (Garret A. Hobart), or the name of the 1959 Nobel Prize winner for literature (Salvatore Quasimodo).

In this chapter, we look at various explanations for how people organize and retrieve information from semantic or generic memory. Although *semantic* memory is the most common term, a better term is Hintzman's (1978) *generic* memory, for three reasons: First, the topic is about everyday, ordinary knowledge (hence, generic); second, it includes information other than purely semantic information (having to do with words and meanings); and finally, the term *semantic memory* is usually taken as implying that semantic and episodic memory are different systems (Tulving, 1972, 1983), which should be a separate issue from the study of knowledge.

Propositions and Concepts

Before examining the most common views of generic memory, we need to define and explain some terms. The most common class of models that attempt to explain generic memory rely on concepts and propositions. A *proposition* is simply a relationship between two concepts that has a truth value. For example, a proposition might be that "A canary can sing." Singing is a concept and canary is a concept; this statement becomes a proposition because the concepts are arranged such that the truth of the statement can be verified. Even though most of the propositions we consider will be in the form of English sentences, this need not be the case. English is simply a convenient way of expressing the information, and people who speak different languages are assumed to have similar propositional representations.

A *concept*, then, is simply a mental representation of something. More technically, a concept is "an idea that includes all that is characteristically associated with it" (Medin, 1989, p. 1469). It could be a type of animal such as aardvark, a part of speech such as adjective, or an idea such as justice. Although words are frequently used to name concepts, a concept is more than a word and does not have to be a verbal entity. An analogy might be that a concept is like the entry in a dictionary that follows the word rather than the word itself.

One final point we need to consider is how best to test the models that will be described. The main problem is that everybody knows that birds fly, canaries sing, and animals eat. If we used an accuracy measure like proportion correct, everyone would score near 100% correct and there would be no observable differences. Instead of accuracy, researchers have used *latency* as their behavioral measure. Measurements of how quickly a person can respond are usually called *response times*, conveniently abbreviated as RT. The key data, therefore, will come from seeing how quickly people process various types of information. One common test is to measure how long it takes people to verify that a proposition is true or false; another is to measure how long it takes people to verify that a target item is a valid word. The former is known as a *semantic verification test* and the latter as a *lexical decision test*.

Collins and Quillian's Hierarchical Model

Collins and Quillian (1969) converted a model for storing generic information in a computer (Quillian, 1967, 1969) into a testable model of human knowledge. Figure 10.1 shows the organization and illustrates the key features. Each black dot represents a category name (or concept), arranged in a hierarchical fashion so that the most general concepts are at the top and more specific instances are further down. Thus, canaries are a type of bird, and birds are a type of animal. The properties that most animals have in common

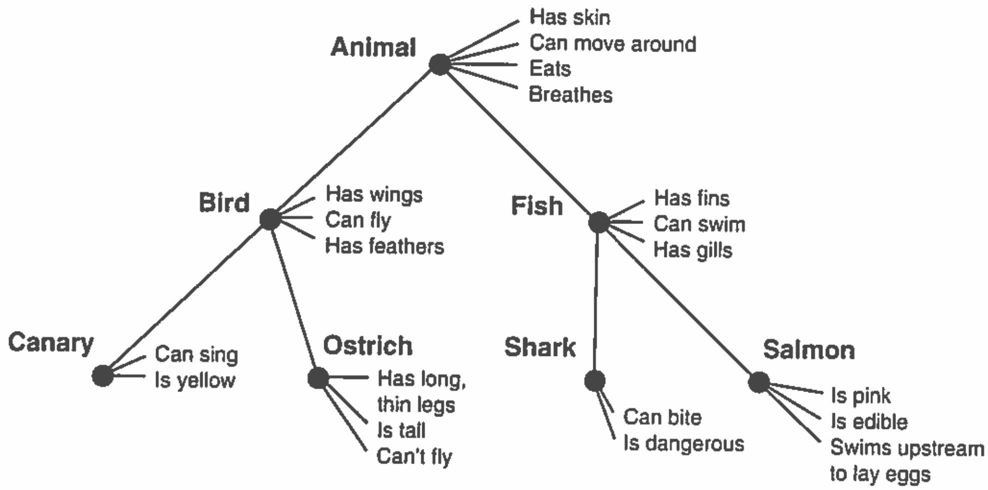

Figure 10.1 Hypothetical generic memory structure for a three-level hierarchy. The properties are not meant to be exhaustive, but rather illustrative. SOURCE: From "Retrieval Time from Semantic Memory," by A. M. Collins and M. R. Quillian, 1969, *Journal of Verbal Learning and Verbal Behavior*, 8, 240–247. Copyright © 1969 Academic Press, Inc. Reprinted with permission.

are represented at the level of the animal concept; those that birds share but that other animals do not are at the level of bird; and those that distinguish canaries from other birds are down at the level of canary. This general principle is known as *cognitive economy*, because each property is listed as few times as possible. If asked whether canaries fly, the subject responds by retrieving the knowledge that canaries are birds and that birds can fly; it can then be inferred that canaries can fly. Ostriches cannot fly, and this information is stored at the level of ostrich to prevent an incorrect inference.

How does this model make testable predictions to see whether this organization is a plausible model for how people organize knowledge? The Collins and Quillian model makes predictions about how long it will take a person to verify a sentence. Suppose a person is asked to verify two sentences: "A canary can sing" and "A canary can fly." The model shown in Figure 10.1 predicts slower responding to the second sentence than to the first. To verify the second sentence, the subject starts at the canary node but then has to move up the hierarchy one level to confirm that the desired property is there. No such metaphoric travel is necessary for the first sentence; the property is stored at the same level as the category.

To state the predictions as precisely as possible, Collins and Quillian (1969) made three assumptions. First, they assumed that both retrieving a property and traversing the hierarchy take time. Second, they assumed that the times are additive whenever one step is dependent on the completion of another. For example, to verify the sentence "A canary can fly," retrieving the property "can fly" is dependent on first moving up the hierarchy. The additive assumption simply means that the time to complete both steps is the sum of completing each step individually. Third, Collins and Quillian assumed that the time to retrieve a property is independent of the level of the hierarchy.

Collins and Quillian (1969) presented subjects with two kinds of sentences to verify. Sentences that involved properties were called P sentences, and those that involved

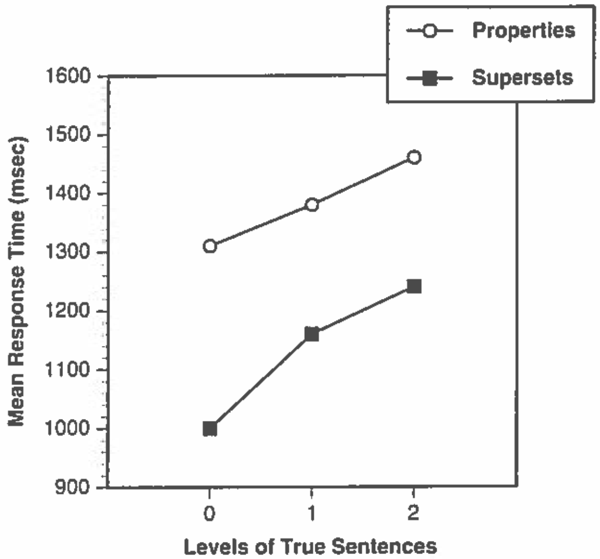

Figure 10.2 Mean response time to verify property or superset sentences as a function of how many levels need to be traveled.
SOURCE: From "Retrieval Time from Semantic Memory," by A. M. Collins and M. R. Quillian, 1969, *Journal of Verbal Learning and Verbal Behavior, 8*, 240–247. Copyright © 1969 Academic Press, Inc. Reprinted with permission.

superset relations were called S sentences. In addition, there were three possible levels of the hierarchy. A 0-level sentence involves properties or supersets at the same level. For example, a P0 sentence might be "A canary can sing." An S0 sentence might be "A canary is a canary." Any sentence that involved moving one level up the hierarchy was called either an S1 or P1 sentence; a sentence that involved moving two levels was called an S2 or P2 sentence. In three experiments, Collins and Quillian (1969) presented true and false sentences from knowledge bases similar to that shown in Figure 10.1. For example, a true P1 sentence from a Games knowledge base might be "Badminton has rules." A false sentence might be "Hockey is a race." Other knowledge domains tested included trees and beverages.

The model predicts two parallel lines, with the property line higher than that for superset questions. As Figure 10.2 shows, this is exactly what happens. The difference between P0 and P1, and P1 and P2 is about 75 ms, as is the difference between S1 and S2. The difference between P1 and S1 and P2 and S2 is about 225 ms. These measures can be interpreted as suggesting that it takes about 75 ms to retrieve a property, regardless of the level in the hierarchy, and that it takes about 225 ms to travel up a level. Given the simplicity of the model, it is remarkably accurate in its predictions.

There were two main problems with this version of the model. First, and most important, there is no clear way of explaining performance on the false sentences. Collins and Quillian considered three different hypotheses: (1) the contradiction hypothesis, in which search stops when a contradiction is reached; (2) the unsuccessful search hypothesis, in which search stops after a certain criterion is reached; and (3) the search and destroy hypothesis, in which search continues until all possible connections are evaluated. None gave a good account of performance.

The second main problem was that the Collins and Quillian (1969) model was proposed as a specific test of the simplest version of the model, and it made assumptions that were stricter than necessary (see Collins & Loftus, 1975). For example, although the description appears to suggest that each item is stored only once, Collins and Quillian (1969, p. 242) acknowledged there are often multiple representations and that structures may not be perfectly hierarchical.

This problem is illustrated in a study by C. Conrad (1972). She first obtained normative data on how frequently subjects produced a particular property when given a category. Properties that were mentioned by more than 50% of the subjects were called high-frequency properties; those that were mentioned by fewer than 25% of subjects were called low-frequency properties; and those that were mentioned by 25% to 50% of subjects were called moderate-frequency properties. Contrary to the predictions of the Collins and Qullian (1969) model, high-frequency properties did not show a regular increase in RT with an increase in level. Moreover, RTs were linearly related to frequency; mean RTs to high-, moderate-, and low-frequency properties were 1080, 1106, and 1140 ms, respectively. Conrad suggested that the regular linear pattern obtained by Collins and Quillian (shown in Figure 10.2) was due in part to their using high-frequency properties at Level 0, moderate-frequency properties at Level 1, and low-frequency properties at Level 2.

The Feature Overlap Model

The next major model was developed by Smith and his colleagues (Smith, Shoben, & Rips, 1974), who assumed that the meaning of a concept is not a single unit but a set of features or attributes. They posited two types of features, defining and characteristic. *Defining features* are essential, whereas *characteristic features* are typical. This relationship is not an either-or situation, however; a particular feature can be more defining or more characteristic. For example, some features of robins are that (1) they are bipeds, (2) they have wings, (3) they have red breasts, (4) they perch in trees, and (5) they are not domesticated. Feature (3) is probably the most defining, and features 1 and 5 are the least defining.

One way of obtaining evidence consistent with this idea is to have subjects rate how typical various instances of various categories are. Rips, Shoben, and Smith (1973) found that robins and sparrows were thought to be more typical birds than were chicken and geese. These judgments are consistent with the idea that subjects are using characteristic features. A more sophisticated way of representing these data is to use *multidimensional scaling*. This procedure converts similarity ratings to distance: The more similar two items are judged to be, the closer the items are when plotted. One such solution is shown in Figure 10.3. Note that goose, duck, and chicken are close together (they are similar) but are far away from robin and sparrow. Notice also that these three birds are closer (more similar) to the concept of an animal than to the concept of a bird. One implication of this view is that category membership is not all or none; rather, membership within a category is a matter of degree.

Further evidence consistent with the idea that the meaning of a concept is a set of features or attributes was reported by Rips (1975). He had subjects read a report about a fictitious island that contained several kinds of animals: geese, ducks, eagles, hawks, robins, sparrows, ostriches, and bats. As can be seen in Figure 10.3, the first three pairs are widely spaced, but each item in the pair is close to the other item. Subjects were told that

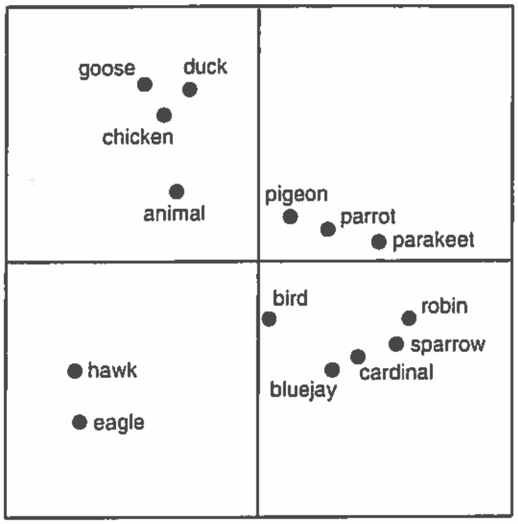

Figure 10.3 A multidimensional scaling solution for birds.
SOURCE: From "Semantic Distance and the Verification of Semantic Relations," by L. J. Rips, E. J. Shoben, and E. E. Smith, 1973, *Journal of Verbal Learning and Verbal Behavior, 12,* 1–20. Copyright © 1973 Academic Press, Inc. Reprinted with permission.

one species had been diagnosed with a contagious disease, and they were asked to estimate the percentages of other animals that also had the disease. The results are shown in Table 10.1. The species closest to the infected bird in Figure 10.3 was the species with the highest estimated infection rate. As the species became more distant, the predicted infection rate decreased.

Rips's (1975) study is important because it provides converging evidence. Although he used different subjects and a very different task, the results are consistent with those from the multidimensional scaling procedure. This is called *converging evidence*, because both sets of results converge, or point to the same answer (Garner, Hake, & Ericksen, 1956). Furthermore, it shows how information in generic memory can affect performance on other tasks.

Table 10.1 Estimated rates of infection for five species when told that a sixth species was infected

	Estimated Percent Infection Rate					
Infected Species	*Goose*	*Duck*	*Robin*	*Sparrow*	*Hawk*	*Eagle*
Goose	—	**74**	17	18	16	13
Duck	**81**	—	18	18	43	35
Robin	26	30	—	**79**	35	41
Sparrow	32	27	**66**	—	49	43
Hawk	40	27	27	29	—	**63**
Eagle	17	16	26	29	**72**	—

NOTE: The boldface figures are for birds that are most similar to the infected species.
SOURCE: Based on Rips (1975).

Experiment *Typicality Effects and Inferences*

Purpose: To demonstrate how typicality can affect inferences

Subjects: Thirty-six subjects are recommended.

Materials: Table 10.1 lists six of the eight animals needed; ostrich and bat should also be included. You will also need an answer sheet on which subjects can write their responses. This answer sheet should have all eight animal names in a different random order for each subject.

Procedure: Inform the subjects that in this experiment they will be asked to make estimates of how many animals from various species are infected by a particular disease. One-sixth of the subjects should be given sparrow as the infected species, one-sixth should be given robin, and so forth. No subjects are told that bat or ostrich is infected.

Instructions: "Imagine an island has been discovered that contains eight different species of animals. These are listed on your answer sheet. Scientists have found that the [name of infected bird]s are infected with a contagious disease. We would like you to estimate how many of the other animals are likely to be infected. On your answer sheet, please write down a number from 0% to 100% to indicate how many of each species is likely to be infected. Any questions?"

Scoring and Analysis: For each infected species, calculate the average percent infection rate for the other five species of birds. The data should look like Table 10.1.

Optional Enhancements: Increase the number of subjects, making sure to keep an even multiple of 6. Use other types of animals, or adapt the experiment to other types of materials.

SOURCE: Based on an experiment by Rips (1975).

According to the *feature overlap model*, how does a person decide whether a robin is a bird? The basic processes involved are outlined in Figure 10.4. After the proposition is presented, the first process is to retrieve the list of features for both concepts. These feature lists contain both characteristic and defining features. It is assumed that the lists are organized with the most defining features listed first, with subsequent features being less defining and more characteristic. The feature lists of the two concepts in the proposition are then compared, and an overall measure of similarity or overlap, x, is computed. What happens next depends on the value of x. There are two criteria: an upper value, c_1, and a lower value, c_0. If x is greater than c_1, there is a high degree of overlap, indicating a match, and a positive response is made quickly. If x is lower than c_0, there is very little overlap, indicating a mismatch, and a negative response is made quickly. Thus, when x has extreme values, only one decision stage is necessary. If x is greater than the lower criterion but less than the upper criterion, however, there is some overlap. In this case, an immediate "false" response cannot be given, but there is not enough overlap to give an immediate "true" response. This is where the second decision stage occurs; this second stage separates the more defining features from the characteristic features. For example, although bats have several characteristic features of birds (for example, they both fly), bats have different defining features (they are mammals whereas birds are not). Comparing all features would produce an intermediate value for x, and the defining features would then be examined. This second comparison is more analytic and slower than the first, which can be thought of as more holistic.

This model can account for all the data that the Collins and Quillian (1969) hierarchical model can, as well as for several results that the former model could not. For example, subjects verify more quickly that "A robin is a bird" than "A robin is an animal."

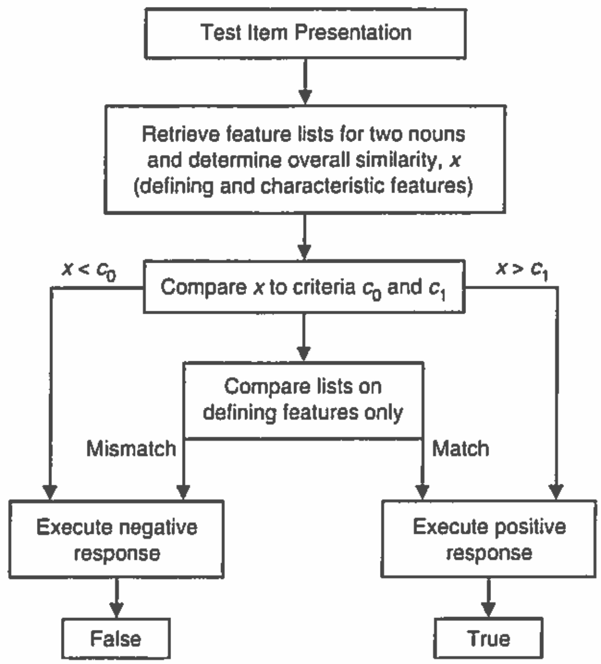

Figure 10.4 The two-stage decision process for feature comparison. SOURCE: Smith, Shoben, & Rips (1974).

The hierarchical model says this is because there are two levels of hierarchy to travel for the second sentence, compared to only one in the first. The Smith et al. (1974) model says this is because robins share more features with the concept bird than with the concept animal. In Figure 10.3, robin is closer to bird than to animal, which indicates that there is more feature overlap between robins and birds than between robins and animals. The second finding from Collins and Quillian (1969) was that people are faster to verify sentences like "A canary can sing" than "A canary can fly." In the hierarchical model, this was because the properties were stored at different levels of the hierarchy. In the feature overlap model, this is explained by the ordering of features within the feature list. The most defining features are listed first, which in the case of a canary would be that it is yellow, can sing, and so forth. Farther down the list are features that are less defining, such as that it can fly and has wings. The farther down the list of features the particular property is, the longer it will take to verify the sentence.

The feature overlap model has two major advantages. It can handle false responses, which occur when the feature overlap between two concepts is very small. But even more important, it can handle different kinds of false responses. For example, subjects more quickly indicate that the proposition "Magnesium is an animal" is false than the proposition "A tree is an animal" (Collins & Quillian, 1970). This is because animals and trees are both living things and will have some features in common, whereas magnesium is inanimate.

The model is not without problems, the most important of which concerns the distinction between defining and characteristic features. A concept such as triangle has defining features: a three-sided, closed figure whose interior angles add to 180°. If a shape has these features, it is a triangle; if it does not, then it is not a triangle. For nontechnical concepts, though—the ones people use every day (furniture, cars, tools)—there is no such thing as a defining feature. This problem, well known in philosophy (Wittgenstein, 1953), is illustrated by asking subjects to answer a simple question: Can you name one feature that all games have in common? For every suggestion, one can easily find a game for which the feature is not true or can find something that has that feature but is not a game. The feature overlap model requires a distinction between characteristic and defining features in order to have two stages, but the distinction is probably not valid for the majority of concepts.

A second problem is that the feature overlap model restricts the kind of information that can be brought to bear on a task. Because the key decision processes are based only on feature comparison, other sources of knowledge are excluded from the categorization process. For example, another task commonly used to uncover the properties of generic memory is called *production frequency*. Here, subjects are either given a category name and asked to name an example, or given an example and asked to name the category. Depending on which item is given first, different results occur. Loftus (1973) found, for example, that although insect is often mentioned as the category for butterfly, butterfly is rarely mentioned as an example of an insect. The problem for the feature overlap model is how to explain these differences when the same set of features is recruited for each comparison.

Collins and Loftus's Spreading Activation Model

Collins and Loftus (1975) proposed a revision of the basic hierarchical model to take into account the problematic findings for both models described so far. The key idea, expanded and clarified from earlier versions, is that activation spreads from one or two concepts to all related concepts. The main differences between this model and the earlier versions are that implied or suggested constraints are explicitly disavowed. For example, the *spreading activation model* (1) is not strictly hierarchical or, to phrase the same idea slightly differently, relaxes the notion of cognitive economy so that some concepts can be represented multiple times; (2) has links between concepts that have differential travel time; and (3) explicitly allows activation to spread from both category and exemplar nodes.

Collins and Loftus list 13 assumptions about the spreading activation model's operation, including the following:

Assumption 1. When a concept is processed, activation spreads out along all paths; the strength of the activation decreases as the number of paths increases.

Assumption 2. Only one concept can be processed at a time, but once processed, activation can spread in parallel.

Assumption 3. Activation decreases over time and/or activity.

Assumption 5. The more properties two concepts have in common, the more links there are between the concepts. For example, most vehicles are very similar, so they will have many interconnecting links, but most red things share only one feature (color) and so will have very few links (see Figure 10.5).

Assumption 8. The decision process requires enough evidence to exceed a positive or negative criterion. Evidence comes from examining intersections, points where activation links from different sources meet.

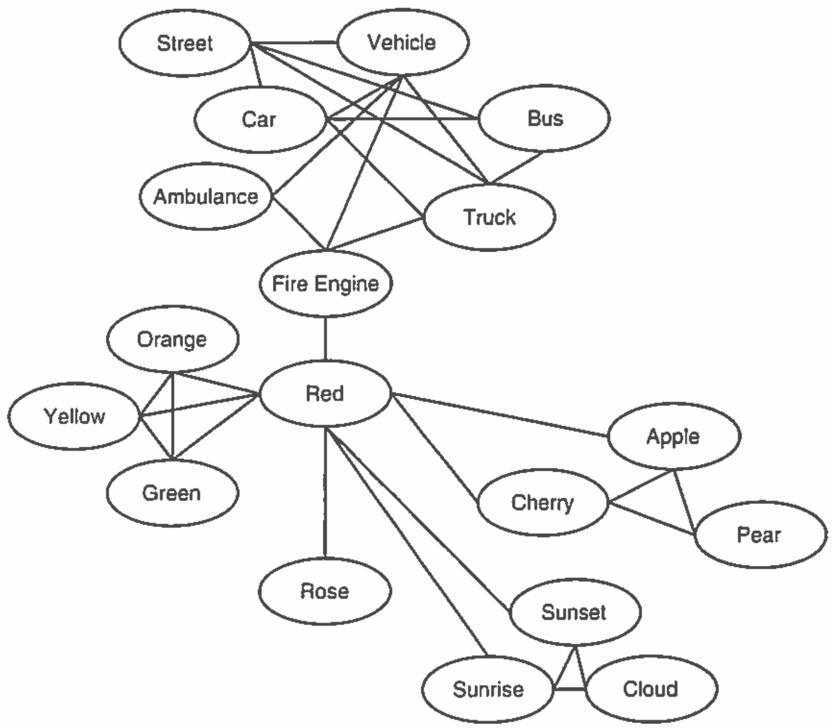

Figure 10.5 A representation of assumption 5 of Collins and Loftus's spreading activation model. SOURCE: Collins & Loftus (1975).

Assumptions 9 through 13 detail the types of positive and negative evidence available. Intersections that involve a superordinate category, properties that match, exclusive subordinates (such as male and female), and counterexamples are all types of evidence that can be used to render a decision, either positive or negative.

Chang (1986) compared the hierarchical model and the spreading activation model in the following way: "As easy as it was to falsify the hierarchical-network model, it is just as difficult to disprove the present spreading-activation theory; but, at the same time, as easy as it was to [generate] empirical implications of the earlier model, it is just as difficult at present to derive unequivocal predictions [of the revised model]" (p. 217). Because of these problems, the Collins and Loftus (1975) version is probably best viewed as a framework rather than as a precise, testable model, and for that reason we do not provide a detailed analysis of its predictions about verifying propositions. We will examine this model in more detail in the section comparing its account of association priming with the account offered by compound cue theories.

Spreading activation quickly became the dominant explanation for theories of generic memory (Anderson, 1983a), as well as word production (Dell, 1986) and word perception (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Indeed, connectionist models, which have been applied to numerous areas in psychology, can be thought of as spreading activation models. Although each of these versions is more specific and detailed than the original proposal, each is based on the same idea.

Knowing That You Don't Know

Before continuing with a discussion of the core feature of spreading activation, it is worthwhile to pause and consider how people decide that they do not know something. There has been relatively little work on this area compared to research on what people do know. For example, all of the models discussed so far have emphasized how people respond "true" or "false," with no option for a "don't know" response.

One notable exception is a series of experiments reported by Glucksberg and McCloskey (1981). In their first experiment, they had subjects memorize a set of sentences—for example, "John has a pencil. John doesn't have a shovel. Bill has a bowl. Bill doesn't have a magazine." After learning these sentences, subjects were given a variety of questions that could be answered "true," "false," or "don't know." The true sentences were the same as the studied sentences, whereas the false sentences contradicted some aspect of a studied sentence (such as "John doesn't have a pencil" or "Bill has a magazine"). The don't-know sentences contained names and objects that had been studied but in new combinations ("Bill has a pencil" or "John doesn't have a magazine"). Subjects were asked to decide true, false, or don't know as fast as they could.

Subjects took 1596 ms to correctly respond "true" to true test items and 1688 ms to correctly respond "false" to false items, but they required only 1337 ms to correctly respond "don't know." An analysis of errors illustrated the same pattern: Subjects made about 12% errors on true items and 12% errors on false items, but only 2% errors on don't-know items. People can thus be both faster and more accurate in saying they don't know than in responding with what they do know.

Glucksberg and McCloskey's (1981) second experiment tested an interesting idea. They hypothesized that people will take more time to respond "don't know" if they have explicitly stored the fact that they don't know something than if they have not explicitly stored that fact. The design was similar to the previous experiment, except that some sentences contained information about what was not known (such as "It is unknown whether John has a chair"). An explicit don't-know test item might be "John has a chair" or "John doesn't have a chair," whereas an implicit don't-know test item would be the same as in the previous experiment. The results are shown in Table 10.2. When the subjects had explicit knowledge that the information was not known, it took them longer to respond and they were less accurate than when they did not have explicit knowledge about their lack of information.

Glucksberg and McCloskey (1981) suggested that don't-know decisions are made by a two-stage process. First, the subject examines whether there are any relevant facts about the question. If there are none, then a quick "don't know" response is made. If

Table 10.2 Mean response time and mean error rate for true, false, explicitly stored uncertain, and not stored uncertain test items

	True	*False*	*Explicit DK*	*Implicit DK*
Response Time (ms)	1888	2093	1892	1594
Error Rate (%)	4.8	7.3	4.0	1.4

SOURCE: Data from Glucksberg & McCloskey (1981).

there is some information available, a more detailed examination of the facts takes place (the second stage). If the information is still not sufficient to answer the question, then a slow "don't know" response is made.

Priming

Spreading activation can be reduced to one main finding: priming. Unfortunately, the term *priming* can refer to at least two different effects. In Chapter 7, we examined *repetition priming* in conjunction with implicit memory: The processing of something a second time benefits from having processed it previously. A second type of priming is *association priming*—the observation that response times are often faster if a second item is related to or associated with the first item. Thus, in repetition priming the target item is processed twice, whereas in association priming the target item is processed only once.

To give a specific example of association priming, in one experiment two strings of letters were shown, one above the other. If both were valid words, the subject was to respond "yes." If one or both strings were not words, the subject was to respond "no." The results are shown in Table 10.3.

Subjects responded approximately 85 ms faster when both strings were related words (*nurse-doctor*, *bread-butter*) than when they were unrelated (*doctor-butter*, *bread-nurse*) (Meyer & Schvaneveldt, 1971). Spreading activation models provide a simple explanation: As the first word is read, the relevant concept is activated. Activation spreads to related concepts, so that by the time the second word is read, its relevant concept is already partially active. This saves time in processing the second item and produces a decrease in response time. When the first string was a nonword, response times were also fast, but this was a result of the task: There is no need to process the second string if the first one gives sufficient information to answer the question. Subjects were slowest when the first string was a word and the second was a nonword.

CogLab Experiment
http://coglab.wadsworth.com/experiments/LexicalDecision/

Priming can also be seen when the stimuli are more complex than single words. For example, Ashcraft (1976) demonstrated priming with topics. Sentences that involved high-frequency properties, such as "A sparrow has feathers," were verified in approximately 1330 ms. If a second sentence followed on the same topic, such as "A robin can fly," response times decreased to approximately 1200 ms, indicating priming.

Table 10.3 Mean response times showing association priming

Top String	*Bottom String*	*Example*	*Mean RT*	*% Errors*
word	associated word	nurse-doctor	855	6.3
word	unassociated word	nurse-butter	940	8.7
word	nonword	bread-marb	1087	27.6
nonword	word	besk-doctor	904	7.8
nonword	nonword	besk-marb	884	2.6

SOURCE: Data from Meyer & Schvaneveldt (1971).

Neely (1977) demonstrated that expectations can affect priming, using a lexical decision task. Subjects were asked to judge as quickly and as accurately as they could whether a target was a word or a nonword. (We will ignore the responses to nonwords; they were there primarily to keep the subjects honest.) In one condition, subjects were told that if the first word (the prime) was *bird*, then the second word (target) would be a type of bird. These subjects might see *bird* followed by *robin*. In a second condition, subjects were told that if the prime was *body*, then the target would be a building part. These subjects might see *body* followed by *door*. Neely also manipulated two other variables. One is called *stimulus onset asynchrony*, or SOA. This is simply the amount of time between the presentation of the first item and the presentation of the second: An SOA of 0 ms means the two items are presented simultaneously; an SOA of 2000 ms means presentation of the second item began 2 seconds after the presentation of the first item began. The final variable was whether the prime-target relationship was as advertised: Subjects who were expecting *bird-robin* might occasionally see *bird-arm*; subjects who were expecting a category shift (*body-door*) might occasionally see *body-arm*.

The results are shown in Figure 10.6, in terms of the amount of facilitation or inhibition compared with baseline performance. Baseline performance is simply the time taken to respond when the prime was *XXX* rather than a word. The left panel of Figure 10.6 shows the results for subjects who were not expecting a category shift: The open circles represent trials in which no shift occurred, and the closed squares represent trials in which a shift did

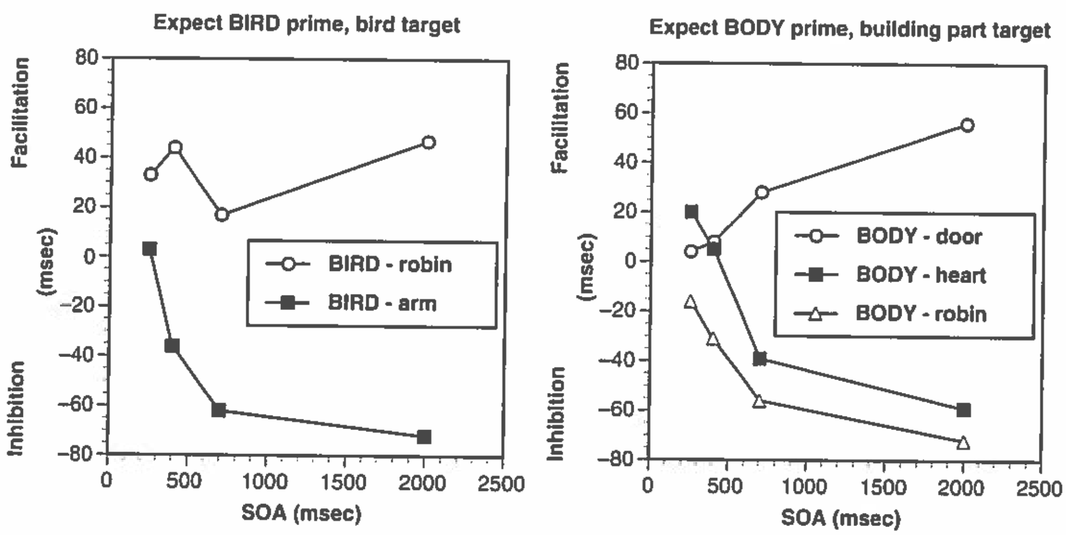

Figure 10.6 The left panel shows what happens when subjects expect a bird-related target to follow the cue *bird*, which is a preexisting relation. When subjects see the expected target, priming occurs at both short and long SOAs. When subjects see an unexpected target, there is neither facilitation nor inhibition at short SOAs, but inhibition increases as the SOA increases. The right panel shows what happens when subjects expect a building-part related target to follow the cue *body*, a relation that does not normally exist. When the expected target occurs, there is no priming at short SOAs, but priming emerges as the SOA increases. When subjects see an unexpected target that has a preexisting relation (e.g., *heart*), priming is seen at short SOAs but not at long SOAs. SOURCE: Based on data from Neely (1977).

occur. The right panel shows the results for subjects who were expecting a category shift. At the shortest SOA, there is priming for semantically related items (*bird-robin* and *body-heart*). However, as the SOA increases, the subject's expectations come into play: *bird-robin* priming continues (left panel), but *body-heart* priming disappears (right panel). Neither *bird-arm* nor *body-robin* shows priming; indeed, as the SOA increases, inhibition increases. Neither group expected this pairing, and both pairs contain unrelated words. The final data come from the *body-door* group in the right panel. These subjects were expecting this relationship, but they show no priming with short SOAs. Because priming here is dependent on expectations, it takes some time to be observable; by 2000 ms SOA, *body* primes *door* (when expected) as well as *bird* primes *robin*.

These results are consistent with the idea that priming involves at least two components. First, there is an automatic component that is independent of the subject's intentions or expectations. This is seen in Neely's (1977) data when related items, such as *body-heart*, show priming at short SOAs even though the subject was not expecting this relationship. The second component is more strategic and reflects the subject's expectations. Thus, *body* can prime *door*, but only after a relatively long SOA; no priming is seen at short SOAs. Most models focus on the automatic aspect, because it is more likely to yield information about the basic structure of generic memory than is the intentional component, which reflects strategies the subject is currently using. It should be noted that further research (Neely, Keefe, & Ross, 1989) has revealed that the process is more complex than described here.

Spreading activation models are so dominant today that many people use the terms *priming* and *activation* as synonyms (Ratcliff & McKoon, 1988). Indeed, the concept of activation is so well accepted that it is widely used in other areas of research. For example, one current view of immediate memory uses activation and decay of activation as the key theoretical idea (see Chapter 4). Immediate memory, according to this view, is that portion of permanent knowledge that is in a heightened state of activation. Because only a very small fraction of information in memory can be active at one time, these views also need to posit some mechanism or process, usually decay, that can deactivate it.

The most fundamental findings that support a spreading activation approach are the association priming data discussed above. These results are widely considered to be the most direct evidence possible: All the subject is required to do is process one word after processing a related item. According to spreading activation, as the first word is read, the relevant concept is activated. Activation spreads to related concepts, so that by the time the second word is read, its relevant concept is already partially active.

If the spreading activation account of association priming is called into question, then spreading activation as a general concept, in theories of both immediate and generic memory, can also be called into question. Compound cue theory, a more recent explanation of association priming, does indeed call into question the fundamental assumption of spreading activation theory.

Alternatives to Spreading Activation

One relatively recent competitor to spreading activation is a class of models known as *compound cue models* (Dosher & Rosedale, 1989; Ratcliff & McKoon, 1988). The basic idea is that instead of selecting items that have been activated by spreading activation, generic memory functions more the way other forms of memory function. Ratcliff and McKoon's (1988; McKoon & Ratcliff, 1992) model, for example, is based on a process similar to that used by SAM (Gillund & Shiffrin, 1984; see the optional chapter at the end of this book), which is designed to explain both free recall and recognition data. However, Ratcliff and McKoon point out that two other models (also discussed in the optional chapter)—MINERVA 2 (Hintzman, 1986) and TODAM (Murdock, 1982)—can both implement the main idea.

In SAM (Gillund & Shiffrin, 1984), items in memory are represented as images. An *image* is an interconnected feature set that contains information about (1) the context in which the item was learned, (2) the item itself (its meaning, name, and so forth), and (3) its relation with other images. In a memory test, the subject assembles a set of cues in short-term memory and then uses these to probe various images in long-term memory. In a recognition test, the result of this probe, called *familiarity*, is used to decide whether to respond "old" or "new."

For normal recognition, the SAM model assumes that the subject uses several pieces of information to judge whether the target is an old item or a new item. Recognition tests usually involve asking whether the subject recognizes a word as one that has appeared during a specific period of time (for example, was the word on the preceding list?). One factor used by SAM is the strength of the association between the target item and context. A second factor is the strength of the association between the target item and other items. For example, during study, two words may have been rehearsed together, and so they become associated. The familiarity of an item on a recognition test, then, depends on the strength of the associations between the cues used and the target item and on the strength of the association between the target item and other items in memory.

In a typical priming study that uses a lexical decision test, one target is shown, and the subject is asked to decide whether it is a valid word. According to compound cue theory as incorporated in SAM, the difference between this test and a recognition test is that there are two cues (the prime and the target) rather than just one (the recognition probe). The model now adds a third type of association, the strength of the association between the prime and other items in memory, to the two already mentioned (the association between the target and the context and the association between the target and other items in memory). The resulting familiarity value will be a combination of the familiarity to both items that form the compound.

The main finding to be explained is why responses to *nurse* are faster when it is preceded by *doctor* than when it is preceded by an unrelated prime such as *butter*. According to compound cue theory, the reason is that the prime and the target have a large number associates in common. A large number of common associates produces a higher level of familiarity than if the prime and target have very few associates in common.

Compound cue theory, as implemented in SAM, produces a number that corresponds to a familiarity, in contrast to lexical decision tasks as measured using RT. To convert familiarity to RT, Ratcliff and McKoon (1988) used the diffusion model (Ratcliff, 1978; see the optional chapter for a detailed description). This model converts high values of familiarity to fast and accurate positive ("yes") response times, low values of familiarity to fast and accurate negative ("no") response times, and intermediate values to slower and less accurate positive and negative response times.

Comparing Spreading Activation and Compound Cue Theory

Although relatively few studies directly compare predictions of spreading activation models and compound cue models, some differences have been noted. The compound cue model referred to below is described more completely by Ratcliff and McKoon (1988, 1995b), and a spreading activation account is described by McNamara (1992a, 1992b).

Priming *Spreading activation* models account for association priming by assuming that activation spreads from one concept to related concepts; the more directly related the concept is, the more priming will occur. *Compound cue theory* accounts for association priming by assuming that both the prime and the target form a compound cue; because they have associates in common, there is more familiarity. There is no such thing as activation within compound cue theory.

Priming Onset Priming onset refers to how quickly priming is evident. Early versions of spreading activation theories (Collins & Quillian, 1969; Collins & Loftus, 1975) assumed that the onset of priming was a function of the number of intervening concepts, or links. These models predict that priming should take longer to see for *canary-animal* than *canary-bird*. (Do not confuse priming with sentence verification. In priming, subjects respond whether the target is a word or not. Responses to the target are facilitated when the prime is associated with it, compared to when the prime is unrelated.) The compound cue model predicts no difference in priming onset, because the same computations are performed regardless of how related the items may be. Ratcliff and McKoon (1981) varied the duration of the SOA to determine when priming was first evident and found that when words rather than sentences were used, there was no difference in response times for primes that are closer together (*canary-bird*) compared with primes that are farther apart (*canary-animal*). Spreading activation models have since been revised to account for this finding by allowing the spread of activation from concept to concept to be much faster (on the order of 5 ms per link).

Decay of Priming As more items intervene between the prime and the target, the amount of facilitation decreases. Compound cue models account for this by having the prime replaced by the intervening item within the compound cue (Ratcliff & McKoon, 1988). Although the compound cue could include any number of items, if more than one or two nonassociated items are included, the effects of priming will be minimal. This places a limit on the model's prediction of how long the target can be delayed and still show priming. If priming is seen after ten intervening items, for example, compound cue theory is disproven. Spreading activation models, in contrast, typically have activation decrease as a function of time (Anderson, 1983b; McClelland & Rumelhart, 1981). There is nothing within the structure of these models that places a limit on how many intervening items can occur.

Multiple Meanings There is evidence that when an ambiguous word is presented, both meanings are primed immediately, but only the appropriate meaning remains primed (Swinney, 1979). For example, the word *bank* can refer to a place where money is kept or to the side of a river; the word *bug* can refer to an insect or to a covert listening device. Spreading activation explains this priming effect by assuming that decay of activation occurs to both meanings; the "correct" meaning is kept active, however, by activation from other words compatible with the context of the sentence. The compound cue model states that no decay occurs, because no activation occurs; rather, a compound cue that contains an ambiguous word will give a high value of familiarity. When the ambiguous word is replaced in the cue by a later word, then only the appropriate meaning will have a high familiarity value.

Mediated Priming Mediated priming refers to priming seen when two items that are unrelated (*lion* and *stripes*) can become related by a third, mediating item (here, *tiger*). According to spreading activation models, activation spreads from *lion* to *stripes* via the mediating link of *tiger*. *Lion* and *tiger* are related, and *tiger* and *stripes* are related. Compound cue theories posit that no mediation is necessary. If the two components in the compound are sufficiently familiar, then there will be priming. One measure related to familiarity should be co-occurrence: how often two words are experienced together. McKoon and Ratcliff (1992) showed that mediated priming (*lion-stripes*, presumably mediated by *tiger*) resulted in as much facilitation as nonmediated priming of words that co-occur frequently (*deer-grain*, where no obvious item associated with deer is also related to grain). Much ongoing work is currently examining mediated priming, but both views can predict the basic effect.

Strengths and Weaknesses Given that both views are consistent with the main data, which is the better explanation? Currently, spreading activation is still the most widely accepted view of how information in generic memory is retrieved. One reason is its intuitive appeal: The basic idea of spreading activation captures the introspection of how one word or idea can lead to another.

The main weakness of the spreading activation view is its lack of specificity. Most versions (one exception is Anderson, 1983a) are so vague that it is difficult to derive a strong, a priori prediction (see Chang, 1986). Related to this is a logical problem (see Ratcliff & McKoon, 1994). Suppose each word has 20 other words associated with it; this assumption is reasonable, given data on word association norms (Postman & Keppel, 1970). Presenting one prime would activate 20 words, and each of those would activate another 20. If activation is allowed to spread, as is required to explain mediated priming (McNamara & Altarriba, 1988), then each of these 400 active words would activate another 20. From one prime, 8000 words are now active, roughly an eighth of the words that the typical adult English speaker knows. McNamara (1992b) has demonstrated mediated priming with four items (for example, *mane-stripes*, presumably mediated by *lion* and *tiger*). According to the account of mediated priming offered by spreading activation theories, 32,000 words are now active, approximately half of the typical English speaker's vocabulary.

Compound cue theory has two major advantages. First, it is better specified, in the equations that describe the processes, than spreading activation models are. Researchers easily agree on the predictions that it makes, and these predictions can be made before the experiment. Second, it uses the mechanisms and processes of the global memory models (see the optional chapter), and so relates memory performance from generic memory to performance on recall and recognition tasks.

Compound cue theory also has two main problems. First, the rules for determining which items will form a compound cue are not yet well specified. Second, there is some question about the accuracy of one of its predictions. The words *spider* and *ant* are related, but they are not associated. In other words, when people are asked to say the first thing that comes into their head when they hear the word *spider*, they do not say *ant*. Compound cue theory predicts that priming should occur because of the semantic relatedness, but some researchers (Shelton & Martin, 1992) have found no priming, whereas others (McKoon & Ratcliff, 1992) have found priming. It remains unclear how to interpret these mixed results.

How Is Generic Memory Organized?

Despite its apparent simplicity, the answer to the question of how generic memory is organized is likely to be complex, elusive, and a long way off. Categories can be organized at different levels of abstraction, some very broad (furniture), some less broad (chair), and some quite specific (rocking chair). These have been termed (respectively) *superordinate*, *basic*, and *subordinate level categories* (Rosch & Mervis, 1975). What is particularly intriguing is that basic level categories (chair, dog, car) seem to be learned first, are the level at which objects are named, and show remarkable cross-cultural consistency (Rosch, Mervis, Gray, Johnson, & Bayes-Braem, 1976). Basic level categories are neither the most inclusive nor the most specific, but they do seem to have a special status relative to other levels of categorization.

The idea that concepts are organized by similarity has intuitive appeal. People seem to group many things together on the basis of shared perceptual qualities. However, as Medin (1989) has argued, rather than being organized by similarity, concepts are organized around theories. According to this view (Murphy & Medin, 1985), the relationship between a concept and an example of that concept is similar to the relationship between theory and data. An example must have the right explanatory relationship to the concept, not merely be similar. We will examine this idea further by focusing on one particular area of research.

One currently popular approach is to examine people who have deficits in particular aspects of generic memory: They can identify certain types of items but have difficulty identifying other items. One early suggestion was that generic memory might be organized by categories, such as animate versus inanimate things.

Warrington and Shallice (1984) described four people who had recovered from herpes encephalitis but who had sustained both left and right temporal lobe damage. In one task, two subjects were asked to identify pictures of living things and nonliving things; in another task, they heard a word and were asked to provide a definition. The results are shown in Table 10.4. For example, when asked to define *ostrich*, JBR responded with "unusual." When asked to define *wasp*, SBY responded with "bird that flies." Even though these subjects were not perfect in identifying or defining all nonliving things, their perfor-

Table 10.4 Performance by two subjects with damage to both left and right temporal lobes on two generic memory tasks

Subject	*Living Things*		*Nonliving Things*
		Picture identification	
JBR	6%		90%
SBY	0%		75%
		Spoken word definition	
JBR	8%		79%
SBY	0%		52%

NOTE: Although subjects' ability to identify and define living things is grossly impaired, their ability to identify and define nonliving things is relatively intact.

SOURCE: Based on data from Warrington & Shallice (1984).

mance was much better than for living things. Similar results have been reported by other investigators (De Renzi & Lucchelli, 1994; Farah, McMullen, & Meyer, 1991; Pietrini et al., 1988; Sartori, Miozzo, & Job, 1993).

One tempting conclusion is that generic memory organizes information about living things and nonliving things differently, such that it is possible to sustain damage to one area but have the other area relatively intact. Such a simple principle quickly became more complicated, however, because there were subtypes that did not fit in with these categories. For example, De Renzi and Lucchelli (1994) reported that their subject, Felicia, had only mild impairment for naming body parts, which technically are living, but had severe impairment for professions, which are clearly not animate. Similarly, performance showed impairment for food items, of which some are living (fruits and vegetables) and others nonliving (soft drinks, spaghetti, ice cream). Thus, Warrington and Shallice (1984; Warrington & McCarthy, 1983) suggested that the relevant difference was actually based on different properties. In general, visual features are of greater importance in discriminating living things, whereas function (what it does) is more important for discriminating nonliving things.

Farah and McClelland (1991) explored this idea by constructing a simulation model and then lesioning the part of the model responsible for visual features in generic memory. The basic architecture of the model is shown in Figure 10.7. In this model, generic memory consists of two different types of knowledge: visual and functional. Input to the system can be either verbal (such as hearing a word) or visual (such as seeing a picture).

What is most intriguing are the results from simulations in which Farah and McClelland damaged part of the model. They removed the visual component of generic memory by altering the weights on the connections or, in some cases, by disconnecting

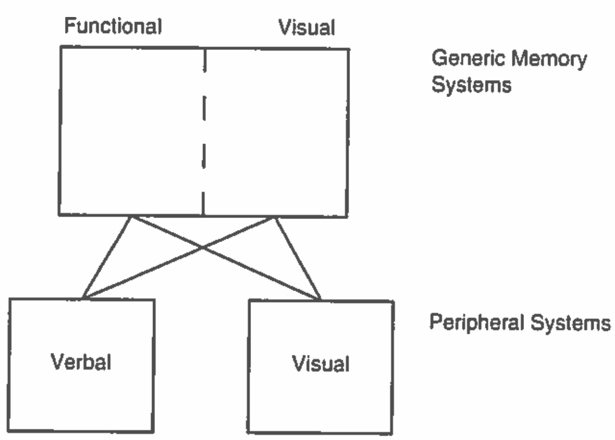

Figure 10.7 A schematic representation of the Farah and McClelland parallel distributed processing model of generic memory. SOURCE: From "A Computational Model of Semantic Memory Impairment," by M. J. Farah and J. L. McClelland, 1991, *Journal of Experimental Psychology: General*, *120*, 339–357. Copyright © 1991 American Psychological Association. Reprinted with permission.

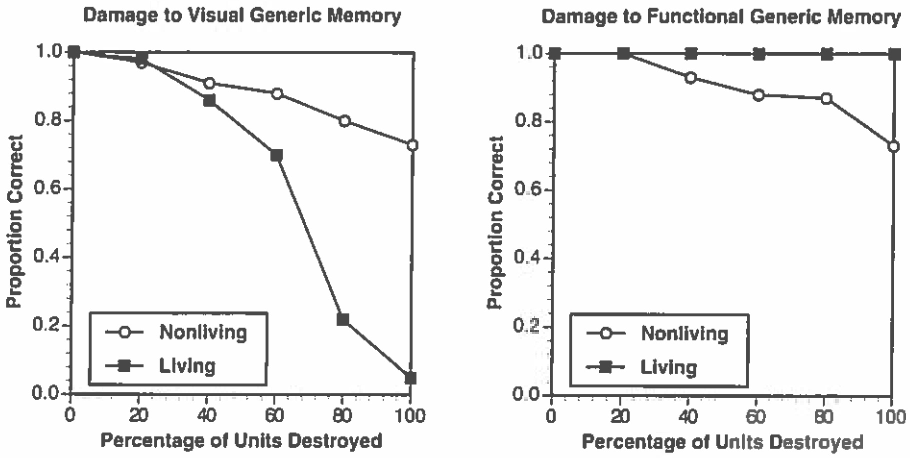

Figure 10.8 Simulation results from the Farah and McClelland model showing the effects of damaging increasing proportions of visual generic memory (left panel) or functional generic memory (right panel). SOURCE: From "A Computational Model of Semantic Memory Impairment," by M. J. Farah and J. L. McClelland, 1991, *Journal of Experimental Psychology: General, 120*, 339–357. Copyright © 1991 American Psychological Association. Reprinted with permission.

the units entirely. As the left panel of Figure 10.8 shows, when visual generic memory is damaged, performance for nonliving things declines only slightly, whereas performance for living things declines to almost 0. This pattern is similar to that seen in Table 10.4. When visual generic memory is left intact and functional generic memory is damaged, there is no deficit apparent for living things and only a slight loss for nonliving things. This is also what subjects show (De Renzi & Lucchelli, 1994).

The results of the simulation are consistent with the organizational scheme proposed by Warrington and Shallice (1984). They do not, of course, prove that the scheme is correct, or that it is the only way of organizing information. Rather, they serve as an existence proof. Can a generic memory system that distinguishes between visual or perceptual information and functional information give rise to the sorts of deficits seen in subjects with bilateral temporal lobe damage? The answer is yes, but with qualifications.

The sensory/functional view can capture the broad pattern, but it fails to produce some deficits that are very fine grained. For example, Hillis and Caramazza (1991) described two patients, PS and JJ, who had contrasting deficits: PS showed a pervasive deficit in processing animal terms, whereas JJ showed a pervasive deficit in processing all categories tested except for animals. In both cases, processing for animals, rather than all living things, was the exception. As another example, Hart, Berndt, and Caramazza (1985) described a patient, MD, whose deficit was limited to naming fruits and vegetables. This distinction cannot be captured by the sensory/functional view.

Although deficits in processing certain types of information from generic memory may suggest how it is organized, there is still no definitive view, and it is likely that this controversy will persist. Nonetheless, it is suggestive that many of the deficits described in a recent review by Caramazza, Hillis, Leek, and Miozzo (1994) correspond to basic level categories (discussed at the beginning of this section).

Capacity and Acquisition

We began this chapter with two opposing viewpoints expressed by two fictional geniuses. It turns out that Nero Wolfe is better informed than Sherlock Holmes. Two series of experiments by Voss and his colleagues (Chiesi, Spilich, & Voss, 1979; Spilich, Vesonder, Chiesi, & Voss, 1979) illustrate the point. Using the criterion of baseball knowledge, subjects were divided into two groups: those with a lot of knowledge about baseball and those with very little. All subjects heard a fictional account of half an inning of a baseball game. Subjects with more knowledge of baseball remembered more of the specific details, provided a more organized response, and included more details relevant to the outcome of the game than did those subjects with less knowledge. Finally, high-knowledge subjects were able to predict the outcome better than low-knowledge subjects were. Existing knowledge, then, allows people to interpret new information, provides structures that add meaning to events, and enables people to make predictions. The more you know about something, the easier it is to acquire new related information; in that sense, the more you know, the more you can know.

There are at least two different ideas about how generic memory develops. One simple notion might be that as new information is received, it is categorized, labeled, and assigned to the relevant location within generic memory (placed at the appropriate level of the hierarchy in Collins and Quillian's structural model, or entered with appropriate connections in spreading activation models). This structure and set of connections can be quite different from that which supports episodic memory. This view predicts that there should be differences between episodic and generic memory, and such dissociations have been found. However, as discussed in Chapter 7, this view is as yet unable to predict the precise nature of the dissociations and has a difficult time accounting for dissociations within one system.

A quite different explanation is offered by *MINERVA2* (Hintzman, 1986; see the optional chapter at the end of this book). In this model, only episodic traces are stored, with each new episode producing a new trace. Generic memory results from parallel activation of all episodic traces, with the generic information being abstracted from the summed responses of those traces that are most strongly activated by the cue. If a compound cue mechanism is added (see Ratcliff & McKoon, 1988), then MINERVA2 can account easily and parsimoniously for both episodic (recall and recognition) and generic (priming, schemas, and abstractions) memory within a single system. All dissociations, according to this view, arise from different processing requirements, because the same memory system is supporting both types of memory performance.

As this chapter has shown, people's knowledge is complex and richly organized, and its retrieval is wonderfully fast. It is the ability to draw on this resource that distinguishes human cognitive capabilities from those of other animals or machines. We will examine the functions of knowledge in other memory situations in more detail in Chapter 12, especially where they lead to systematic biases in what people perceive, encode, and recall.

Chapter Summary

Most explanations of generic memory rely on concept, a mental representation of something, and proposition, a relationship between two concepts that has a truth value. Collins and Quillian's hierarchical model used the principle of cognitive economy, storing each concept as few times as possible. The model assumed it took time to traverse the network and to retrieve property information. Its major problems were in explaining how people decide a sentence is false and in overly strict assumptions that did not allow for multiple representations and nonhierarchical structures. The feature overlap model distinguished between defining features, those that are essential, and characteristic features, those that are typical. Propositions are compared by evaluating the similarity of the features. Although it accounted well for data that the hierarchical model could not explain, the feature overlap model ran into problems with the very idea of defining features.

Spreading activation models assume that when a concept is accessed, its activation level increases and also spreads to related concepts. These models explain association priming by suggesting that activation from processing the prime spreads to the related target so that by the time the target is read, its relevant concepts is already partially active. An alternative account, compound cue theory, attributes the result to the same processes that explain recognition memory.

It is not yet clear exactly how generic memory is organized or whether there is a limit on the amount of knowledge that a person can store and retrieve. The data that we do have suggest that the more you know about something, the easier it is to acquire new related information.