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9 A SCHEMA-THEORETIC VIEW OF BASIC PROCESSES IN READING COMPREHENSION

Richard C. Anderson
and P. David Pearson

> . . . to completely analyze what we do when we read would almost be the acme of a psychologist's dream for it would be to describe very many of the most intricate workings of the human mind, as well as to unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history.
>
> (*Huey, 1908/1968, p. 8*)

Huey's eloquent statement about the goals of the psychology of reading is as relevant today as it was when he wrote it in 1908. The quotation usually precedes an apology for how little we have learned in the past 75 years. We wish to break with that tradition and use Huey's statement to introduce an essay in which we will try to demonstrate that while we have not fully achieved Huey's goal, we have made substantial progress.

Our task is to characterize basic processes of reading comprehension. We will not present a model of the entire reading process, beginning with the focusing of the eye on the printed page and ending with the encoding of information into long-term semantic memory or its subsequent retrieval for purposes of demonstrating comprehension to someone in the outer world. Instead, we will focus on one aspect of comprehension of particular importance to reading comprehension: the issue of how the reader's *schemata,* or knowledge already stored in memory, function in the process of interpreting new information and allowing it to enter and become a part of the knowledge store. Whether we are aware of it or not, it is this interaction of new information with old knowledge that we mean when we use the term comprehension. To say that one has comprehended a text is to say that she has found a mental "home" for the information in the text, or else that she has modified an existing mental home in order to accommodate that new information. It is precisely this interaction between old and new information that we address in this chapter.

Our plan for the chapter is straightforward. First, we will trace the historical antecedents of schema theory. Then we will outline the basic elements of the theory and point out problems with current realizations of the theory and possible solutions. Next, we will consider the interplay between the abstracted knowledge embodied in schemata and memory for particular examples. Then we will decompose the comprehension process in order to examine components of encoding (attention, instantiation, and inference) and retrieval (retrieval plans, editing and summarizing, and reconstructive processes). Finally, we will evaluate the contributions of schema theory to our understanding of the comprehension process and speculate about the directions future research should take.

HISTORY OF THE NOTION OF A SCHEMA

While Sir Frederic Bartlett (1932) is usually acknowledged as the first psychologist to use the term schema in the sense that it is used today, historical precedence must surely be given to the Gestalt psychologists. The starting point for Gestalt psychology was a paper by Max Wertheimer in 1912 reporting research in which Wolfgang Kohler and Kurt Koffka served as assistants. These three became the principal figures in the Gestalt movement.

The term Gestalt literally means shape or form. Gestalt psychology emphasized holistic properties. It was the study of mental organization. The Gestalt movement was a reaction against the Zeitgeist at the turn of the century, which held that perception, thought, and emotion could be resolved into elemental sensations. According to Wilhelm Wundt, the dominant figure in psychology during that period, the business of psychology "was (1) the *analysis* of conscious processes into *elements*, (2) the determination of the manner of *connection* of these elements, and (3) the determination of their laws of connection" (cited in Boring, 1950, p. 333). The popular metaphor was that psychology was "mental chemistry."

The insight of the Gestalt psychologists was that the properties of a whole experience cannot be inferred from its parts. Carrying the mental chemistry metaphor a step further, they liked to point out that the molecules of chemical compounds have emergent properties that cannot be predicted in a simple fashion from the properties of the constituent elements (cf. Kohler, 1947, p. 115).

The basic principle of Gestalt psychology, called the Law of Pragnanz, is that mental organization will always be as good as prevailing conditions allow (cf. Koffka, 1935, p. 110). In this definition, "good" embraces such properties as simplicity, regularity, and symmetry. The theory stresses that mental organization is "dynamic," which means that the tendency toward coherent organization is a spontaneous process that can happen without an external goad.

Gestalt ideas were applied especially to visual perception. A notable example, which had a considerable influence on subsequent thinking, was Wulf's (1922/1938) research on memory for geometric designs. Subjects were asked to make drawings that reproduced the designs shortly after exposure, after 24 hours, and after a week. As the interval lengthened, Wulf observed characteristic changes in the reproductions that he termed "leveling" and "sharpening." Leveling means smoothing an irregularity. Sharpening means emphasizing or exagger-

ating a salient feature. The overall effect generally was to "normalize" reproductions. Wulf (1922/1938, p. 140) illustrated the process with the design shown in Figure 9.1.

FIGURE 9.1 (*From Wulf, 1922/1938, p. 140.*)

Four subjects spoke of this as a "bridge," while another called it an "arch." In their reproductions of this figure, these subjects all lengthened the "supports." Wulf (1922/1938, p. 141) explained his results in these terms:

> In addition to, or even instead of, purely visual data there were also general types or schemata in terms of which the subject constructed his responses. . . . The schema itself becomes with time ever more dominant; visual imagery of the original disappears, . . . details contained in the original are forgotten and incorrectly reproduced, yet even the last reproduction will usually show a steady progress towards representation of the type or schema originally conceived.

According to Bartlett in his classic book *Remembering* (1932, p. 201) the term "schema" refers to "an active organization of past reactions, or past experience." The term active was intended to emphasize what he saw as the constructive character of remembering, which he contrasted with a passive retrieval of "fixed and lifeless" memories. "The first notion to get rid of," Bartlett wrote (1932, p. 204), "is that memory is primarily or literally reduplicative, or reproductive. . . . It is with remembering as it is with the stroke in a skilled game [of tennis or cricket]. . . . Every time we make it, it has its own characteristics."

Though he used phrases such as "mental set," "active organization," and "general impression" a great deal, Bartlett was never very clear about what he meant by them, other than to indicate a top-down influence:

> an individual does not ordinarily take . . . a situation detail by detail and meticulously build up the whole. In all ordinary instances he has an overmastering tendency simply to get a general impression of the whole; and, on the basis of this, he constructs the probable detail. Very little of his construction is literally observed. . . . But it is the sort of construction which serves to justify his general impression. (1932, p. 206)

Bartlett was vague about just how schemata work. For example, he said several times that a central idea in his theory was "turning around on one's schemata." He apparently meant deducing the way the past must have been from one's current schema. But he never explicated the idea. Indeed, he admitted, "I wish I knew exactly how it was done" (1932, p. 206).

Bartlett's ideas resembled those of Gestalt psychology, and he even described research of his own on memory for pictorial material that was similar to Wulf's. Nevertheless, there is no indication that he was directly influenced

by the Gestalt tradition. The only Gestalt psychologist that Bartlett cited was Kohler, and he in just a passing note that "recent general psychological theories are still in a fluid state" (1932, p. 186). At least one of the major Gestalt psychologists was aware of Bartlett's work. In *Principles of Gestalt Psychology,* Koffka (1935, p. 519) complained that he found Bartlett difficult to understand but acknowledged that there was "a great affinity between Bartlett's theory of memory and our own."

With respect to empirical research, Bartlett is best remembered for his study of the recall of the North American Indian folktale, *The War of the Ghosts.* He reported that, especially after a long interval, subjects' reproductions became simplified and stereotyped. Details that "fit in with a subject's preformed interests and tendencies" (1932, p. 93) were recalled. Other details were either omitted or "rationalized by linking them together and so rendering them apparently coherent, or linking given detail with detail not actually present . . ." (p. 94). As time passed, elaborations, importations, and inventions appeared in subjects' reproductions with increasing frequency. Usually these intrusions could be seen as contributing to the subject's rationalization of the text.

We turn now to a major figure in the recent history of education and psychology, David P. Ausubel. He has had a direct influence on the thinking of the current generation of educational research workers, including the present authors. His thinking, in turn, bears resemblances to that of Bartlett, the Gestalt psychologists and, perhaps even more, to nineteenth-century figures, such as Herbart, as Barnes and Clawson (1975) have pointed out. However, Ausubel himself has emphatically denied such intellectual debts (1978). It seems only fair to conclude that he reinvented the ideas associated with his name and gave them a distinctive flourish.

According to Ausubel (Ausubel, 1963; Ausubel & Robinson, 1969), in meaningful learning, already-known general ideas "subsume" or "anchor" the new particular propositions found in texts. This happens only when the existing ideas are stable, clear, discriminable from other ideas, and directly relevant to the to-be-understood propositions. The reader has to be aware of which aspects of his knowledge are relevant. Sometimes this will be obvious. Sometimes the text will be explicit. When neither of these conditions holds or the reader's grasp of the required knowledge is shaky, an "advance organizer" may be prescribed. An advance organizer is a statement written in abstract, inclusive terms deliberately introduced before a text and intended to provide a conceptual bridge between what the reader already knows and the propositions in the text that it is hoped he will understand and learn.

Ausubel has not called his theory a schema theory, but it clearly is. Ausubel's own research and the research of those inspired by him has dealt mainly with advance organizers, which have proved to have facilitative effects (Luiten, Ames, & Ackerson, 1980; Mayer, 1979).

Among educators, something like schema theory has driven conceptions about reading. Take, for instance, Huey's (1908/1968) conclusion about whether we read letter by letter or in larger chunks:

> So it is clear that the larger the amount read during a reading pause, the more inevitably must the reading be by suggestion and inference from

> clews of whatsoever kind, internal or external. In reading, the deficient picture is filled in, retouched, by the mind, and the page is thus made to present the familiar appearance of completeness in its details which we suppose to exist in the actual page. (p. 68)

Implicit, if not explicit, in the philosophy of Francis Parker when he ran the laboratory school at the University of Chicago at the turn of the last century was the importance of building knowledge structures through experience as a prerequisite to reading (see Mathews, 1966). Ernest Horn (1937), famous for his work in spelling, recognized the active contribution of the reader: "[The author] does not really convey ideas to the reader; he merely stimulates him to construct them out of his own experience. If the concept is . . . new to the reader, its construction more nearly approaches problem solving than simple association" (Horn, 1937, p. 154). And, of course, William S. Gray recognized, both in his professional writing (1948) and in his suggestions for teachers in basal reader manuals, the necessity of engaging children's prior knowledge before reading.

But the full development of schema theory as a model for representing how knowledge is stored in human memory had to await the revolution in our conception of how humans process information spurred by the thinking of computer scientists doing simulations of human cognition (e.g., Minsky, 1975; Winograd, 1975). Hence, it was in the late 1970s that ambitious statements of schema theories began to emerge (Rumelhart, 1980; Schank & Abelson, 1977) and to be applied to entities like stories (e.g., Mandler & Johnson, 1977; Rumelhart, 1975; Stein & Glenn, 1979) and processes like reading (see Adams & Collins, 1979; R. C. Anderson, 1977, 1978). Concurrently, schema-theoretic notions became the driving force behind empirical investigations of basic processes in reading. Much of this research is described later in this chapter. First, however, we attempt to elucidate schema theory as a model of human knowledge.

SOME ELEMENTS OF SCHEMA THEORY

A schema is an abstract knowledge structure. A schema is abstract in the sense that it summarizes what is known about a variety of cases that differ in many particulars. An important theoretical puzzle is to determine just how much and what sort of knowledge is abstracted and how much remains tied to knowledge of specific instances. A schema is structured in the sense that it represents the relationships among its component parts. The theoretical issue is to specify the set of relationships needed for a general analysis of knowledge. The overriding challenge for the theorist is to specify the form and substance of schemata and the processes by which the knowledge embodied in schemata is used.

We will hang our discussion of these issues on a concrete case, the SHIP CHRISTENING schema. A possible representation of this schema is diagrammed in Figure 9.2. If for the sake of the argument, one takes this as a serious attempt to represent the average person's knowledge of ship christening, what does it say and what follows from it?

Figure 9.2 says that the typical person's knowledge of ship christening can

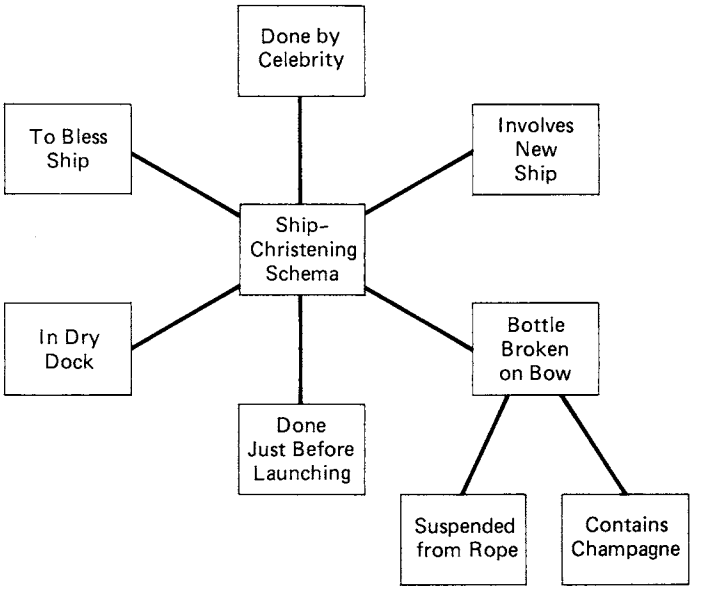

FIGURE 9.2

be analyzed into six parts: that it is done to bless a ship, that it normally takes place in a dry dock, and so on. In the jargon of schema theory, these parts are called "nodes," "variables," or "slots." When the schema gets activated and is used to interpret some event, the slots are "instantiated" with particular information.

There are constraints on the information with which a slot can be instantiated. Presumably, for instance, the ⟨celebrity⟩ slot could be instantiated with a congressman, the husband or wife of a governor, the secretary of defense, or the Prince of Wales, but not a garbage collector or barmaid.

Suppose you read in the newspaper that,

> Queen Elizabeth participated in a long-delayed ceremony in Clydebank, Scotland, yesterday. While there is still bitterness here following the protracted strike, on this occasion a crowd of shipyard workers numbering in the hundreds joined dignitaries in cheering as the HMS *Pinafore* slipped into the water.

It is the generally good fit of most of this information with the SHIP CHRISTENING schema that provides the confidence that (part of the) message has been comprehended. In particular, Queen Elizabeth fits the ⟨celebrity⟩ slot, the fact that Clydebank is a well-known shipbuilding port and that shipyard workers are involved is consistent with the ⟨dry dock⟩ slot, the HMS *Pinafore* is obviously a ship and the information that it "slipped into the water" is consistent with the ⟨just before launching⟩ slot. Therefore, the ceremony mentioned is probably a ship christening. No mention is made of a bottle of champagne being broken on the ship's bow, but this "default" inference is easily made.

The foregoing informal treatment of the process of schema "activation" can be made more precise. Assume that words mentioning any component of a schema have a certain probability of bringing to mind the schema as a whole. Assume also that, once the schema is activated, there is a certain probability of being reminded of each of the other parts. It is not necessary to assume that the likelihood that a part will remind a person of the whole schema is the same as the likelihood that the schema will remind the person of that part. It seems likely, for example, that a person's SHIP CHRISTENING schema is more likely to activate the component concept of a celebrity than the mention of a celebrity is to activate the schema. The reason is that ⟨celebrity⟩ is a component of many schemata and SHIP CHRISTENING is not very prominent among them; therefore, the probability that words about a celebrity will activate SHIP CHRISTENING is low.

Some components of a schema are particularly salient; that is to say, words mentioning the component have a high probability of bringing to mind the schema and only that schema and, therefore, these words have great diagnostic value for the reader. One would suppose, for example, that words to the effect that a bottle was broken on the bow of a ship would be extremely likely to remind a person of ship christening.

A final assumption in this simple model of schema activation is that, when two or more components of a schema are mentioned, the aggregate probability of the whole schema being activated is a function of the sum of the probabilities that the individual components will activate the schema.

Ross and Bower (1981) worked out a formal, mathematical version of the schema-activation theory that has just been outlined and subjected it to experimental test. In one of their experiments, subjects studied 80 sets of four words, each related to a more or less obvious schema. For instance, one set was "driver," "trap," "rough," and "handicap," which relate to a GOLF schema. Another set was "princess," "mouth," "hold," and "dial," which relate to a TELEPHONE schema. After studying the word sets, subjects attempted to recall the words, given one or two words from each set as a cue. The schema model gave a good account of the recall patterns observed in this and two other experiments. In fact, it did better than a model based on S-R learning theory and traditional associationism.

To get a feeling for how a model of schema activation of this type might work with text, consider the following two sentences:

Princess Anne broke the bottle on the ship.

The waitress broke the bottle on the ship.

In the first case, the ⟨celebrity⟩ slot as well as the ⟨ship⟩ and ⟨bottle-breaking⟩ slots are matched and a ship christening interpretation is invited. If there is any hiatus over the end of the first sentence, it can be treated as elliptical for "broke the bottle on the bow of the ship." For most people, the second sentence does not suggest a ship christening but instead, perhaps, a scene in the ship's dining room. This intuition is consistent with the schema-activation model because a waitress will not fit in the ⟨celebrity⟩ slot and thus there is less evidence for a ship christening interpretation.

The simple model we are considering is likely to fail with the following sentence, though:

> During the ceremony on the ship, Prince Charles took a swig from the bottle of champagne.

Here many slots in the schema are matched and the model cannot resist predicting activation of the SHIP CHRISTENING schema. How could the model be made smarter so that, like a person, it would not come to this conclusion?

First, consider a nonsolution. As a general rule people are unlikely to include in their schemata knowledge of the form, "in a ship christening the ceremony does *not* take place on board the ship" and "the celebrity does *not* drink from the bottle of champagne." The problem is that there are infinitely many things that are not true of any given type of event. Thus, it seems reasonable to suppose that what is *not* true of a type of event is "directly stored" only in special circumstances. For instance, one might store that a warbler does not have a thick beak if this is the critical feature that distinguishes it from the otherwise very similar song sparrow.

In general, though, determining what is *not* true requires an inference from what is true or is believed to be true. In the case of the Prince Charles sentence, the inference chain might look like the following:

1. A ship christening takes place on a platform on the dock next to the bow of the ship (from stored knowledge).
2. The celebrity playing the key role in the ceremony stands on this platform (from stored knowledge).
3. If Prince Charles were the celebrity taking the principal part in a ship christening ceremony, then he would have been standing on this platform (inference).
4. A platform on the dock next to the bow of a ship is not on the ship (inference).
5. During the ceremony, Prince Charles was on the ship (given in to-be-interpreted sentence).
6. During the ceremony, Prince Charles was not on a platform used for ship christening (inference).
7. The ceremony in which Prince Charles was participating was not a ship christening (inference).

Converging evidence that the sentence is not about a ship christening might come from analysis of the fact that Prince Charles took a swig of the champagne. In this case, the reader might make a lack-of-knowledge inference (Collins, 1978), which would work something like the following:

1. I (the reader) do not have stored the information that the celebrity takes a swig from the bottle of champagne during a ship christening (computation based on stored knowledge).
2. I have many facts stored about ship christenings that are at the same level of detail as the information that the celebrity takes a swig from the bottle (computation based on stored knowledge).
3. If the celebrity's taking a drink from the bottle were a part of a ship christening, I would probably know that fact (inference).
4. A ceremony during which the celebrity takes a drink from a bottle of champagne is probably not a ship christening (inference).

5. Prince Charles took a swig from a bottle of champagne (from the to-be-interpreted sentence).
6. The ceremony in which Prince Charles is participating is probably not a ship christening (inference).

Plainly, the representation of the SHIP CHRISTENING schema diagramed in Figure 9.2 is not adequate to support the chains of inference required to deal with the Prince Charles sentence. One problem is that some pieces of knowledge, such as that the christening takes place on a platform under the bow of the ship, are missing. But this is the least of the problems with the representation.

The fundamental problem with the representation is that it does not make explicit the temporal, causal, spatial, part-whole, and member-set relations among the components of a ship christening. For instance, the representationdoes not include the information that it is the celebrity who breaks the bottle on the bow of the ship and that the reason for the breaking of the bottle is to bless the ship. Figure 9.3 shows some of the relationships among these components. Such relational knowledge is necessary for inferencing and, as we have just seen, inferencing can be necessary to get the right schema activated.

Because the representation of the SHIP CHRISTENING schema portrayed in Figure 9.2 is impoverished, the relationships among the parts and between the parts and the whole are arbitrary and unmotivated. It can be predicted with some confidence on the basis of accumulated experimental evidence that a person who possessed the knowledge, and only the knowledge, represented in Figure 9.2 would not only have trouble making perspicuous inferences, but also (a) would have trouble learning similarly arbitrary additional facts about ship christening, (b) would be vulnerable to confusions when attempting to recall and use facts about ship christening, and (c) would be relatively slow to retrieve even well-known facts. Each of the preceding problems would grow more severe as the number of arbitrarily related facts that were known increased.

Every schema theorist has emphasized the nonarbitrary nature of knowledge. Notably, John Bransford (e.g., 1983) has stressed that "seeing the significance" of the parts in terms of the whole is the sine qua non of a schema-theoretic view of comprehension. In one of a number of experiments that Bransford and his colleagues have done which provide evidence for this claim, Stein and Brans-

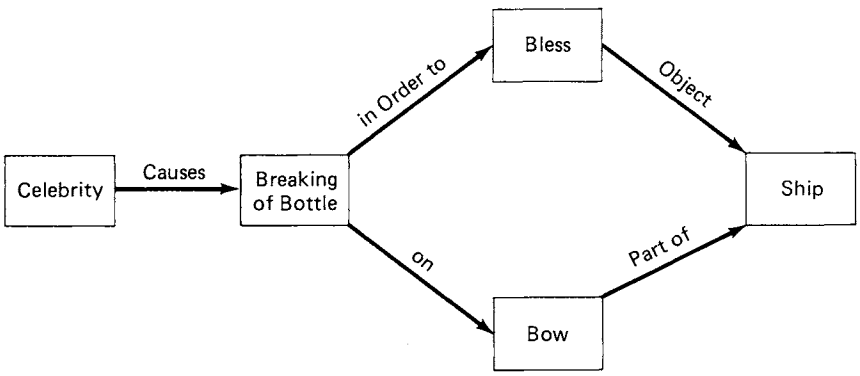

FIGURE 9.3

ford (1979) found that subjects were slightly worse at recalling core sentences, such as,

The fat man read the sign.

when the sentences were arbitrarily elaborated, as in,

The fat man read the sign that was 2-feet high.

In contrast, recall of the core sentences improved substantially when the core sentences were "precisely elaborated," as in,

The fat man read the sign warning of the thin ice.

A precise elaboration clarified the significance of the concepts in the core sentence and indicated how the concepts fit together.

Smith, Adams, and Schorr (1978; see also Clifton & Slowiaczek, 1981, and Reder & Anderson, 1980) have presented some strong evidence showing the benefits of integrating otherwise arbitrary information under the aegis of a schema. Subjects learnedpairs of apparently unrelated propositions attributed to a member of some profession. For instance,

The banker broke the bottle.

The banker did not delay the trip.

Then, a third proposition was learned that either allowed the subject to integrate the three sentences in terms of a common schema or which was unintegratable with the other two sentences, as is illustrated below:

The banker was chosen to christen the ship.

The banker was asked to address the crowd.

Subjects required fewer study opportunities to learn the third sentence when it was readily integratable than when it was unintegratable. Most interesting was the fact that after all of the sentences had been learned to a high criterion of mastery, it took subjects longer to verify that sentences from the unintegratable sets were ones they had seen.

The explanation for this subtle finding is that, in an unintegrated set, all of the propositions fan out from a single common node representing, for instance, "the banker." This means that each new proposition added to the set increases the burden of memory search and verification and, therefore, causes an increase in memory search time called the "fanning effect" (J. R. Anderson, 1976). In contrast, the interconnections among the concepts in integrated sets facilitate retrieval and verification; thus, adding a proposition to an integrated set causes little or no increase in search time.

Most discussions of schema theory have emphasized the use of schemata to assimilate information. Here, instead, we will deal with how a schema may be modified to accommodate new information. Obviously, a person may modify a schema by being told new information. For instance, a person might add to

his or her SHIP CHRISTENING schema upon being informed that the platform on which the ceremony takes place is typically draped with bunting displaying the national colors.

Presumably, a logical person will check to make sure new information is consistent with the information already stored and, if it is not, will either reject the new information or modify the old. Presumably, a careful person will evaluate whether the source of new information is creditable or the evidence is persuasive before changing a schema. Lipson (1983) has evidence that suggests that even young readers will reject text information if it is inconsistent with an already possessed interpretation that they believe to be correct.

A primary source of data for schema change and development is experience with particular cases. In a process that is still not well-understood, even though thinkers have wrestled with how it happens since the time of the ancient Greeks, people make inductive generalizations based on perceptible or functional features or patterns of particular cases. Traditional psychological theories envisioned a slow, grinding process of generalization, so slow and uncertain that the wonder was that anyone acquired the knowledge of a five-year-old. Current theories envision powerful inferential heuristics and generalization from a few cases or even a single case. Now the wonder is how people avoid filling their heads with all sorts of inaccurate and farfetched beliefs. How, for instance, is the nonexpert in ship christening, upon reading the newspaper describing the putative christening of the HMS *Pinafore,* to be restrained from inferring that the purpose of a ship christening is to celebrate the end of a labor dispute?

We turn now to the question of the relationship between the knowledge embodied in schemata and the knowledge of particular scenes, happenings, or messages. An attractive theory is that a schema includes just the propositions that are true of every member of a class. For instance, a BIRD schema may be supposed to include the information that birds lay eggs, have feathers, have wings, and fly, that the wings enable flying, and so on.

Collins and Quillian (1969) proposed the interesting additional assumption that, for reasons of "cognitive economy," propositions about the general case are not included in the representation for particular cases. So, the representation for a robin is supposed to include propositions about distinctive features of robins: that they have red breasts, but not that they fly or lay eggs. These facts can be deduced from the fact that a robin is a bird and that a robin has any property ascribed to all birds. Similarly, the bird representation does not directly include the information that birds breathe since birds are animals and breathing is a property of all animals.

Collins and Quillian theorized that knowledge is organized in semantic networks that permit graphical representations of the type illustrated in Figure 9.4. Notice that there is an increasingly long path in the network from the canary node to the information (or predicate) in each of the following sentences:

Canaries are yellow.

Canaries lay eggs.

Canaries can breathe.

It is a straightforward prediction that the greater the distance in the network that must be traversed to find the stored information, the longer it will take to

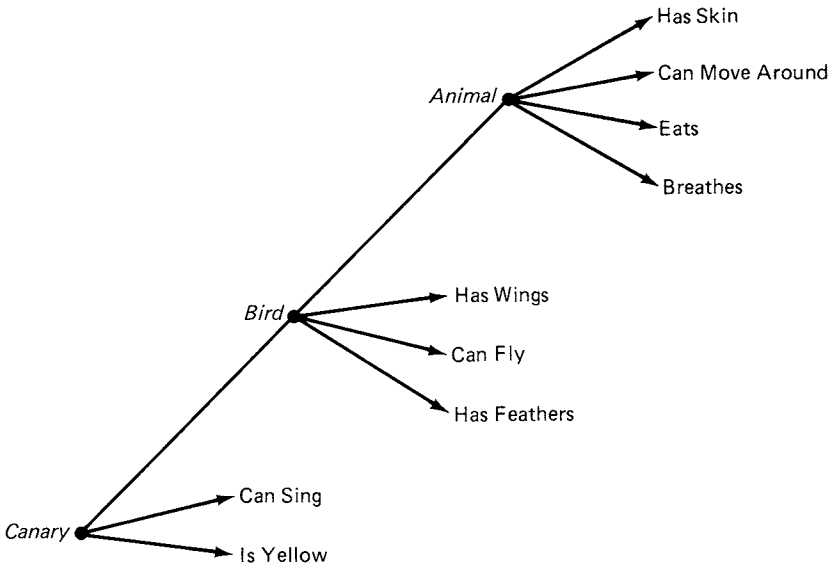

FIGURE 9.4 (*From Collins & Quillian, 1969, p. 241.*)

verify the proposition. This prediction has been confirmed many times in many laboratories.

The appeal of the cognitive-economy hypothesis is that, while long-term human memory capacity is no doubt very large, it is not infinite. People could save a lot of memory space if they stored information at the most inclusive possible levels in their knowledge representations. Furthermore, most people have probably never seen a canary lay an egg or a giant condor fly, so there is little reason to suppose that this information would be directly stored in their canary or condor representations.

But what about the information that a robin can fly? Surely the typical person has seen countless flying robins. It would be an odd theory of human information processing that could explain why this fact was not stored directly in a person's robin representation. To do so would require postulating a mental librarian who, when the senses return information about flying robins, steadfastly files it on a higher shelf.

Current theories of concepts posit that the information represented in specific concepts, such as robin, overlaps with the information in general concepts, such as bird (Smith & Medin, 1981). In fact, robin is a "good" example of a bird since the overlap is large, while penguin is a "poor" example because the overlap is small.

What is the best way in a theory of knowledge representations to cope with exceptional cases? In the first place, people probably place an implicit hedge on all the facts they think they know, of the form, "This proposition is true in only normal states of the world." At the very least, such a hedge helps fend off philosophers who ask questions like, "If a dog *is* a four-legged animal, what is a creature that has three legs but is otherwise a dog?"

The real theoretical problem, however, is not with abnormal cases such as dogs with three legs and hens that do not lay eggs, but with more mundane exceptions: most birds fly, however some, such as penguins, do not; canaries

are often domesticated, however many more are wild; cups tend to be used to hold liquids, but they can be used to hold solids.

The classical issue in concept analysis was to specify the features that were individually necessary and jointly sufficient before a thing could rightly be called an instance of a concept. For example, following Katz (1972), some of the necessary features of bachelor are said to be ⟨male⟩, ⟨adult⟩, ⟨human⟩, and ⟨unmarried⟩. If a feature is *necessary,* then *all* instances of the concept display that feature. However, a feature that all instances possess may not be a necessary one. It may be safe to assume that every bachelor has a nose, but ⟨having a nose⟩ is not a necessary feature. If an unmarried, adult, human male without a nose did turn up, no one would be reluctant to call him a bachelor. In contrast, calling a married man a bachelor would be regarded as a non sequitur (or a joke or a metaphor). Thus, ⟨having a nose⟩ is a characteristic feature, while ⟨unmarried⟩ is a necessary feature, even though, by hypothesis, every bachelor displays both features.

The very idea that concepts or schemata (there is no principled distinction between the two) have necessary features has come under lethal attack in recent years. Wittgenstein (1953) noticed that it can be difficult, if not impossible, to specify the necessary features of most ordinary concepts. His famous analysis of games suggested that there are no features common to all games and that the relationship among games is most aptly characterized as one of "family resemblance." Putnam (1975; see also, Kripke, 1972) has shown that features of ordinary concepts that at first glance might seem to be necessary are really only characteristic. For instance, ⟨precious⟩ cannot be a necessary feature of gold because gold would no longer be precious if large quantities of it were discovered somewhere.

If there are few ordinary concepts with clearly necessary features and, indeed, not many with characteristic features true of all cases, the basis for positing that knowledge consists of abstract summaries of particular cases begins to erode. And this leads one to consider granting a greater role to memories for particular cases. It could be that much that passes for general knowledge is actually derived as needed by retrieving specific cases and making calculations based on what is known about them.

Let's do a thought experiment. What kind of nests do birds build? Try to pause before reading on and notice how your mind works as you answer this question.

Probably you answered the question by thinking of particular types of birds and then trying to remember occasions when you saw the nests of these birds, either in nature or in books. Probably, you began your search with a familiar, typical bird, such as a robin. If you know quite a bit about birds, your search probably turned up diverse kinds of nests, such as those of ducks, Baltimore orioles, barn swallows, and bald eagles.

Your intuitions were no doubt consistent with the hypothesized process of searching memories of specific cases. Experimental evidence, which does not rely on intuition, is also consistent with the hypothesized process. Walker (1975) asked subjects to accept or reject as quickly as possible propositions about a wide variety of things with quantifiable dimensions, such as the following:

A large dog could weigh 12 pounds.

Subjects quickly rejected this proposition and also quickly rejected sentences that ascribed an extremely heavy weight, such as 400 pounds, to a large dog. Furthermore, subjects quickly accepted statements ascribing a weight rated as typical of a large dog, such as 100 pounds. However, subjects were slow to accept or reject weights rated at the boundaries of a large dog, say 40 to 60 pounds.

It is very difficult to accommodate Walker's findings to a theory that says that people have directly stored as part of their general concept of a large dog that large dogs weigh from, say, 51 to 140 pounds. Such a theory would have to predict that people would be equally fast at accepting any weight between 51 and 140 pounds and equally fast at rejecting any weight outside this range. Moreover, the theory that people directly store as part of their knowledge of a class of objects generalizations about the range on each dimension along which the objects can be classified is highly implausible. Objects vary in innumerable dimensions. If a person has stored the range of weights of large dogs, why not the widths of their ears and the lengths of their tails? The more plausible and parsimonious theory, then, is that people make use of knowledge of specific cases in calculations such as the foregoing.

It is well established that words can have different meanings in different contexts, even when the words are being used in the same sense (Anderson, Pichert, Goetz, Schallert, Stevens, & Trollip, 1976; Anderson & Shiffrin, 1980). This fact poses a grave problem for any theory along the lines that the meaning of a compound is the product of the general meanings of the constituent words. This conventional theory does work in some cases. For instance, it seems to work in the case of the compound, *red dress.* The dress can be construed as having a typical shade of red.

Now consider the following compounds, however: *red strawberry, red barn, red sunset,* and *red hair.* The red visualized is different in each of these cases, as Halff, Ortony, and Anderson (1976) have demonstrated empirically. To explain this effect, we propose that specific memories of, for instance, red hair are retrieved and the range of hues calculated. We further suggest that the hue of the compound is predicted on the basis of the generic concept of red and the generic concept of the object only when the person has not experienced this combination before or when an indeterminate range of hues is possible.

Stating the foregoing theory in general form, word meanings are context sensitive because people treat words and phrases as instructions to locate specific examples in memory. The sense and reference of the terms are then refined on the basis of these examples. When specific examples representing the intersection of the sets of examples signified by the terms cannot be located, then the default inference of a typical meaning is made, based on the general schemata that the terms represent.

How are the phrases, "a particular case" and "a specific example," to be interpreted? A robin is a specific example of a bird, but notice that ROBIN is itself an abstracted and generic schema. Still more specific is the-robin-I-saw-nesting-in-the-hawthorne-tree-outside-my-front-door-this-morning. Following Smith and Medin (1981), we assume that people have knowledge represented at various levels of specificity. Nothing about our thinking requires people always to get back to memories of cases experienced at particular moments in time and space.

In summary, the three main points of this section were that an adequate account of the structure of schemata will include information about the relationships among components, that a complete theory of schema activation will include a major role for inference, and that, during language comprehension, people probably rely on knowledge of particular cases as well as abstract and general schemata.

SCHEMATA AND INFERENCE

One of the key processes in a schema-theoretic account of cognitive processing is inferencing. In choosing to highlight inferences in a special section, we run the risk of suggesting that inferencing occupies some special stage in the comprehension process. We assert no such claim; in fact, we will demonstrate that inferences can occur either at the time of initial encoding of text information into memory *or* at the time that information is retrieved from memory. The reason for devoting a special section to inferences is to acknowledge their centrality to the overall process of comprehension. At least four kinds of inference can be identified in reading comprehension.

Inferences may be involved in the process of *deciding what schema among many should be called into play* in order to comprehend a text. It is rarely the case when reading that one is told directly what schema to use. Subtle cues are usually picked up from the text that allow schema selection. For example, to read a lead sentence from a newspaper article indicating that Princess Anne took part in a ceremony involving a new ship may provide sufficient evidence to allow a reader to infer that a SHIP CHRISTENING schema should be invoked.

Inference is also involved in the process of *instantiating slots* within a selected schema. A reader typically makes inferences when deciding that a particular character or item mentioned in a story is intended to fill a particular slot. Consider the earlier example about Queen Elizabeth in Clydebank. There was nothing explicitly stated in the text to tell the reader that Queen Elizabeth should fill the ⟨celebrity⟩ slot. The reader who decides she should fill that slot has made the inference that she, among all the characters and items in the text, is the most likely candidate to fill that slot. Furthermore a reader may fill a particular slot in a schema by *assigning default values* in the absence of any specifically substantiating information in the text. Again, using the SHIP CHRISTENING example, deciding that a bottle of champagne was used is an example of such a default inference. It should be stressed that filling slots by default is not a rare event. Rather, it is a routine aspect of the ongoing process of comprehension. Writers rely on the fact that there is a considerable amount of knowledge that they share with their audience. When it can be assumed that their audience will be able to infer accurately what shared knowledge has been omitted, writers will usually omit it (Clark & Haviland, 1977; Grice, 1975). It is this process of filling slots by default that most people think of when they are told that an inference has been made.

There is a fourth kind of inference involved in comprehension: it involves *drawing a conclusion based upon lack of knowledge.* It has the logic, "If *X*

were true, I would know it were true. Since I do not know *X* to be true, it is probably false." Recall the earlier example in which this sort of inference was involved in deciding that since Prince Charles took a swig of champagne from the bottle, he must not be participating in a ship christening.

One paradigm of studies designed to investigate schema-selection inferences involves presenting students with an ambiguous text, written to permit two or more interpretations, and later asking them to recall it. Then on the basis of theme-revealing intrusions into subjects' recall protocols, one can infer the schema that a given reader selected to provide the best account of the data in the text.

The paradigm is illustrated in a study by Anderson, Reynolds, Schallert, and Goetz (1977), who presented college students with two texts. One text permitted the interpretation of a prisoner planning his escape from a cell or that of a wrestler trying to get out of his opponent's hold. The second permitted the interpretation of four people getting together to play cards or that of a quartet about to begin their weekly music practice. Physical education majors and music majors tended to select the specialized schema (wrestling or quartet) for only that passage consistent with their experience, selecting the more common schema (prison or cards) for the other passage. The study suggests these conclusions: (a) schema selection is often based upon inference, (b) the schema one selects influences the amount and nature of recall, and (c) once a schema has been selected, even by inference, it will drive other inferences, particularly slot-filling inferences (see section on Schemata and Remembering).

Evidence for the second kind of inference, using a schema already selected to guide the instantiation of slots within the schema, comes from a slightly different research paradigm. Subjects are given a passage written in language so general and vague that it is difficult to remember by itself, such as this one (used by Dooling & Lachman, 1971, and Bransford & Johnson, 1972):

> The procedure is actually quite simple. First, you arrange the items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one never can tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

Some subjects are given the title, "Washing Clothes," before they read the passage, some after, others not at all. Passage recall is enhanced only for the condition in which subjects are given the title before reading. Without a

title, which allows subjects to invoke a schema, a reader cannot decide what to do with the information in the text. Once a reader is able to activate the WASHING CLOTHES schema, however, even the vague terms in the text can be matched with the appropriate slots (e.g., "somewhere else" = laundromat). Hence, memory for the text is improved. Variations on this paradigm have used disambiguating pictures (Bransford & Johnson, 1972) or names of historical characters (Dooling & Lachman, 1971). The broader point to be made is that even normal texts, with no intentional ambiguity, are rarely completely clear about what text items ought to instantiate which slots within the schema that has been selected; usually, the reader herself has to decide, for example, which character is the heroine or why someone performed a particular act.

The third type of inference—using a selected schema to fill important slots by assigning a default value—is, as we have said, the normal sense of what we mean when we say someone has drawn an inference. And it is this type of inference that has been studied most often, particularly developmentally. The developmental research is ambivalent concerning precisely what accounts for the observed growth across age in the sheer number of inferences readers are able to draw. The work of Paris and his colleagues (e.g. Paris & Lindauer, 1976; Paris & Upton, 1976) suggests that younger children are simply not predisposed to draw inferences spontaneously. They found that five-year-olds were less able to infer the implied instrument in sentences like, "The man dug a hole," than were eight-year-olds. However, when the five-year-olds were told to act out the action in the sentence as they heard it, they were just as able as the eight-year-olds to infer the instrument in response to a later probe.

An alternative, although not mutually exclusive, argument is that age-related growth in inference ability is really a difference in the growth of knowledge available for drawing inferences. Omanson, Warren, and Trabasso (1978) concluded that it was available prior knowledge, not differences in memory capacity or control mechanisms, that accounted for differences in the quantity of inferences drawn by eight- versus five-year-olds. Pearson, Hansen, and Gordon (1979) found that differences in prior knowledge of the topic accounted for large differences in children's ability to answer inferential questions, but only for very modest differences in literal questions. Nicholson and Imlach (1981) have reported even more convincing evidence for the influence of knowledge on slot-filling inferences. They found that when children were given texts about familiar topics that they often resorted to prior knowledge to answer inference questions, even when the text provided explicit information that could have been used.

Regarding the fourth type of inference, the lack-of-knowledge inference, only anecdotal case study data are currently available to evaluate the role and frequency of this sort of inference. However, Collins (1978) does provide numerous examples of questions that it would appear that readers could answer only by invoking lack-of-knowledge inferences. One point about them: they seem to be made primarily at the point of retrieval or when an interrogator (teacher or experimenter) imposes a task upon the reader demanding such reasoning. Unlike default inferences, for example, they may not be made routinely during the ongoing comprehension process.

Two important questions about inferences that any good theory of comprehension will have to deal with are: (1) Which inferences, among the indefinitely

large number that could be made, will a reader make during comprehension? and (2) When do readers make inferences, at the time of initial encoding of information into memory or at the time of retrieval?

Regarding the first question, the best evidence comes from a study by Goetz (1979). Goetz created alternative texts in which a target piece of information was either essential or unessential to understanding a story, and was either explicitly stated in the text or only implied by the information in the text. He then measured the probability that the target information would be recognized (Experiment 1) or recalled (Experiment 2) as a function of explicitness and importance. He found that importance was a good predictor of both the probability that the implied information would be recognized and the probability that it would be recalled. Interestingly, however, when the target information was stated explicitly, importance predicted recall but not recognition. Goetz's findings are significant because they provide insight into constraints on an otherwise unwieldy process. Without some criterion for deciding which inferences are to be made, there is no principled way for a theory to explain how the inference mechanism is stopped from churning out countless elaborations of the text.

The issue of when inferences are made, during encoding or retrieval, has a checkered experimental history. The usual paradigm for determining the locus of inferences is to give subjects a passage to read and to later test their recognition latency for information that was directly stated in the text in comparison to that which was only implied. Equivalent recognition latencies imply that the inferences must have been made during encoding; longer latencies for inferences imply that they must have been computed at the point of retrieval.

Kintsch (1974) reported three studies in which he found shorter times for explicitly stated information only when the recognition test was given immediately; with delays of either 20 minutes or 48 hours, there were no differences in the recognition latencies for explicit and implicit information. Singer, on the other hand, has consistently found shorter latencies for explicit information (Singer, 1979a, 1979b). However, in a more recent experiment, Singer (1980) found that importance, as indexed by how crucial the inference was to maintaining the coherence of the text, is a moderating factor. Necessary inferences were recognized as rapidly as explicit information. Both of these types were recognized about 245 milliseconds more rapidly than plausible but unnecessary inferences.

In summary, it is somewhat ironic that in order to fulfill the basic goal of creating a model of the meaning of a text that accounts for all the explicit information or as much of it as is possible, interpretations must be made that often go well beyond the text itself. Current evidence suggests that inferences important for a coherent understanding of the text will be made at the time the text is read. Other inferences will be drawn only when circumstances demand.

SCHEMATA AND THE ALLOCATION OF ATTENTION

Perhaps the most pervasive and consistent finding of research on discourse is that important text elements are more likely to be learned and remembered than less important elements. One attractive theory to explain this fact is that readers selectively attend to important elements. The following is a simple version of this theory:

1. The schema to which the text is being assimilated, already-processed text information, and an analysis of task demands provide a gauge for judging the importance of upcoming text elements.
2. As it is encountered, each text element is processed to some minimum level and then graded for importance.
3. Extra attention is devoted to elements that surpass a criterion of importance.
4. Because of the extra attention they receive, important text elements are learned better; because they are learned better, these text elements are also remembered better.

Recently there have been several attempts to test a selective-attention model, such as the foregoing, by directly measuring indicators of amount of attention. It should be emphasized that attention is a hypothetical construct that may be imperfectly reflected in any operational measure (see Kahneman, 1973). One index that has commonsense appeal, as well as a substantial history of use in experimental research, is the amount of time a subject takes to complete a task or a segment of a task. Other measures that have been argued to reflect aspects of attention include eye fixations, pupil dilation, brain waves, and latency of response to a secondary-task probe.

We will begin the review of empirical studies with ones that gave readers a task that almost certainly influenced the aspects of the text to which they paid attention. Rothkopf and Billington (1979) completed three experiments in which high school students memorized simple learning objectives before studying a 1481 word passage on oceanography. Readers got either five or ten objectives, all stated in specific terms and relevant to a single, readily identifiable sentence in the passage. For instance, one of the learning objectives was: What is the name of the scale used by oceanographers when recording the color of water? The test sentence that satisfied the objective was: Oceanographers record the color of the ocean by comparison with a series of bottles of colored water known as the Forel scale. The data confirmed that students who read with objectives in mind spent more time on sentences relevant to these objectives and less time on ones not relevant to the objectives than did students who read without objectives. In the third experiment, patterns of eye movements were found to be consistent with the reading-time results. In each study, subjects learned and remembered substantially more information relevant to assigned objectives. These experiments produced exactly the results that would be expected on the basis of the selective-attention hypothesis.

Questions inserted in a text have been hypothesized to cause readers to pay more attention to information of the type that the questions are about. Reynolds, Standiford, and Anderson (1979) investigated this hypothesis in an experiment in which college undergraduates were periodically questioned while they read a 48-page marine biology text. The questions were of a clear and distinctive type. For instance, one group of readers received questions every four pages that could always be answered with a proper name. Other groups were asked questions that could always be answered with a technical term or a number. Time to read the text was recorded for every four-line segment. The main result of the experiment was that readers who answered questions spent more time on the segments of the text that contained information from the category needed to answer the questions. Performance on a later test showed that questioned

groups learned and remembered more question-relevant information than the nonquestioned groups. The results were entirely consistent with a simple selective attention theory.

Several studies by Britton and his associates (cf. Britton, Piha, Davis, & Wehausen, 1978) have used the length of time before a secondary task is performed as a measure of the amount of attention being devoted to reading. Subjects were told that comprehending the text was their primary task. They were also given the "secondary task" of depressing a key whenever an auditory signal, or probe, was sounded. The idea behind this procedure is that, when the mind is occupied with the primary task, there will be a slight delay in responding to the secondary task. To explain this more fully, there is an upper limit to the amount of attention, or "cognitive capacity," that people can devote to a task. Ordinarily, there is plenty of spare capacity when doing mental work such as reading. However, if a reader were to put substantial extra effort into a text element, this would place peak load demands on the cognitive system. Then there would be little capacity left over to process the probe and respond to it. Hence, the reaction to the probe would be delayed until capacity had been freed.

Britton, Piha, Davis, and Wehausen (1978) and Reynolds and Anderson (1982) have employed the secondary-task procedure to investigate whether periodic questions cause readers to allocate attention selectively. In the latter study, college students again read the 48-page marine biology text. They were asked either a proper-name question or a technical-term question every four pages. During each four-line text segment, the reader heard either zero, one, or two probes presented through earphones, at which points he or she was to push a key as quickly as possible. The results showed that readers took longer to respond to the probe when studying a segment that contained question-relevant information than when studying one that did not. Reading times were also longer on segments containing question-relevant information. Thus, using two different measures, this study supported the selective-attention interpretation of the effects of questions.

The selective-attention hypothesis provides a parsimonious and convincing interpretation of the effects of equipping readers with instructional objectives or occasionally asking them questions. It is much more problematical, though, that the reader's schema acts primarily as a device for allocating attention. To assimilate the following vignette, it may be supposed that most readers would employ a WHO DONE IT schema.

> Detective Lieutenant Bill Roberts bent over the corpse. It was apparent the victim had been stabbed. Roberts searched the room looking for evidence. There, near the foot of the bed, partly covered by a newspaper, he discovered the butcher knife.

The question is whether extra cognitive capacity will be devoted to processing the important information expressed by "the butcher knife." The selective attention hypothesis says yes. An alternative explanation is that the WHO DONE IT schema furnishes the "ideational scaffolding" (Ausubel, 1963; Anderson, Spiro, & Anderson, 1978) for the information in the text. Presumably the (murder

weapon) occupies an important niche, or slot, in this structure. Furthermore, the second sentence of the text constrains the murder weapon to a sharp instrument. Thus, there is a slot established in the schema for which a knife is a leading candidate by the time the phrase, "the butcher knife," is encountered. As a consequence, according to the ideational-scaffolding hypothesis, the information about the knife will be readily assimilated and there is no reason why it ought to require, or will receive, extra attention.

Another alternative to the selective attention model outlined at the beginning of this section has been formulated by Kintsch and van Dijk (1978). They theorized that important propositions are maintained in working memory throughout more processing "cycles" than less important ones. This is a kind of selective-attention theory since Kintsch and van Dijk believe that important propositions are more memorable because of the greater amount of processing they receive. However, the extra attention is not given when the proposition is encoded but rather is said to come later when subsidiary propositions are being processed.

Still another alternative hypothesis, as will be explained at length in the next section, is that the greater likelihood of recall of important text elements may be attributable to a memory process rather than a learning process. This hypothesis, the ideational-scaffolding hypothesis, and the Kintsch and van Dijk multiple-cycles hypothesis are all rivals to the simple selective-attention hypothesis. Thus, the outcome of research on attention involving variations in schemata or text organization is not a foregone conclusion; and the results will be of genuine interest.

Goetz, Schallert, Reynolds, and Radin (1983) examined the effects of the reader's perspective on the allocation of attention. Policemen, people in training to be real estate agents, and college students were instructed to take the perspective of a burglar, a person interested in buying a home, or no particular perspective while reading a story ostensibly about what two boys did at one boy's home while playing hooky from school. The research confirmed previous research that has established that the reader's perspective strongly influences which information will be recalled from this story (Anderson & Pichert, 1978; Grabe, 1979; Pichert & Anderson, 1977). Persons playing the role of a burglar are more likely to recall, for instance, that money is kept in a desk drawer, whereas those imagining themselves to be home buyers more often reproduce, for example, the information that the place had spacious grounds. The new finding obtained by Goetz and his colleagues is that subjects spent more time reading sentences that contained information important in the light of the schema activated by perspective instructions. They also spent somewhat more time on sentences important in the light of their background. For instance, the policemen took longer to read sentences containing information important to burglars than the other subjects. Reynolds (1981) and R. C. Anderson (1982) have summarized research consistent with these findings.

Cirilo and Foss (1980) have reported two experiments in which time to read sentences was assessed when the sentences were of high importance in one story and low importance in another. The sentence, He could no longer talk at all, was highly important in a story in which it described the effect of a witch's curse on a wise king. The same sentence was of low importance in a

story in which it described the momentary reaction of a simple soldier upon hearing that he would receive a large reward for finding a precious ring. In two experiments Cirilo and Foss found that readers spent more time on a sentence when it played an important role in a story.

Britton, Meyer, Simpson, Holdredge, and Curry (1979) have recently reported another test of the selective-attention hypothesis. The materials included two expository texts involving the energy crisis. In one, according to Meyer's (1975) analysis, a paragraph on the breeder reactor was high in the content structure; the passage said the fast breeder reactor is the solution to energy problems. In the context of the other passage, the paragraph was low in the content structure; the breeder reactor is only one of five possible solutions to the energy crisis. Subjects recalled more information from the critical paragraph when it was of high importance. However, they took the same amount of time to read the critical paragraph and the same amount of time to react to a secondary-task probe regardless of the paragraph's importance. Hence, the selective-attention hypothesis was not confirmed. Britton and his collaborators theorized that the superior recall of the critical paragraph when it was of higher importance was due to a memory process.

We don't know how to reconcile the conflicting results obtained by Cirilo and Foss (1980) and in our own research, on the one hand, and Britton et al. (1979), on the other. There were several differences in materials and procedures. Most notably, there were different definitions of what makes a text element "important." It is apparent that one ought to be cautious in assuming that every operation that can be said to make a segment of text salient, interesting, or important will affect processing in the same manner (see R. C. Anderson, 1982). An important task facing the field of reading research is a further explication of the notion of "importance."

Improvements in the simple, first-order theory of selective attention will be required before the theory can cope with the demands of texts of any complexity. For instance, readers often will be unable to gauge the importance of elements when first encountered. Indeed, in some literary forms, such as short stories and the detective novels, innocuous happenings frequently turn out to be significant at some later point.

What "fix-up strategy" (Alessi, Anderson, & Goetz, 1979) could readers use for dealing with text information whose significance was not initially appreciated? If the information were available in memory, perhaps in fragmentary and unassimilated form, it could simply be retrieved and processed further at the point at which its importance was discovered. If the information were not in memory, the reader could look back and reread the relevant section of the text. Efficient use of "look backs" (Alessi et al., 1979) would require the person to know where in the text the information could be found. Rothkopf (1971) has discovered that readers incidentally acquire a surprising amount of information about the geography of a text. Though they had not been forewarned that they would be asked where information was located, after reading a 3000-word passage people were able to report the page on which information appeared, and even the location within the page with much better than chance accuracy.

A fundamental question is why an extra allocation of cognitive capacity ought to be facilitative. Some would simply take it as axiomatic that attention

is the precursor to learning, and let the argument rest there (cf. Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Our view is that ultimately this is not a satisfying level of explanation. A complete theory will require an analysis of what readers are doing with the cognitive capacity they invest. They could be rehearsing selected segments of the text in the traditional sense of implicitly repeating the segments to themselves, as actors learning their lines do. Rehearsal appears to be the operation that Rothkopf and Billington (1979) had in mind as the explanation for the effects of learning objectives. Another view is that readers pay extra attention to certain text segments in order to process them at a semantically deeper level. A problem with the depth-of-processing notion is that a semantic level of representation is required before a reader could have a basis for determining that a segment was important enough to deserve more attention. At this point the reader might engage in still "deeper" processing, but no one has been able to say exactly what that could mean, as critics of the idea have noted (Baddeley, 1978; Nelson, 1977). In any event, Craik and his associates, who introduced the phrase "depth of processing" (Craik & Lockhart, 1972), have abandoned the concept. He and his colleagues now speak in terms of the "elaboration" of to-be-learned material (Craik & Tulving, 1975) and the "distinctiveness" of the encoded representation (Jacoby, Craik, & Begg, 1979).

Our conjecture is that extra attention is invested in important propositions in a text in order to connect these propositions with the overall representation that is being constructed. So, if a person pretending to be a burglar reads that coins are kept in a desk drawer, the connection is made that the coins are potential loot and what a burglar is interested in is loot. Drawing such connecting inferences requires cognitive capacity. The fact that they are drawn is the reason, or part of the reason, for the superior recall of important text elements.

When a person is *studying* a text—that is, reading with the deliberate intention of learning ideas and information—some form of the selective-attention hypothesis would appear to give a highly plausible account of aspects of the reader's processing activities (see T. H. Anderson, 1979). However, as a characterization of the activity of a person who is *simply reading,* the hypothesis has much less *a priori* appeal. We would not be surprised to find no evidence of differential allocation of capacity on the part of an individual engrossed with the sports page or curled up with a novel. Such learning of information as takes place under these conditions is the incidental by-product of comprehension. The demand characteristics of laboratory experiments on discourse processes put subjects more in the mode of studying than simply reading. Direct, systematic study of what is happening when people are simply reading will not be easy since procedures for the real-time measurement of attention are especially intrusive.

A complete theory of the allocation of attention during reading will have to take account of all major demands on cognitive capacity. Included is the capacity needed to analyze words and access their meanings, to parse sentences into constituents, and to construct propositions. Many aspects of reading may be automatic, at least in the skilled reader, and, hence, require very little cognitive capacity (LaBerge & Samuels, 1974; Posner, 1978). Nevertheless, as a general rule, it is probably a safe bet that every level of linguistic analysis requires some attention. Even highly overlearned, largely habitual operations must be monitored because of occasional breakdowns.

Graesser, Hoffman, and Clark (1980) and Just and Carpenter (1980) have demonstrated that a range of language-processing operations do require cognitive capacity. In the former study, reading times were collected for 275 sentences in 12 passages. The sentences were analyzed in terms of three variables believed to relate to the text macrostructure—that is, the interrelationships among sentences and the organization of the passage as a whole. There were also three variables related to the microstructure, or linguistic units within sentences. Reading time was strongly influenced by macrostructure variables, especially whether the sentence was from a story or expository text, but also by the familiarity of the topic (see Steffensen, Joag-dev, & Anderson, 1979), and by the amount of new information in the sentence. The microstructure variables had smaller but still significant effects on overall reading time. When subjects were split into groups of fast and slow readers, there was no difference between groups on macrostructure components, but a substantial difference with respect to microstructure variables. The cost in time to process an additional word or proposition or to cope with unpredictable syntax was much greater for slow than fast readers. Graesser and colleagues went on to show that readers instructed to prepare for an essay, in contrast to a multiple-choice, examination devoted increasing amounts of time to difficult macrostructure components of the texts, whereas time to process microstructure components did not vary. This is a reasonable result since an essay exam requires an organized understanding of a text. Multiple-choice questions can be answered from a piecemeal representation.

In summary, despite some inconsistent findings and several unanswered questions, based on the evidence available at this time, the selective attention hypothesis looks promising.

SCHEMATA AND REMEMBERING

Thus far, we have dealt with processes supported by the person's schema when a message is being comprehended and aspects of its content learned. In this section we turn to the influence of schemata on processes that may be at work later when the information and ideas in the message are being remembered and used.

Much research that is ostensibly about remembering is really about comprehension and learning. In such research, the operational measure is recall, which seems to implicate memory, but in fact the measure is collected in order to make inferences about earlier processes that are not directly observable. Such research rests on the assumption that what gets stored is the major determiner of what can be remembered. Notice, however, that if learning entirely determines remembering, then remembering is an uninteresting, derivative process. Loosely speaking, any factor that affects performance on a recall test can be said to affect remembering. In a serious discussion, though, a result should not be attributed to remembering unless there is an effect above and beyond that which can be explained in terms of learning.

Pichert and Anderson (1977) obtained evidence which suggested that a person's schema has an effect on memory in addition to an effect on learning. Subjects read the passage already described about what two boys did at one

boy's home while skipping school, or they read a passage about two gulls frolicking over a remote island. Readers' schemata were manipulated by assigning different perspectives. For the boys-playing-hooky-from-school passage, one-third of the subjects were instructed to read the story from the perspective of a potential home buyer, one-third were to read it from the perspective of a burglar, and one-third (a control group) were given no special perspective. For the gulls-frolicking-over-an-island story, one-third of the subjects were told to take the perspective of an eccentric florist who desired a remote place to raise exotic flowers, one-third were to read the story from the perspective of a shipwrecked person eager to stay alive and get home, and one-third were controls.

The passages were written so as to contain information of contrasting importance to the perspectives. For instance, the passage ostensibly about two boys playing hooky from school contained the information that the house had a leaky roof, which would be important to a real estate prospect but not a burglar, and the information that the family had a large color TV set, where the reverse would be true.

Subjects were asked to recall the passage shortly after reading and a week later. Table 9.1 summarizes the results. As can be seen, the importance of the information to the assigned perspective had a powerful influence on learning and also a positive, though small, influence on memory after one week. The index of memory was the proportion of information recalled, given that the same information had also been recalled on the first test shortly after reading a week earlier. This index is logically independent of level of recall on the first test. If the first test is regarded as representing level of learning, then the experiment provides evidence that a person's schema has separate effects on learning and memory.

This interpretation is open to challenge, however. It could be argued that the schema operative when a person is reading has an influence on learning that is not manifested in an immediate opportunity to recall. Text elements that are important in the light of the reader's schema might be overlearned because they receive more processing or deeper processing. As a result, these elements may have enough strength to appear at both immediate and delayed recall. On the other hand, a larger proportion of the less well-learned, unimpor-

TABLE 9.1 MEAN PROPORTION RECALLED AS A FUNCTION OF IDEA UNIT IMPORTANCE

	IDEA UNIT IMPORTANCE[a]		
	HIGH	MEDIUM	LOW
Learning[b]	.48	.36	.25
Memory[c]	.68	.65	.53

SOURCE: Pichert and Anderson, 1977, p. 311.

[a] Coded according to the perspective operative while the passage was read.

[b] Proprotion of idea units recalled on immediate test.

[c] Proportion of idea units recalled on delayed test given recall on immediate test.

tant elements may be above a recall threshold when the first test is given but below the threshold a week later.

Anderson and Pichert (1978) attempted to design a test of the effects of schemata on memory that would be free from possible latent effects of level of learning. Subjects read the boys-playing-hooky-from-school passage from one of the two perspectives, recalled the passage for a first time, changed perspectives—from home buyer to burglar or vice versa—and then recalled the passage for a second time. The data showed that people recalled additional, previously unrecalled information following the shift in perspective. There was a significant increase in recall of information important to the new perspective but unimportant to the one operative when the passage was read. It is impossible to explain this result in terms of a learning process since the switch of perspectives occurred after the material had been read and recalled once. The phenomenon must be attributed to a remembering process.

The finding that a change of perspective leads to an increment in recall of information important to the new perspective as well as a decrement in recall of information unimportant to the new perspective has been replicated a number of times under several variations of design and procedure. For example, Anderson, Pichert, and Shirey (1983) asked high school students to read a passage and recall it just once, either from the perspective operative during reading or a different perspective assigned prior to recall. Table 9.2 contains the results. As can be seen, there were independent effects of the reading perspective and the recall perspective on recall. The data plainly show that the schemata brought into place by perspective instructions affect both learning and remembering.

In a second experiment, Anderson et al. (1983) found that a new perspective had lost most of its power to reinstate previously unrecalled text information after an interval of a week. Similarly, Fass and Schumacher (1981) reported a diminished perspective shift effect after an interval of 24 hours. On the other hand, Flammer and Tauber (1982), in a study involving German-speaking Swiss university students, found only slightly reduced recall of information important in the light of the new perspective when the perspective was introduced 20 minutes after reading. Evidently unassimilated bits and pieces of information in the recesses of the mind will be irretrievably lost unless a complementary schema is introduced within a fairly short period after reading.

Exactly how does a person's schema influence remembering? In previous papers (e.g., R. C. Anderson, 1978), we have outlined three possible answers to this question, which we labeled the retrieval-plan hypothesis, the output-editing hypothesis, and the reconstruction hypothesis.

TABLE 9.2 MEAN PROPORTIONS OF TEXT ELEMENTS RECALLED

IMPORTANCE TO RECALL PERSPECTIVE	IMPORTANCE TO READING PERSPECTIVE	
	LOW	HIGH
High	.41	.51
Low	.32	.43

SOURCE: Anderson, Pichert, and Shirley, 1983.

According to the retrieval-plan hypothesis, the schema provides the framework for a "top-down" (Bobrow & Norman, 1975) search of memory. The idea is that search proceeds from the general concepts incorporated in the schema to the particular information related to these concepts that was learned while the passage was being read. According to the theory, a top-down, schema-guided search provides access to information important in the light of the schema, but it cannot turn up information unrelated to the schema.

The retrieval-plan hypothesis can be illustrated with reference to the burglar perspective on the hooky passage. Most peoples' BURGLARY schema will include the general concepts of entering the premises to be robbed, trying to avoid detection, finding objects that qualify as loot—namely, valuable objects that are easily moved and readily fenced—and making a clean getaway. The statement in the passage that the side door to the house is kept unlocked is likely to be made accessible when the general need of burglars to enter the premises is considered. The statement that tall trees hid the house from the road is a candidate for reinstatement by the AVOIDING DETECTION subschema. Similarly, various objects mentioned in the story, such as the color TV set and money in the desk in the den, are likely to occur to the rememberer when he thinks about loot. The general point is that, by reviewing his knowledge of what is true of most burglaries, the rememberer is reminded of the burglar-relevant information in the passage. Though the processes of remembering are not necessarily deliberate or conscious, a useful way to think about the retrieval-plan hypothesis is that the schema provides the rememberer with an outline of the questions he ought to ask himself.

A second possible hypothesis to explain effects on remembering is that the schema provides the basis and the motivation for output editing. By "output editing" we mean selection/rejection of information to report when recalling a passage. The hypothesis says that the criteria for this decision favor the currently operative schema. If a piece of information is relevant to his schema, a person might be willing to report it even though he is uncertain of his recollection. On the other hand, the person might impose high standards of certainty for evaluating information not relevant to his schema. The pattern of results that involves increased recall of important information and decreased recall of unimportant information could be explained in terms of perspective-induced shifts in standards for output editing.

A third hypothesis is that the rememberer's schema facilitates reconstruction. According to this hypothesis, the person generates inferences about what must have been in the passage based on his schema and aspects of the passage that can be recalled. For instance, a person attempting to recall the hooky passage from the perspective of a burglar will surely recall that the narrative involved an affluent, middle-class family. Knowing the lifestyle and spending habits of persons in this social stratum and the concern of a burglar with valuable, portable, fencible items, it may occur to the rememberer that the passage mentioned one or another small appliance, such as a food processer, color TV, camera, chain saw, sewing machine, or stereo. As a matter of fact, among these items only a color TV is mentioned. However, a person's degree of conviction that he "read" about a particular appliance may relate not only to whether the item was actually there, but also to such factors as the likelihood that a family of this type would have such an appliance and whether that appliance is typically

part of a burglar's loot. Thus, a person might be fairly certain that he read about a stereo, even though none was mentioned. As Spiro (1977) has noted, a similar process could produce instances of correct recall. Suppose a person did not actually remember the information about the color TV set. He might infer its existence anyway and become convinced that he read about it because of the high likelihood of a color TV set in well-to-do-households. In this fashion, an inventive person with a slack criterion for output editing may be able to "remember" additional information from a text as well as produce fabrications (cf. Gauld & Stephenson, 1967).

Next, we will consider the evidence that bears on the mechanisms by which a schema affects remembering. The simplest and least interesting explanation is provided by the output-editing hypothesis. Indeed, one may wonder whether a change in criterion ought to be called a memory process.

Several studies have examined the output-editing hypothesis. Surber (1977) varied the incentive for recall. He reasoned that if the increment in recall observed among people who shift to a new perspective were due to the adoption of a lax criterion, then the increment would disappear under conditions of high incentive because then, presumably, everybody would apply a lax criterion. The results showed a difference in recall in favor of people who shifted perspective, regardless of whether a $.25 bonus was paid for each new idea.

Anderson and Pichert (1978) used a direct approach to see whether output editing was a creditable hypothesis. They interviewed subjects who had recalled a passage for the second time after changing perspectives. Of 12 subjects, 9 insisted that each time they recalled the passage they wrote down everything they could remember whether important or unimportant. In the words of one of them, "I tried to write down everything even if it seemed stupid, you know. I generally wrote what I could remember."

Two unpublished experiments by Anderson, Shirey, and Pichert have assessed the output-editing hypothesis using recognition memory. For one experiment, alternate versions of the boys-playing-hooky passage were written that contained different but comparable information of roughly equal attractiveness to burglars or to real estate prospects. For instance, a piece of information relevant to home buyers was a damaged ceiling due to a leaky roof. The comparable information in the other version was a crack in a wall due to a settling foundation. In this experiment, half the subjects read one of the versions of the passage, half read the other, and later everyone took a test based on information from both versions. The test required subjects to evaluate whether or not each of a series of sentences expressed a proposition that they had read. According to the output-editing hypothesis, people will apply a lenient criterion for evaluating items expressing information relevant to their perspective. As a consequence, they will tend to accept perspective-relevant items they have not actually seen. In the case being used for illustration, a person given the home buyer perspective would be expected to accept both the item about the settling foundation and the one about the leaky roof. This did not happen. Indeed, neither reading perspective nor recall perspective had any discernible effect on recognition memory in two large experiments using somewhat different materials and procedures.

Presumably, people can and do evaluate what they are saying according to criteria of relevance and veracity, and, presumably, these criteria change

according to circumstances. Nonetheless, based on the accumulated evidence, it seems safe to conclude that output editing is not responsible for the changes in recall of passages that have been observed when people shift perspectives, at least under the conditions that have prevailed in the experiments reviewed in this chapter.

The retrieval-plan hypothesis is able to explain why perspective instructions have consistent effects on recall but no apparent effects on recognition. A recognition test item minimizes the need for retrieving information from memory since the information is provided in the item itself. The essence of the retrieval-plan hypothesis is that the schema is a structure that provides *access* to information in memory. Since access is not a problem on recognition items, the retrieval-plan hypothesis predicts no effect. Access is a critical process in free recall, so large effects are predicted there. Intermediate effects would be expected on a cued recall test that provided some guidance but did not eliminate the need for retrieval.

Anderson and Pichert (1978) obtained interview protocols that supported the notion of using a schema as the basis for a retrieval plan. The interviewer probed to determine why subjects thought they had come up with new information the second time they recalled a passage. Of the 16 subjects, 7 expressly stated that considering categories of information which were significant in the light of the perspective caused them to recall additional items of information from these categories. For instance, one subject who shifted from the home buyer to the burglar perspective said:

> I just thought of myself as a burglar walking through the house. So I had a different point of view, a different objective point of view for different details, you know. I noticed the door was open, and where would I go here, go there, take this, take that, what rooms would I go to and what rooms wouldn't I go to. Like, you know, who cares about the outside and stuff? You can't steal a wall or nothing. . . . I remembered [the color TV] in the second one, but not in the first one. I was thinking about things to steal, things you could take and steal. In the den was the money. China, jewelry, other stuff in other places. [Q: Why do you think you remembered the color TV the second time and not the first time?] Because I was thinking of things to steal, I guess.

In addition, 6 other subjects, who were less explicit about recall strategies, said that the new perspective "jogged" their memories or that, when given the new perspective, additional information "popped" into their heads. Hence, in all, 13 of 16 subjects made statements consistent with the retrieval-plan hypothesis.

A subtle prediction that can be made based on the retrieval-plan hypothesis is that rememberers ought to recall information in conceptually related clusters. The hypothesis asserts that memory search is organized in terms of the general categories that comprise the schema. So, for instance, a person pretending to be a home buyer might be expected to recall, one after another, several defects of the house that were discussed at locations scattered across the passage. We have failed to find much clustering in informal analyses of attempts to recall

the hooky passage. One reason for this may be that the assigned perspective is not the only schema subjects are using to organize recall. Two other schemata that come into play involve the spatial organization of the house and the temporal organization of the plot, such as it is, involving the two boys. These supplementary schemata may tend to minimize clustering in terms of burglar or home buyers concerns.

Grabe (1979) has also investigated the role of schemata in recall organization. He used the boys-playing-hooky-passage and a passage about a nursery school which was recalled from the perspective of either a toy manufacturer or a child psychologist. Clustering was significantly greater among subjects assigned perspectives than among no-perspective control subjects, largely because of the strong results obtained with the nursery school material. In Grabe's (1979) study, the perspective was assigned before the passage was read, so, it can be assumed that it provided the framework for learning as well as remembering. A worthwhile project would be to see if recall organization changes when the perspective shifts after reading.

In summary, the retrieval-plan hypothesis gives a good account of several different kinds of data. It remains a plausible candidate to explain some of the effects of schemata on remembering.

There is a substantial research literature bearing on the inferential-reconstruction hypothesis. We will consider here only studies that provide a clear basis for distinguishing between memory effects and effects attributable to the representation built up when a message was initially interpreted. A memory effect must be involved when a person acquires a certain perspective *after* reading a message, as was the case in the research of Spiro (1977, 1980) and Snyder and Uranowitz (1978).

In the latter study, people read a case history of a woman named Betty K. Later some subjects were informed that Betty K. was living a lesbian lifestyle, while others were told she was a heterosexual. Although subjects were told that they were being tested for accuracy of memory for factual information in the case history, answers to a multiple-choice test indicated selective remembering of information that supported their current interpretation of Betty K's sexuality and also distortion of information that contradicted their current view. For example, subjects who were informed that Betty K. was a lesbian said she never went out with boys during high school, whereas some subjects given the information that she was a heterosexual said she had a steady boyfriend. The correct answer was that she occasionally dated boys.

Loftus and her colleagues have done some especially provocative research on reconstructive memory (cf. Loftus, 1979). In one study (Loftus & Palmer, 1974), people saw a film of an automobile accident and then answered questions about what they had seen. The question, "About how fast were the cars going when they smashed into each other?" elicited a higher estimate of speed than questions that used verbs such as *bumped* or *hit* in place of *smashed.* On a test administered one week later, those subjects who had heard the verb *smashed* were more likely to answer "yes" to the question, "Did you see any broken glass?" even though broken glass was not present in the film. This experiment (and many others using similar procedures) shows that related information is usually assimilated into a single schema, with the frequent result that people are unable to distinguish between information with a direct basis in experience

and that which was not actually experienced but which is consistent with the schema.

Several studies show that the longer the interval between reading and recall, the larger the effects of the reader's schema. A remembering process is implicated, therefore, rather than a learning process because the effects of a learning process would be strongest immediately following a passage and would diminish thereafter. The schema manifests itself as an increase with time in the frequency of schema-consistent distortions in free recall (Bartlett, 1932) or in susceptibility to schema-consistent foils in recognition (Sulin & Dooling, 1974). This phenomenon is nicely illustrated in a study by Read and Rossen (1981). They asked people who were either strongly for or strongly against nuclear power to read a text about a fire at a nuclear power plant. The data revealed very little effect on a multiple-choice test given immediately after the story. However, when the test was given one or two weeks later, there was a substantial degree of acceptance of belief-consistent distortions of the original information. Subjects who were personally opposed to nuclear power correctly rejected spurious, pronuclear statements; however, they tended to accept incorrect antinuclear statements. Subjects who favored nuclear power produced the opposite pattern of results.

There have been studies that have failed to support a reconstructive view of memory (Brigham & Cook, 1969). In general, these studies have used arbitrary, disconnected material, have involved reading this material in an unnatural manner, or have given the test immediately after the material was exposed. Conversely, when people read lifelike prose in a normal manner so that their knowledge and belief about the world is actually engaged, and when the test is delayed for more than a few moments, typically the results strongly support the reconstructive hypothesis (Read & Rossen, 1981; Sheppard, 1981; Spiro, 1977).

In summary, available data support the ideas that the reader's schema is a structure that facilitates planful retrieval of text information from memory and permits reconstruction of elements that were not learned or have been forgotten.

FUTURE DIRECTIONS FOR RESEARCH IN COMPREHENSION

In our judgment, Huey would have been delighted with the progress that reading research has made in unraveling "the tangled story of the most remarkable specific performance that civilization has learned in all its history" (1908/1968, p. 8). It is true, of course, that there are gaps in understanding and alternative explanations of phenomena for which the available evidence provides no resolution. Thus, there is still much work to be done in order to build THE definitive model of basic processes in reading comprehension.

We close by discussing some of the implications that basic research in comprehension holds for educational research and practice (see also the thoughtful review of research on comprehension instruction by Tierney and Cunningham, this volume). These ideas are offered in the spirit of conjecture, as hypotheses in need of elaboration and explication, and in need of testing in the laboratory and in the classroom.

First, poor readers are likely to have gaps in knowledge. Since what a person already knows is a principal determiner of what she can comprehend, the less she knows the less she can comprehend.

Second, poor readers are likely to have an impoverished understanding of the relationships among the facts they do know about a topic. Arbitrary information is a source of confusion, slow learning, slow processing, and unsatisfactory reasoning.

Third, poor readers are unlikely to make the inferences required to weave the information given in a text into a coherent overall representation. Poor readers do not seem consistently to appreciate that—using the analogy of Wilson and Anderson (in press)—comprehending a story or text is like completing a jigsaw puzzle: all of the information must be used, the information must fit into place without forcing, all of the important slots must contain information, and the completed interpretation must make sense. Forming a coherent representation requires drawing precise, integrating inferences, and drawing such inferences is not something poor readers do routinely and spontaneously (see Bransford, Stein, Nye, Franks, Auble, Merynski, & Perfetto, 1982, and the companion articles).

If the foregoing problems have been accurately identified and they are the central ones, then plausible solutions naturally suggest themselves: becoming a good reader demands a curriculum rich with concepts from the everyday world and learned fields of study. Becoming a good reader requires books that explain how and why things function as they do. Becoming a good reader depends upon teachers who insist that students think about the interconnections among ideas as they read.

We hope that these conjectures provide impetus for instructional researchers to conduct the kind of painstaking classroom and materials research necessary to build and validate better programs of comprehension instruction and for educators to begin to develop and evaluate instructional programs that will lead to the literate citizenry our future will demand.

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