

Chapter 3: Memory

Structures and
Models



3.1 Structures and Models

Depending on the moment, our memory the register of our experiences - can be a source of frustration, of pain, of delight, or of wonder. When we want to access it, often we cannot. Sometimes, when we wish memories would fade, they will not. At unaccountable moments, sweet dreams may find their way into our consciousness. Now and then, our sure recall of figure or fact may allow us to act with uncommon confidence and authority.

For as long as we have thought about “**human nature**,” that aspect called “**memory**” has intrigued us. The scientific study of memory is a recent matter, however, tracing back only a little more than a century to the beginnings of psychology as a systematic, experimental science.

The tradition of memory research first begun by **Ebbinghaus** dominated the study of memory for nearly a century (1850-1909). In general, this tradition was based on the **following assumptions**: (1) *that words were the primary mental units of language*, (2) *that when units were used together they became linked and were chained into larger units*, (3) *that complex behaviours and patterns of thought were assembled from simple units*, and (4) *that the mechanisms that produced learning and memory largely were automatic*.

Today, however, our conception of what constitutes the valid study of memory has been broadened considerably. **Memory theories** based on rote memorization and extrapolation of basic principles from simple to complex behaviour largely have been supplanted by those that have attempted to describe complex, meaningful cognitive processes more directly. In the past three decades, especially, memory theorists have made immense strides in describing the nature of knowledge and in developing theories that permit predictions about the nature of learning, memory, and utilization of meaningful information.

Fundamental
Distinctions in
the Study of
Memory



3.2 Fundamental Distinctions in the Study of Memory

As cognitive theorists began more and more to grapple with issues in the learning and recall of meaningful materials, they quickly faced questions about the nature of knowledge and how it is stored in

memory. **Are there basic differences, for instance, between "knowing" something and "knowing how to do" something? Does personal experience lead to different storage and retrieval than the more abstracted general knowledge of, say, subject areas such as history and chemistry?** Is memory for language different than memory for images? Are there differences between memory for events just experienced and those experienced some time in the past? **Questions such as these have led to a number of distinctions.** Among the most useful and enduring have been those between *episodic and semantic memory, between declarative and procedural knowledge, between language-based and imagery-based systems in memory, and between short-term and long-term memory.*

Episodic versus
Semantic
Memory



3.2.1 Episodic versus Semantic Memory

In proposing a distinction between episodic and semantic memory, **Tulving** argued for the utility of distinguishing between the traces of personal experience, on one hand, and general knowledge, on the other. Specifically, **episodic memory refers to storage and retrieval of personally dated, autobiographical experiences.** *Recall of childhood experiences, recollection of the details of a conversation with a friend, and remembering what you had for breakfast all would fall within the realm of episodic memory.* **The critical feature of episodic memory is the existence of a "personal tag",** and the basis for retrieval is an association with a particular time or place. Obviously, a great deal of what we must recall in order to function effectively in our daily lives is of an episodic nature.

Semantic memory, in contrast, refers to memory of general concepts and principles and their associations. Unlike episodic memory, semantic memory is not linked to a particular time and place. In our semantic, memory is such information as the fact that lemons are yellow and that computers contain chips. *Semantic memory contains the organized knowledge we have about words and concepts and how they are associated.* For instance, a subject area such as Egyptian literature or American history represents a vast body of semantic information that we (as we become more expert in the area) encode, organize, and have available for retrieval. Recalling word meanings, geographic locations, and chemical formulas similarly requires searches of semantic memory.

Although the psychological validity of the episodic-semantic distinction has been criticized, it continues to be useful in helping us think about the different types of information we must remember. On one hand, the episodic aspect of our memories must function well enough for us to locate ourselves in time and space and have a reasonably accurate record of our experiences. At the same time, we have to have available a general knowledge base in order to think and reason effectively. *Of course, the episodic-semantic distinction*

does not presuppose two physically separate systems in the brain, but rather is a conceptual distinction useful to researchers and practitioners.

Declarative
versus
Procedural
Knowledge



3.2.2 Declarative versus Procedural Knowledge

A second important distinction in the study of memory is between declarative and procedural knowledge. **Declarative knowledge is knowledge about facts and things**, knowledge that something is the case. In contrast, **procedural knowledge is knowledge about how to perform certain cognitive activities**, such as reasoning, decision making, and problem solving.

Declarative
memory



Declarative memory

The memory associated with cognitive skills not directly attributable to muscular or glandular responses. The complete memory may be acquired through a single exposure, but practice is beneficial. Declarative memory is required to recall factual information, and it is sometimes called fact memory. The ability to recognize a face, recall a number, or recall any verbal or sensory information requires declarative memory.

One important use for the **declarative-procedural distinction is to describe the kinds of learning students may achieve**. A novice student in a teacher education program, for instance, may memorize principles of classroom management (e.g., "Allow students to make value judgments.") as declarative knowledge, but he may have little or no notion of how these principles actually would be used in effective teaching (procedural knowledge).

Although it has not been described with the terms declarative knowledge and procedural knowledge, the declarative-procedural distinction has been implicit in the work of a number of learning theorists—for instance, in the work of **Benjamin Bloom** and his associates. In Bloom's analysis, for instance, a contrast was drawn between **lower levels of learning** (i.e., knowledge, comprehension), in which facts, concepts, and rules are learned and understood, **and "higher-order" learning** (i.e., application, analysis, synthesis, and evaluation), in which knowledge is used as part of higher level cognitive processes.

Of course, not all procedural knowledge is "higher-order" knowledge based on more fundamental declarative knowledge. Procedural knowledge can be quite simple and only implicitly linked with declarative knowledge. *A young child, for instance, who remembers how to unlatch the door, turn off a faucet, brush her teeth, and open a*

book, is showing her recall of procedural knowledge.

Also, procedural knowledge often is "**automated**" we often begin "**doing**" **without any apparent conscious attention** to what we are doing or why we are doing it. In a lecture class at a university, for example, most students will enter the class, find a seat, take out a notebook, and begin taking notes with little or no conscious attention to the task. Similarly, as we read, decoding words and comprehending the meaning of what we are reading ordinarily occurs quite automatically. Sometimes, however, our searches of declarative knowledge come at least partially under conscious control. ("Who is the author of *Hamlet*?")

In most learning, of course, **there is interplay between declarative and procedural knowledge**. A concert pianist learning a new song by **Domenico Scarlatti**, for instance, may search her memory for declarative knowledge about that composer's preferred method of executing certain embellishments such as the appoggiatura, mordent, and trill-declarative knowledge that will be utilized in the development of procedural knowledge. **Conversely, procedural knowledge has undeniable impact on declarative knowledge**. Like most experts, our pianist has procedural knowledge about how she best recalls information about composers and their works and will search her declarative knowledge accordingly. Yet another cluster of procedural knowledge-her skills in performing-enhances and gives substance to the declarative knowledge she possesses (e.g., "Scarlatti intended for the mordents to be played according to the basic tempo of the passage. That would mean that they should be thirty-second notes here.")

In **most school learning**, similarly, there will be **goals** for the acquisition of both **declarative and procedural knowledge**. *One important goal of education is the development of relatively large, stable, and interrelated sets of declarative knowledge*. As educators, we expect students will be "knowledgeable". At the same time, however, we place a considerable premium on knowing "how to." For the practitioner, usable knowledge is critical. Especially in applied programs such as journalism, architecture, teaching, management business, and medicine, procedural knowledge is an important outcome of the educational process.

3.2.3 Verbal and Imaginal Representation in Memory

Verbal and
Imaginal
Representation
in Memory



"**A picture is worth a thousand words.**" Although the validity of this aphorism may be debatable, there is little doubt that we humans have extraordinary capabilities for remembering information about visual events. There is little doubt that pictorial information can be represented in our memories quite well. **Certainly**, our subjective experiences would tell its so. Most of us easily can conjure up an image of a book, a soaring bird, a train wreck, or a walk in the woods.

One of the main contributions of cognitive psychology has been a revitalization of interest in the study of mental imagery. Once largely banished from experimental psychology as subjective, mentalistic, and therefore unscientific, imagery has become a significant feature of the work of a number of cognitive psychologists.

One such psychologist, **Alan Paivio**, has proposed **that information can be represented in two fundamentally distinct systems, one suited to verbal information and the other to images**. The verbal coding system is adapted for linguistically based information and emphasizes verbal associations. According to Paivio, words, sentences, the content of conversations, and stories are coded within this system. **In contrast**, nonverbal information is stored within the imaginal coding system. Pictures, sensations, and sounds are coded here.

Paivio's theory has been called a dual coding theory, in that incoming information can be coded within one or both of the systems. Although the systems are separate, they are strongly interconnected in their impact on the recall ability of information. To the extent that information can be coded into both systems, memory will be enhanced, whereas information coded only in the verbal system or imaginal system will be less well recalled. In **Paivio's view**, the verbal and nonverbal codes basically are functionally independent and "contribute additively to memory performance". **Paivio** also hypothesizes that nonverbal components of memory traces generally are stronger than verbal memories.

Much of Paivio's early work was devoted to demonstrating the effects of the abstractness of materials on its memorability and relating these results to dual coding theory. For instance, some words (bird, star, ball, and desk) have concrete referents and presumably are highly imaginable. Thus, when presented with such words, both the verbal (e.g., the linguistic representation of the word bird, its pronunciation, its meaning) and the imaginal (an image of a bird soaring) representations are activated simultaneously. Other words, however, are more abstract and far less readily imaginable (e.g., aspect, value, unable). These words, although they activate the verbal coding system, are hypothesized to activate the nonverbal system only minimally. In Paivio's view, memory for abstract materials should be poorer since such materials are represented only within a single system. Pictures, since they tend to be automatically labeled, should be more memorable than words because, although pictures are automatically labeled (and hence dual-coded), words, even concrete ones, are not necessarily automatically imaged.

In a large number of studies, Paivio and his associates have demonstrated the beneficial effects of imagery on learning and memory, consistent with his predictions. Words rated high in imagery have been shown to be better remembered in free recall, in serial learning

(where a series of words must be recalled in order), and in paired-associate learning (in which the "associate" of a word must be recalled when the word is presented). Similarly, instructions to subjects to "form images" also have been shown to enhance memory.

Mental Rotation

3.3 Mental Rotation



An intriguing set of studies carried out by **Roger Shepard** and his associates has provided additional information about **the nature of mental images**, their distinctiveness from verbal information, and the role they play in cognition. In an early study, **Shepard** had subjects think about such questions as the number of windows in their house. **He noted that the time required to produce an answer increased with the number of windows counted**, consistent with the idea that individuals actually were mentally manipulating some sort of image. Further, subjects described themselves as taking a "**mental tour**" of their house in order to respond to this question. At least subjectively, there was a strong impression of mentally picturing - looking at or scanning - images.

In a later series of studies, Shepard and his co-workers showed that **mental images generated by persons underlie a number of cognitive operations**. In one set of studies, for example, persons were asked to judge whether three-dimensional objects presented in different orientations were identical; see Figure 3.1. The fascinating result was that the time required to make the judgments increased linearly with the extent of rotation required. That is, it appeared that persons were mentally rotating the objects in order to make the comparison; the greater the rotation, the longer it took to make a judgment.

More recently, **Stephen Kosslyn** and his colleagues have demonstrated other interesting effects. For example, in one study, persons were asked to memorize a map of an island on which such objects as a tree, rock, or hut were depicted at varying locations; see Figure 3.2. After the map was committed to memory, they were asked to focus on a named object on the map. They then were given the name of a second object and told to locate it by imagining a black speck moving in a straight line from the first object to the second. Objects were, of course, varying distances from one another on the map. If the mental image is being scanned, as **Kosslyn** hypothesized, then time required to move from one object to the next should vary directly with the distance on the image. In fact, this was what **Kosslyn and his associates** found. "**Distant**" objects took longer to reach than "**near**" objects, demonstrating that images, like pictures, contain information about the spatial relations among objects.

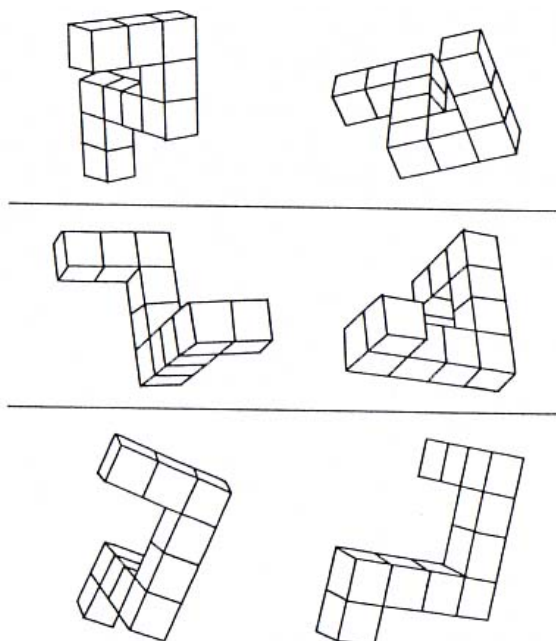


Figure 3.1: Pairs of patterns with different orientation.

These pairs of figures are similar to those used by Shepard and Xletzler (1971) in their study of the mental rotation of three-dimensional objects.



Figure 3.2: An island map.

Using persons' ability to form images of different sizes (e.g., a large rabbit versus a very tiny rabbit) and at different locations (e.g., nearby versus far away), **Kosslyn** also has shown that **when persons are asked to verify certain features of mental images** (e.g., "Do rabbits have whiskers?"), **details of "small" images** (e.g., a small rabbit) **take longer to verify than those of "large" images** (a large rabbit). According to Kosslyn, such evidence points to the conclusion

that **images have a "grain" or resolution**. Thus, portions of images visualized as subjectively smaller actually make details harder to discern.

Short-Term
versus
Long-Term
Memory



3.4 Short-Term versus Long-Term Memory

Beginning in the late 1950s and increasing rapidly thereafter, the research journals in learning and memory began to be flooded with research on a new topic. **What was being studied and reported on was not a new phenomenon, but a new dimension of the already well studied area of human memory.** The new dimension being investigated was the nature of **memory over very short intervals-seconds or minutes**. The name given to this phenomenon was **short-term memory, or simply STM**.

Memory theorists long had proposed that **there may not be one, but two, mechanisms for memory storage**. What they suggested was that **one type of storage mechanism is available for events recently experienced**. This mechanism is the realm of STM. Another type of storage system seems to exist, however, **for traces of experiences developed over longer periods through repetition, habit, and study**. This aspect of memory is called long-term memory, **or LTM**.

Several differences between STM and LTM were hypothesized. **First**, it was contended that STM involves "activity" traces in contrast to LTM's "structural" traces. That is, STM is dependent on ongoing electrochemical brain activity; in contrast, LTM is based on relatively permanent changes in brain cell structure. **Another**, related contention was that STM decays autonomously, whenever attention is diverted from what is to be remembered. LTM, however, is based on irreversible, non-decaying traces. **Third**, obvious differences in capacity between STM and LTM were noted. Whereas STM has relatively fixed limits, LTM was judged to have apparently unlimited capacity.

These distinctions match well with our own introspective assessment of our memory capabilities. For instance, when we encounter new information, we generally need to continue to pay attention to it and rehearse it in order to **"keep it in mind."** **Remembering a phone number** we have just looked up or the names of several new acquaintances, for most of us, **requires some attention and repetition**. Especially on first encounter, our memory for such information can be exceedingly fragile-even a brief interruption or distraction may cause us to lose the thought entirely.

Once information has been well learned and committed to memory, however, rehearsal and repetition seem much less critical. We easily can state our uncles' names, recall the names of

two large cities on the Red Sea, or give three examples of large hairy animals without having to rehearse any of this information-despite the fact that we may not have thought of these topics for months or even years!

In more recent models of memory, however, **the importance of the STM-LTM distinction has diminished**. Although memory theorists have continued to pay attention to the differences between STM and LTM, most models of memory have shifted from storage to a "**processing**" emphasis. This processing emphasis is retained in most current models. Rather than being conceived of as a "place" where information is held for brief periods, the concept of STM has been broadened so that it reflects the many different ways in which we deal with information. The STM now more and more reflects the concept of "working memory"-that part of our cognitive systems we would refer to as our consciousness. For example, **J.R. Anderson's ACT model incorporates a "working memory"** and a long-term memory." These two are not emphasized as "separate places," however, but rather as being closely interrelated. The current contents of consciousness set up a pattern of activation in LTM; this activation of LTM, in turn, may "reverberate" back into working memory.

Concepts



3.5 Concepts

One of the major ways in which we deal with the bewildering array of information in the world is **to form categories**. Our language mirrors these categories-the words grandfather, data, bird, psychology, red, dog, and man each represent a category meaningful to most of us. **Concepts** are the mental structures by which we represent these categories. **Particular objects or events** are grouped together based on perceived similarities; those that "fit" the category are examples or instances of the concept; those that do not are non examples. **The similar features across examples of a concept** (e.g., all oceans contain water and are large) are called attributes; features essential to defining the concept **are called defining attributes**. Learning concepts involves discovering the defining attributes along with discovering the rule or rules that relate the attributes to one another.

The work of **Bruner** and others has shown that individuals typically solve concept identification problems by trying to discover the rules relating the concept attributes. In general, **concepts that have more difficult rules are more difficult to learn**. **The simplest rules involve affirmation** (e.g., any green object) and **negation** (e.g., any object that is not green), which apply if there is only one attribute being considered. *Most concepts, however, involve more than one relevant attribute and hence more complex rules. Among the most common are conjunctive rules, in which two or more attributes must*

be present (e.g., any triangle that is green), and disjunctive rules, in which an object is an example of a concept if it has one or the other attribute (e.g., either a triangle OR a green object).

In recent years, **Bourne's work** has represented the clearest statement of rule-governed conceptual structure. In his view, concepts are differentiated from one another on the basis of rules such as the above. **These rules provide the means for classifying new instances as either linked to a concept or not.** According to Bourne, membership in a conceptual class (e.g., grandfathers, data, and birds) is determined by applying a set of rules. These rules can be learned either through instruction or through experience with instances that either are members of the class (positive instances) or are not (negative instances). Thus, one learns to classify a set of animals as birds or not birds on the basis of instruction or experience that leads to acquiring rules for combining characteristic attributes of birds (e.g., wings, bills, feathers). Instruction, according to **Bourne**, should involve presentation of both positive and negative instances (e.g., for birds, pigeons versus bats) so that critical attributes clearly can be linked to the concept. Presumably, use of these rules unambiguously classifies a new instance as either a bird or nonbird. Note, however, that this classification is a very simple one—a new instance either is a bird or is something else, a nonbird!

Although a rule-based conceptual system works to organize information for many concepts, it is inadequate for others. **Most natural or "real-world" concepts are more "fuzzy" and differ qualitatively from those studied in the laboratory.** For instance, consider the concept furniture. Our past experience would let all of us quickly agree that furniture includes tables, chairs, sofas, and floor lamps. *Furthermore, we can describe many rules that differentiate articles of furniture from other objects. But some of our attempts at rule formation quickly run into trouble.* **Presence of legs?** But what about some floor lamps? A seating surface? But what about tables or a desk? Is rug furniture? Some would say that it is, but would wish to include a Qualifying statement or "hedge"—it is like furniture, but not exactly like it. What is the set of rules that unambiguously determine which objects are members of the concept class furniture? Logical efforts to determine such sets of rules mostly have been unsuccessful, especially with ambiguous examples such as **Rug**. **Rosch and Mervi**, dissatisfied both with the artificiality of laboratory work on concept formation and with the difficulties of classifying concepts with rule-governed approaches, proposed an alternative view based on-degree of family resemblance" to a highly typical instance of the concept, a prototype.



3.6 Analogy and Metaphor Comprehension

Analogy is to human reasoning as bricklaying is to human building. In conjunction with categorization, it is one of the principal means by which knowledge about the world is acquired and structured. As a result, considerable effort has been put into the understanding of analogy by a variety of disciplines. **Verbal analogies** *have been the target of a considerable amount of that attention, and such research has begun to be integrated with research on metaphor comprehension.* The requirement for integration arises because it is known that **some analogies can be metaphorical**, and because metaphors can often be regarded as analogies. One view of metaphor is that it constitutes a mapping of the elements of one set on to another; and that it is the use of a given relation in a group of things to facilitate the discrimination of an analogous relation in another group. Simple, or sentential, metaphors are assumed to be represented by simple, proportional analogies (A: B: C: D), whereas extended metaphors, or models, require more complex analogical representation. There are many accounts of the nature of the relationship between analogy and metaphor, to which the interested reader is directed.

Analogical thinking, in the general propositional view, **is a means of recording similarities** between elements that already exist in the knowledge base, and whose properties are static; **subject to a set of constraints.** There is a similarity between this and a view of metaphor in which comprehension is seen to proceed by (a) *a retrieval of sets of semantic features that are propositional in nature, and (b) a selection from these features of an appropriate 'common ground' for the metaphor.* **In terms of Miller**, the propositional view of metaphor is more akin to the construction of semantic models than it is of memory images.

From the point of view of cognitive psychology, **we come to know things by gathering, processing, and storing information.** This is accomplished through **sensation and perception, learning and memory, and thinking.** Thinking involves mentally acting upon the information that senses, perceives, learns, and stores.

Meant of
mentally act on
information

What do you mean when you say that we mentally act on information? Suppose you are **Dave Bowman** and, upset by the death of your fellow astronauts, you cloister yourself and a colleague inside a cubicle, away (so you assume) from the discerning ear of **Hal**. (Unfortunately, best known to you, Hal also has a discerning eye that is adroit at up-reading.) As you discuss the astronauts' deaths and other computer-related problems, **you mentally picture Hal's computer console and the countless wires, computer chips, and other electronic hardware comprising Hal.** You recall strange events and snatches of conversations you've heard in the past few days and start drawing connections between them. You trace the

problems to Hal. You discuss ways to remedy the problems and decide on one: disconnect the source of the problems.

What have you been doing? You have been thinking. You have been using information that was previously gathered and stored and have been mentally acting on it by forming ideas, reasoning, solving problems, drawing conclusions, making decisions, expressing your thoughts, and comprehending the thoughts of others. Thinking involves a variety of mental processes and operations. The ones we will examine here are mental imagery, problem solving, and creativity. But before we get to these topics, we must address the large issue of how we think. By what means do we encode incoming information so that we can think about it?

How Do We
Think? Pictures
and Words



3.7 How Do We Think? Pictures and Words

Think about these two very different sentences:

1. **The bulbous blue hippopotamus**, reeking from the odour of stale fishy brine, waddled into the room and plopped onto the floor with a self-satisfied grin spreading over its face.
2. **Our nation was conceived in a spirit of unity for all time**, freedom from persecution, equality for the populace, and justice unequivocal.

After reading the first sentence, could you just "see" the hippo walking through the room? Were you almost disgusted at the fish odour? Could you "feel" the vibrations when the hippo plopped to the floor? Flow about the second sentence, could you "see" unity? Freedom? Justice? How do we represent information in our minds? Do we think in pictures as the sentence about the blue hippo illustrates, the answer seems to be yes. But most of us probably didn't call to mind any mental pictures when we read about the abstract concepts of justice and equality, yet we still understood what was being said.

There is some controversy over how information is represented in our minds. Some experts believe we encode information about real objects and events into mental representations of those objects and events. **When we think, we mentally manipulate these mental images.** Others believe that we encode information in terms of verbal descriptions called propositions and that mental images are sometimes added to the propositions after they are retrieved from memory.

A proposition is defined as the smallest unit of knowledge that can be validated as true or false. Even though propositions are really abstract cognitive events, most propositional theories depict them as short sentences, such as "**Clinton is president.**" **John Anderson** has proposed a theory called adaptive control of thought

(ACT) based on propositions. Anderson envisions propositions at the nodes of a net with all strands of the net leading to propositions. In this way, all thought processes are made up of propositions or combinations of propositions. **Allan Paivio** has combined mental images and verbal images (propositions) into a theory of cognitive processing known as the dual-coding hypothesis.

The
Dual-Coding
Hypothesis



3.7.1 The Dual-Coding Hypothesis

According to the dual-coding hypothesis, **information is encoded by means of both an imagery system and a verbal system**, each working independently. We use the imagery system for processing real, concrete items and pictures, such as blue hippos and a painting of the **Mona Lisa**. We use the verbal system for more abstract items, such as spoken or written words and concepts such as liberty. So the imagery system is specialized for processing information about nonverbal objects and events, whereas the verbal system is specialized for processing linguistic information and generating speech.