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The Generative Processes of Memory

by M. C. Wittrock

M. C. Wittrock is a professor of educational psychology in the Graduate School of Education at UCLA specializing in learning and instruction, especially among children. In the following chapter he traces the history of methods for stimulating learning and memory from ancient times to current practice. He shows how central findings from recent research on the processes of the brain can help explain ways schoolchildren learn. The generative model of learning he presents emphasizes that verbal processes and imagery can be used to construct meaning for events and subject matter. He also discusses implications of recent research for teaching and presents the results of an extensive series of research studies on human learning, reading, and instruction.

Historical Context

To understand some of the meanings and educational implications of the recent research on the human brain, we will begin

with a discussion of the methods developed in ancient Greece and Rome to help teachers, students, orators, and statesmen to remember information, ideas, and speeches. In those days inexpensive writing instruments and books were not readily available to serve as memory aids. In their stead, imagery and mnemonic devices were used to facilitate memory by constructing vivid representations for ideas and information.

ANCIENT TIMES

Simonides, a Greek lyrical poet from Ceos (556–468 B.C.), recorded an ingenious system for teaching people to use imagery to improve their memories.* His system, described in at least three Latin sources (Cicero's *De Oratore,* Quintilian's *Institutio Oratoria,* and the anonymously authored *Rhetorica Ad Herennium*), was taught to many Greek and Roman orators. As established by Isocrates, Greek higher education and later Roman higher education essentially consisted of training in rhetoric, the art of public speaking (Marrou, 1956, pp. 84, 194–205). Without notes or cue cards, orators, statesmen, lawyers, politicians, and teachers spoke in public at great length, sometimes for several consecutive hours. Simonides' system enabled these speakers to remember their many points and arguments in an unambiguous sequence, beginning at any place in the series. The widely taught system was also used to memorize words, quotations, plays, and essays. His system of memory training was centrally important to the classical art of memory, which provides a useful context for understanding recent developments in research in psychology, education, and neurology.

*Frances Yates's excellent book *The Art of Memory* (1966) is the source of many of the facts reported in the historical sections of this paper. However, the quotations presented in this section are all exactly as they appear in the Loeb Classical Library translations. Yates uses some of the same quotations, but she has translated them, altering them slightly. I am deeply indebted to her for her stimulating volume on the art of memory, and to Walter Ong for his several volunes on related issues.

To introduce the classical art of memory excerpts from the three Latin sources summarizing Simonides' system are presented below.

Cicero tersely summarizes Simonides' system, as follows, emphasizing places and images.

> He [Simonides] inferred that persons desiring to train this faculty [memory] must select localities and form mental images of the facts they wish to remember and store those images in the localities, with the result that the arrangement of the localities will preserve the order of the facts, and the images of the facts will designate the facts themselves, and we shall employ the localities and images respectively as a wax writing tablet and letters written on it. (*De Oratore* 2. lxxxvi. 354)

Quintilian, an educator, the foremost teacher of rhetoric in Rome during the first century A.D., taught Simonides' system to orators and students. They were taught to use the rooms and furniture of a familiar building, often their home, as the places or the loci for the images of the events to be remembered (See Figure 8.1)

> The first thought is placed, as it were, in the forecourt; the second, let us say, in the living room; the remainder are placed in due order all around the *impluvium,* and entrusted not merely to bedrooms and parlours, but even to the care of statues and the like. This done, as soon as the memory of the facts requires to be revived, all these places are visited in turn and the various deposits are demanded from their custodians, as the sight of each recalls the respective details (Quintilian, *Institutio Oratoria* 11. 2. 20)

A more detailed description of the memory system is presented in the anonymously authored *Rhetorica Ad Herennium* (3. 17. 30). Part of that description is as follows:

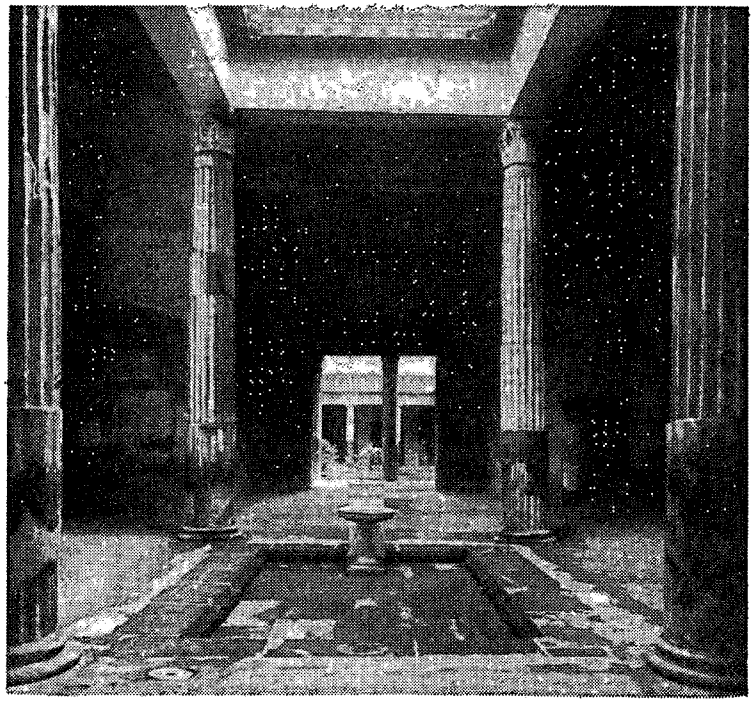

FIGURE 8.1. Photograph courtesy of Alinari-Scala.

> We should therefore, if we desire to memorize a large number of items, equip ourselves with a large number of backgrounds, so that in these we may set a large number of images. I likewise think it obligatory to have these backgrounds in a series, so that we may never by confusion in their order be prevented from following the images—proceeding from any background we wish, whatsoever its place in the series, and whether we go forwards or backwards—nor from delivering orally what has been committed to the backgrounds.

The anonymous author later discusses the qualities of images that make them effective for improving memory. His suggestions are highly similar to those given today to learners participating in

psychological studies of the effects of imagery upon memory. Ancient and modern directions emphasize distinctive, vivid, active, and comic images constructed by the learner.

> We ought, then, to set up images of a kind that can adhere longest in the memory. And we shall do so if we establish likenesses as striking as possible, if we set up images that are not so many or vague, but doing something; if we assign to them exceptional beauty or singular ugliness, if we dress some of them with crowns or purple cloaks, for example, so that the likeness may be more distinct to us; or if we somehow disfigure them, as by introducing one stained with blood . . . so that its form is more striking, or by assigning certain comic effects to our images, for that too will ensure our remembering them more readily. (*Ad Herennium* 3. 22. 37)

Let us imagine how an orator or student might have been taught to proceed, using Simonides' system. First, the speaker would have had to select a building, order its rooms from first through last, and then order the furniture and other objects within each room in an unambiguous sequence. Beginning with the first object or piece of furniture in the first room, the orator or student would then create and associate active, vivid, dramatic, idiosyncratic, comic, or grotesque images involving his points and his loci. For example, if his first point were to thank the emperor for the privilege of speaking, and his first memory locus was his living room sofa, he might imagine a comically, vividly attired emperor seated on the sofa, actively accepting his thanks. By arranging the loci within a room in a definite order, say clockwise, and then by ordering the rooms in a similar fashion, the orator could establish an unambiguous sequence for remembering his talk.

To comprehend the classical art of memory, we must now turn to Aristotle's theory of memory and recollection, which completes the ancient art of memory as it is known today. The teacher of Alexander the Great and the founder of formal logic believed

that imagery was essential to thinking and to remembering. In *De Anima (On the Soul)* and one of its appendices, *On Memory and Recollection,* Aristotle wrote, "It is impossible even to think without a mental picture. The same affection is involved in thinking as in drawing a diagram . . ." (*On Memory and Recollection* 1.450a). Later, in summarizing the section on memory, he writes, "Thus we have explained (a) what memory or remembering is; that it is a state induced by a mental image related as a likeness to that of which it is an image . . ." (*On Memory and Recollection* 1.451b).

In the same paper, Aristotle later presents his two principles of recollection, which were association and order, and his three principles of association, which were similarity, contrast, and contiguity. Aristotle used imagery as the basis of memory, and association and order as the bases for recollection.

Although it was incompatible with Plato's theory of knowledge, Simonides' memory system was supported by Aristotle's writings about imagery in memory, and order and association in recollection. Simonides' memory system and Aristotle's theory of memory and recollection comprised the classical art of memory, which persevered for over a thousand years, until incompatible neoplatonic ideas began gradually to remove it from prominence.

Yates (1966) credits Simonides system for its practical significance to orators and for its important role in convincing Romans that the orators' phenomenal memory was a god-given faculty that defied understanding. In the Roman era, the general populace regarded memory as a divine attribute.

THE MIDDLE AGES

For nearly a thousand years after the many sackings of Rome, only the *Ad Herennium* version of Simonides' memory system survived. During the Dark Ages, oratory probably was not greatly

needed nor valued. Rhetoric became largely a temporarily lost art, as did the classical art of memory.

The eleventh and twelfth centuries were the times when scholasticism and religious dogma flourished throughout Europe. With the bloom of religion came the need for effective ways to teach abstract religious ideas to millions of people in Europe. To the scholastics, memory systems again became useful and practical devices for accomplishing their purposes of remembering and making memorable the central Christian ideas which they wished to teach.

Two separate and distinct methods of memory training emerged and flourished during the late medieval period.* The first method was basically a revised version of the classical art of memory of Simonides and Aristotle. Saint Thomas Aquinas and his teacher from Paris, Albertus Magnus, led in the development and spread of the classical art of memory.

Above all others, Thomas Aquinas was responsible for the resurgence of interest in the classical rules for stimulating memory. He wrote that man's mind cannot understand thoughts without images of them, or as he called the images, "phantasmata." In Tomistic thinking, an image is a similitude of a corporeal thing. Saint Thomas believed that the understanding of universals, which to him were the commonalities across particulars (which was Aristotle's concept of them also) necessarily involved imagery. The priests of the Order of Saint Dominic, to which Thomas Aquinas belonged since before he studied with Albert the Great, tolerated and used images only because of what they considered the weakness of man's memory. Images, as physically represented in medieval architecture, painting, and sculpture, were worldly, but still necessary and important as memory aides.

*A third, less influential type of memory system was also found in medieval times (Yates, 1966). The system, which credits Democritus as its originator and Aristotle as the contributor of the laws of association, may have descended through Byzantine cultures. However, the system was not nearly as widespread as the classical and Lullian memory systems. For these two reasons it is not discussed further.

Thomas Aquinas, who was influenced by Aristotle's *De Memoria,* taught and wrote about Aristotle's theory of memory and recollection, including its three laws of association, and the *Ad Herennium* rules for places and images, which are given above. From these classical sources, Aquinas developed four rules for training the memory, which explained how to use images, order, places, and meditation and repetition. His four rules for the training of memory were set forth in a clear, straightforward manner and were widely taught throughout Europe by the Dominican priests. The rules were used by public speakers, especially clergymen, for organizing and remembering speeches and for making abstract religious concepts memorable to their audiences. In medieval times, students were again taught Simonides' art of memory, but now Gothic buildings, their statues and their decorations, were used for the loci and the images.

Frances Yates (1966) suggests that medieval architecture, painting, and sculpture, with their bizarre, grotesque, beautiful, sometimes ugly imagery, were greatly influenced by the rules of the classical art of memory, especially by Thomas Aquinas' writings about them. The bizarre, vivid imagery and personification of abstract verbal ideas (sin, love, hate, heaven, and hell) embodied in the architecture, sculpture, and painting of medieval times may have represented organized memory aids, designed after Simonides' art of memory, to facilitate recall of important religious concepts (Yates, 1966, pp. 95–96). The medieval imagery represented in the gargoyles, statues, figures, and painted glass of medieval buildings may have been a way to elaborate, organize, and make concrete the central abstract religious virtues, vices, rewards, and punishments of the Christian religion. Yates suggests that Dante's *Divine Comedy,* especially the *Inferno,* was a memory system designed to teach people to remember the punishments and rewards that followed their actions by associating them with images of the specific compartments of heaven or hell.

Yates has developed an intriguing hypothesis. To her emphasis on memory aids I would add an emphasis upon the pedagogical value of the imagery represented in medieval statues, paintings, and buildings. Together these two emphases suggest that modern scholars may have misunderstood the psychology and character of many medieval people by generalizing about them from the grotesque and fanciful figures which adorned their buildings and paintings. Perhaps, without ready access to inexpensive teaching aids such as printed pages, some of the spiritual and intellectual leaders of medieval societies adopted and used the classical art of memory to design paintings, buildings, and statues to help them teach the central ideas of the Christian religion. If Yates's hypothesis is sound, it is ironic that the pagan concept of using images to facilitate memory should have survived through medieval times because it was an effective tool for teaching Christian dogma, vices, and virtues.

In sharp contrast to the memory-training system of Thomas Aquinas, which was basically a revival and recombination of the rules of memory of Aristotle and the *Ad Herennium* version of Simonides' system, was a system developed by Ramon Lull, the second major memory system widely used during the Renaissance. Born ten years after Thomas Aquinas, Lull devoted much of his adult life to the development of his abstract verbal system for training the memory.

Lull, an eccentric whose thinking was far removed from medieval philosophy, used almost no dramatic images or corporeal similitudes in his memory system. Instead he used letters, divine attributes, abstract symbols, abstract ideas, and dynamic loci which revolved on concentric circles called memory wheels (e.g., *Ars Magna,* pp. 1–4). His system was designed to help one remember all subject matters.

In his system were the attributes of Goodness, Greatness, Eternity, Power, Wisdom, Will, Virtue, Truth, and Glory. Each of these nine attributes was used at each of the following levels leading into the house of wisdom. In descending order, the levels were (1) God, (2) angels, (3) stars, (4) man, (5) imagination, (6) animals, (7) plants, (8) elements, and (9) the virtues and the arts

and sciences. The configuration of nine attributes at each of nine levels yielded 81 loci useful for remembering information in an organized way.

Lull also used other, more pictorial representations (*Le Livre Des Bêtes,* pp. 48, 64, 80, 96, et passim), including one where the branches and roots of a tree comprise an encyclopedic system of knowledge (*Arbor Scientiae*). In all of Lull's visual representations of verbal knowledge there are no vivid images as taught by the originators of the classical memory system. Instead, in Lullian diagrams we usually find abstract formulas, verbal symbols, words, names, and attributes.

The Lullian system seems more compatible with neoplatonic ideas than with scholasticism and the Aristotelian laws of association and reminiscence, with Renaissance ideas more than with medieval philosophy and psychology. Even so, the Lullian system still represents a visual, spatial organization of verbal concepts.

As the Dominican friars taught and circulated Thomas Aquinas' revival of the classical art of memory, the Franciscan fathers learned and circulated the Lullian memory system.

In the sixteenth century, a chair of Lullism was established at the Sorbonne. The first holder of the chair, Bernardus de Lavinheta, recommended and taught the classical memory system of Simonides and Aquinas for remembering "sensibilia," and the Lullian system for remembering "initelligiblia." Lavinheta's synthesis represented the two major memory systems that dominated the medieval era.

THE RENAISSANCE

During the Renaissance, sweeping changes occurred in psychology, in philosophy, and in the spirit of the times. These changes were reflected in education, in teaching, and in the training of memory.

In ancient times, imagination was used to compose striking images to aid people, especially orators, to learn and to remember

their speeches. In the Middle Ages, the earthly and base imagination was used to compensate for what was considered the human weakness in memory. Images became euphemistically termed "corporeal similitudes," which were needed to aid the weak mental faculty of memory.

Among the changes in psychology during the Renaissance was a new concept of cognition, especially imagination. Imagination rose from its earthly, venal, medieval status to become a divine and magically powerful faculty. In the Renaissance imagination became the essence of the art of facilitating learning and memory, which then became a constructive process of generating new secular knowledge as well as the more familiar process of remembering previously learned religious concepts. In the Renaissance it was believed that through his divine and magical imagination, man could understand the entire universe, especially with the aid of organized, magical memory systems. The new self-confidence in man's imagination must surely have been an important factor in producing a rebirth of learning, invention, and discovery.

Among the changes in philosophy of the Renaissance was the neoplatonic conception of the primacy of abstract ideas. This conception intruded upon the Aristotelian concept of ideas or universals being the commonalities across the particulars. Platonic conceptions of knowledge and ideas deemphasized the role of imagery in learning and in understanding.

The above changes in philosophy and psychology are represented in the changes in ways people during the Renaissance learned to remember organized bodies of information and subject matter. In addition, the increasing technological sophistication of the times influenced the training of memory. The printed book became an effective memory aid which greatly affected the memory systems that teachers and preachers used to remember their ideas and to make them memorable to their charges.

The two distinct, highly prominent memory systems of medieval times—the classical system, as revived by Thomas

Aquinas and circulated by the Dominicans, and the Lullian system, invented by Ramon Lull and taught by the Franciscan fathers—led to complicated, highly elaborate memory systems during the Renaissance. The complicated Renaissance systems based upon using the imagination were used as magical ways to generate new knowledge.

Guilio Camillo's memory theater (Yates, 1966) is an excellent representation of such Renaissance memory systems. Camillo's wooden theater was crowded with images. However, the places and the images were strictly Renaissance, not medieval, in character. The theater was hierarchically organized into seven levels divided into seven gangways. The seven gangways represented the seven planets; and each of the seven levels represented a dimension of knowledge, with the lowest layer representing the most fundamental.

The seven planets and their images represented the first layer of knowledge and also provided the names for the seven gangways. The second layer of knowledge was represented by images of a banquet given to the gods, which symbolized the first day of creation in Homeric mythology. The third level depicted a cave, which in the *Odyssey* symbolized a further stage in man's creation. The other levels represented the creation of man's soul, soul and body, man's behavior, culture, art, science, and so on. These two series then represented the two dimensions of an organized system of the knowledge of the universe. For example, in the banquet level, the image for the planet Jupiter represented air as a simple element, while the same image appearing in the next higher layer, the cave, represented air as a mixed element (Paivio, 1971, p. 164). In Camillo's theater we find the classical rules for images and places adapted to a Renaissance, magical, ambitious representation of the organization of all knowledge of the world.

Giordano Bruno, a Dominican born in 1548, devoted his life to philosophy and to the construction of memory systems. Many volumes have been written about this extraordinary man, including one by Frances Yates (*Giordano Bruno and the Hermetic Tradition*, 1964). Bruno combined the classical memory system with Lullian ideas. Bruno meshed Thomas Aquinas' four rules for memory with images from the zodiac, astrology, and the planets. As in Lull's system, Bruno placed these magical images on revolving concentric circles; each with thirty segments. In his most complicated system he combined the round Lullian system with a square system composed of memory rooms, each divided into nine memory places, which were further divided into representations of the physical world, man's culture, and knowledge. Bruno seems to have combined in his systems nearly every principle we have previously encountered.

Camillo's and Bruno's systems represented a revolution in the Renaissance in thinking and in attitude about imagination. From the lowly status of a base faculty, imagination and acquired magical properties and had risen to a divine status, where ironically memory had been since ancient days.

The memory systems of the Renaissance reflected a related change in the training of memory. Although the systems still used visual and spatial configurations, the Renaissance memory systems were becoming increasingly abstract and verbal and were used for generating new knowledge. Words, not striking images, appeared commonly in them. The physical universe and the discovery of knowledge about it became the central concern. The religious vices and virtues remained in the systems, but they became part of a larger whole.

Perhaps printed words and books, perhaps also the discoveries of scientists, were producing these effects upon the art of memory. In any event, new ways were needed in the Renaissance to organize, to communicate, and to remember the burst of knowledge about the physical universe and to express the new confident conception of man's creative intellectual powers. The tried and venerable classical memory-training techniques were modified to accommodate the problems of the times and the emphasis on verbal symbols and universals. However, the techniques became more generative and hierarchical, with the printed words and abstract symbols

appearing contiguously with the concrete images representing them.

The best example of the continuation of the progression of events described above was the memory system of a sixteenth-century reformer of educational methods, Pierre de La Ramée (Peter Ramus), a French dialectician (1515–1572). His master's examination thesis was rashly entitled "All That Aristotle Has Said Is False" (Graves, 1912, p. 26). He introduced a "dialectical order" that nearly abolished the classical art of memory. W. S. Ong also discusses Ramus's contribution in *Ramus: Method and the Decay of Dialogue* (1958) and another book (Ong, 1971).

In place of images, Ramus substituted hierarchical arrays of words in which, as in an organizational chart, the most general categories are given first. These categories are divided into sub-parts or sub-categories, which in turn are further subdivided. Gone were the images and places and the classical rules for them. Spatial organization and visualization of hierarchical relations were still present. But the representation was more abstract and verbal, without the imaginative figures and the concrete images common to most ancient, medieval, and Renaissance memory systems.

It is interesting to note that in his forties, Ramus became a Protestant convert, openly critical of the imagery in Catholic churches and in Greek and Roman architecture. With his disdain for imagery, Ramus reformed teaching methods in France. His dialectical order, with its focus upon hierarchical organization, introduced a new emphasis on abstract but hierarchical verbal relationships in school learning.

MODERN TIMES

Memory systems declined in influence after the Renaissance, although they were still known and used by some scholars. Francis Bacon wrote about memory systems and images, as did Descartes.

Leibnitz apparently knew the memory treatises well and was influenced by Lull's system. Nonetheless, the standard images used in the organized memory systems declined within men's minds as quickly as did their external counterparts, the statues and the ornaments that formerly graced their buildings.

In modern times variations of the above systems appeared, with the loci adapted to the changing interests and problems of the learners. For example, in England in the seventeenth century, Robert Fludd, a medical doctor, developed a square system using a theater resembling the Globe theater, and a round system using celestial images.

However, the memory systems, especially their generative characteristics, were rapidly declining and falling into disrepute, becoming used primarily as **mnemonics** (memory aids). For example, Gregor von Feinagle* used rooms with images associated with numbered areas on the walls, floors, and ceilings. To remember numbers, dates, and historical events, the numbers were coded into words, using consonants to represent the ordered digits. An image in the room was used to represent the event. One part of the image was the word whose consonants could be decoded into the year of the historical event. Related mnemonic systems based upon imagery still exist today, but they are no longer in the mainstream of educational methods.

The causes of the decline and fall of the use of imagery in training memory in post-Renaissance times are not well understood. Perhaps this decline was due to the new availability of inexpensive writing instruments and printed books, and, if you are a daring speculator, perhaps to an increasing dominance of the left hemisphere over the right hemisphere. The Neoplatonic movement in philosophy and the Protestant Reformation, which disparaged the use of imagery in the sculpture, painting, and

**Webster's New Word Dictionary, College Edition* (1964) states that the word *finagle* (or *fenagle* is a "probable respelling of Fenaigle, G." and means "to cheat, get by trickery, or, in card games, to renege or revoke." However, the word may derive its meaning from Fenaigle's expertise in whist.

architecture of ancient, medieval, and Renaissance cultures, may also have diminished the need to use imagery to facilitate learning and memory in schools. (See Yates, 1966 for further discussion of the training of memory.)

Whatever the reasons for the decline and fall after the Renaissance of the use of imagery to facilitate learning and memory, an understanding of the history of the art of training the memory provides an excellent context for understanding recent research in cognition, educational methods, and the lateralization of processes of the human brain. Since about 1950 there has been a renewal of interest in the use of imagery to facilitate memory and understanding*

Recent Research

The new shift in emphasis, I believe is the result of the decline of one line of research, the rise of several relatively independent but converging lines of research, the ubiquitousness of television and movies, and a new belief in the dignity of the individual in a technological society. First, there is the recent decline of behaviorism which prevailed in America from 1900 to about 1950 in research in psychology, in educational psychology, and in education.† In this area, the positivism of American behaviorists directed

*Walter Ong (1971) interprets the progression differently. He views the progression as a continual increase in the visual presentation of information through and including contemporary American society. See also his other works on the same theme (1958, 1967, 1968).

†The heavy American emphasis on functional behaviorism may have helped to bring about the fall of interest in imagery in psychology. Paivio (1971, p. 167) states, "Behaviorism in general represented a "protestant reformation" movement in psychology, and Watson's rejection of imagery and his concomitant emphasis on verbal processes as the mechanism of thought (including memory) in particular bears a striking resemblance to Perkins' earlier rejection of Brunian memory and his advocation of Ramism."

research away from cognitive processes, such as thinking, attention, memory, and imagery. Educational psychology was part of the trend, to the point of disparaging cognitive conceptualizations of school learning.

Within that behavioristic theory, school learning and teaching were often conceived as the art of getting students to practice verbal or motor behavior to obtain reinforcement or reward. That is, school learning was often conceived primarily as the operant or instrumental conditioning of stimuli to responses.

Within the last several years, the dominant paradigm for research in education is beginning to shift as a result of the findings from several lines of research. Ironically, even the research on computer technology has helped to lead researchers to hypothesize internal cognitive processing devices, such as buffers, memory, and storage.

At a popular level, television and movies brought active, dramatic, bizarre, and comical images into the daily lives of most Americans. The impact of these media has been written about frequently elsewhere, although not in terms of their mnemonic and generative characteristics as I am suggesting here. Nonetheless, I will not elaborate upon the deep effects of the media upon our values and lives.

In psychology, the shift to research on memory and away from immediate performance hastened the reconstruction of internal cognitive states to mediate across the time between learning and delayed performance. Also in psychology, interest in modeling and observational learning led to the reconsideration of the values of positing hypothetical cognitive states, such as attention, motivation, and imagery, to explain how learning is retained and retrieved.

Almost simultaneously with the these renewed interests in memory, computer technology, and observational learning came the independently discovered findings of the researchers studying the lateralization of the human brain. Their findings, some of which are reported in other chapters, have fundamental signifi-

cance for understanding human learning and memory, for integrating the several lines of research mentioned above, and for advancing knowledge about teaching and instruction.

The historical context that I developed above will aid in the understanding of recent findings and recent theories and models. The earliest of the research reported below, done by my students and me, was conducted independently of the recent brain research. However, our data are quite compatible with the findings of this research, which supply us new explanations and hypotheses. Our interests now center upon converging these lines of research into a model of the generative processes of learning and remembering, and upon understanding and facilitating the processing systems of the brain. Below are some of the findings of our research and related research by other people.

IMAGERY AND SPATIAL ELABORATION

Allan Paivio (1971) describes empirical studies on imagery. Most of these studies indicate that the following three imaginal techniques facilitate recall in psychological laboratories.

First, instructions to the learner to "image" the information to be remembered usually facilitates recall. If the learner develops an interactive image involving two or more of the words to be remembered, recall is facilitated. Second, high-imagery words (i. e., concrete words) usually produce a sizable facilitation of recall. Third, pictures facilitate recall of the objects or concepts they represent. Paivio writes that imagery is the single most important variable determining free recall in his studies (1971).

Studies with schoolchildren also usually indicate that instructions, pictures, and high-imagery words facilitate learning and recall, although the size of the effect is often less than that obtained in the laboratory. At UCLA several experiments were conducted to determine if kinetic molecular theory could be taught to kindergarteners and primary school children using

pictures, concrete examples, and simple verbal text to introduce and explain the concepts of molecules in motion, states of matter, and changes in states of matter (Keislar & McNeil, 1962; Wittrock, 1963). Several hundred original colored drawings prepared by artists were used to represent molecules, gases, liquids, solids, evaporation, and condensation. After two to four weeks of instruction, two-thirds of the children in one study (Wittrock, 1963) successfully learned and remembered the concepts one year later. These concepts were previously thought to be too complicated for children below Piaget's symbolic (age eleven) or concrete (age seven) levels of intellectual development.

But in this study the verbal abstractions were all iconically presented, using concrete examples familiar to the child. The verbal and the spatial materials were presented simultaneously, perhaps allowing the two to interact, and perhaps allowing the spatial materials to elaborate and make more specific the abstract verbal concepts.

In another study (Wittrock, 1967), primary school children were taught to solve problems using cards with pictures pasted on them to represent the four hypotheses they were to test. These concrete pictorial representations of abstract hypotheses enabled the children to outperform the control group given the same instruction and problems but no cards. A third group given the cards plus a procedure for testing each hypothesis in turn—by "hanging the hypothesis card on a hook and discarding the card after refuting the hypothesis"—performed the best of the three groups, even on transfer tests where the problems and hypotheses were new and the cards were unavailable.

In a more recent study (Bull & Wittrock, 1973) definitions of vocabulary words were taught to elementary school children. We compared three different procedures:

- Read and write the words and their definitions (verbal).
- Read the definition and trace the picture of it (image given).

- Read the definition and draw your own picture to represent the definition (generate an image).

We predicted and found that generating images would produce the best recall, tracing images the second best recall, and learning the words only, the lowest recall. These differences were statistically significant but not large.

We explained the results as follows. Learning verbal materials by elaborating them imaginally enhances their recall probably because they are processed in two interacting ways. Compared with tracing, generating one's own image of each word further increases recall probably because it stimulates relating the new abstract term to one's idiosyncratic experience, giving it a distinctive meaning.

VERBAL AND SEMANTIC PROCESSING

The findings of laboratory experiments in psychology, in which verbal organizations are constructed by learners, sometimes include sizable effects upon memory. Bower and Clark (1969) gave college students twelve tests of ten unrelated nouns. The control group was asked to learn and to remember the ordered lists in whatever way they wished. The experimental group was asked to make a story from the words of each list. The control group remembered 14 percent of the ordered lists of words. The experimental group remembered 93 percent of them. With results as impressive as these, statistical tests seem superfluous.

In another study, Bower, Clark, Lesgold, and Winzenz (1969) used three different hierarchical arrays of words: (1) unrelated words, (2) randomly arrayed conceptually related words, and (3) properly arrayed conceptually related words. Recall of the words increased with the increases in their verbal and spatial organization from group 1 through group 3.

In a related study (Wittrock & Carter, 1975) the same three treatments were presented, but with instructions either to process the words *generatively* (rearrange them until they fitted a logical pattern) or to process them reproductively (copy them). The results found by Bower et al. were replicated in the copying treatment. More importantly, the **generative processing** condition greatly increased retention in each condition, usually doubling it, even when there was no logical pattern to be discovered.

This study suggests that in addition to the type of representation, verbal or imaginal, the kind of processing performed by the learner is important. When the learner relates new information to his experience and is required to construct associations or meaning involving the new information, his learning and recall is facilitated. The above study provided a useful test of the *generative hypothesis,* which I have been developing over a number of years. Unlike semantic processing hypotheses, which suggest that meaningful learning is primarily a process of constructing abstract verbal associations or dictionarylike lexical meanings, the generative hypothesis interprets learning primarily as the construction of concrete, specific verbal and imaginal associations, using one's prior experience as part of context for the construction. It is a model of learning as the transfer of previous learning.

The generative hypothesis has been investigated in several experiments on reading (Marks, Doctorow, and Wittrock, 1974; Wittrock, Doctorow, and Marks, 1975; and Doctorow, Wittrock, and Marks, in preparation), the latest one of which will be briefly described in Figure 8.2. In it, children read commercially published stories commonly used in public schools to teach reading. As they read these stories, the children were asked to generate (G) headings for each paragraph of each story, or were given one (O_1) or two-word (O_2) organizers for each paragraph, or were asked to read stories in the three control groups (C). From the generative hypothesis I predicted the experimental treatments to rank above the control treatments, and from high to low in the left-to-

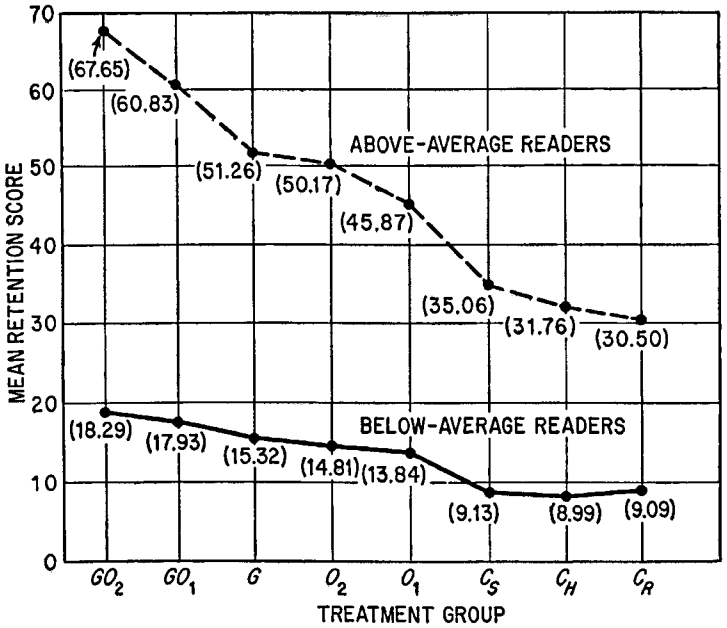

FIGURE 8.2. Mean retention scores for above-average and below-average readers. (Adapted from an article by the author appearing in the 1974 *Educational Psychologist,* 11, *2,* 89. Copyrighted by the American Psychological Association, Inc., 1974).

right order indicated in Figure 8.2. As the figure indicates the predicted rank order occurs without exception in both experiments with the measures of comprehension and recall ($p < .001$).

In sum, it appears that when schoolchildren process information generatively their learning and recall is facilitated, sometimes dramatically. These results are quite compatible with research on the human brain, which helps us understand why and how what we have called verbal and imaginal processing techniques may produce their effects in the classroom and in the laboratory.

For the future, we need to study and learn more about how our teaching techniques can be designed to stimulate the two hemispheres and their processes to interact with one another to

construct representations that are long remembered. That is, having analyzed some of the different processes of the brain, we now need to synthesize them into an understanding of how they relate to each other in complicated educational contexts, such as the teaching of reading, mathematics, art, and music. We also need to determine when an interaction between brain processes is inhibitory to learning.

RELATED THEORETICAL MODELS AND EDUCATIONAL RESEARCH

There are additional theoretical and empirical lines of research that are investigating closely related problems, a few of which are briefly mentioned below.

First of all, a large number of studies have been conducted on the effects produced by inserting into texts a number of adjunct questions for the readers to answer. These complicated findings are well summarized in a forthcoming chapter by Anderson and Biddle (1975). As they indicate, the recent research on adjunct questions has involved little theorizing. Unfortunately, the interesting data have not been adequately synthesized into a model nor closely related to cognitively oriented research and research on human brain processes.

In his *dual-processing model* of encoding, Allan Paivio (1971) has related much of the recent laboratory research on imagery and verbal processing of information to the recent research on the human brain. He posits two separate but interacting systems of encoding and storing information: *verbal processing* and *imaginal processing.* He cites a wealth of research data to support his model.

However, in one area of research—the study of the effects of instructions to process words either verbally or imaginally—the data often conflict with Paivio's model. To try to reconcile these conflicting findings, two recent experiments were conducted (Wittrock & Goldberg, 1975) in which verbal processing and imaginal

processing were varied in the instructions to the learners and in the characteristics of the words to be remembered. We hypothesized that the studies conflicting with the dual-processing model may not have considered the strong imaginal or verbal associations of the words to be learned. These characteristics, developed over many years, may be more important than the instructions.

In our studies, one with college learners and one with junior high school learners, the conflict was resolved. More specifically, high-imagery words tended to be imaginally processed regardless of the instructions to process them verbally. The reverse was true for words high in verbal meaningfulness but low in imagery. After reexamining the findings of other studies in terms of word associations rather than instructions, we discovered that most of the findings ostensibly disagreeing with a dual-process theory are actually consistent with it. Word meanings have developed over many years. As a result, they tend to override the situational effects of directions, at least when the directions involve a type of processing contrary to the learner's long history of experience with the words.

School Learning as a Generative Process

In the context of the historical events mentioned above and of the recent research on the human brain, imagery, and semantic and verbal processing, I suggest that learning in schools be reconceived as a generative cognitive process (see Wittrock, 1974). That is, learning involves the active construction of meaning for stimuli, using verbal processing, imaginal processing (or propositional and appositional processing), and perhaps other types of processing. From this point of view, it is plausible that learning is basically a process of relating stimuli to previous experience, from which one

induces and elaborates meanings and representations. According to this model, learning with understanding is the process of transferring previous experience to new events and problems. This position is quite compatible with recent brain research and with the classical art of training the memory.

In this view, teaching is more than the reinforcement of correct responses in the presence of discriminative stimuli. In large part teaching is the process of organizing and relating new information to the learner's previous experience, stimulating him to construct his own representations for what he is encountering. Students learn by active construction of meaning, by what reactions the teacher causes them to generate.

Implications for Teaching

The recent research on the brain has implications for fundamental changes in education. In Chapter 7, J. E. Bogen has cogently discussed many of these important implications, including educating both hemispheres, the need to increase diversity in curricula and methods, and the newly found basis for reemphasizing methods of learning. In the following paragraphs, I would like to emphasize three educational implications from the research presented in this and preceding chapters.

First, the research presented in this book indicates the importance of understanding that people process information in different and multiple ways which may interact with one another. We have also found that we can facilitate learning by stimulating generative processing of information. The first implication of these findings is that the art of teaching needs to devise sophisticated ways to facilitate the multiple processing systems of the brain.

Second, the research described in this book gives us some new insights into old issues, such as the teaching of reading and

inductive-deductive learning. In the case of reading, a complex set of cognitive processes is involved, as the brain hemispheres work in conjunction with each other in recognizing shapes and phonemes, in associating meanings with syllables and words, in comprehending sentence and story meaning by relating previous learning to the text, and in converting meaning into speech, including selecting syllables, intonation, pitch, and stress. Reading then is a much more complicated process than some of us thought it was.

The recent research mentioned above also gives us a better understanding of a wide range of reading problems, such as dyslexia, developmental lag, and incomplete cerebral dominance. For example, suppose that, as Gazzaniga (1970) summarizes it, very young children have language present in both hemispheres and have an incompletely developed corpus callosum. Through growth and developmental processes and through stimulation from people and experience, the left hemisphere gradually becomes dominant for sequential, verbal-semantic, or propositional functions, the right hemisphere for simultaneous, spatial-imaginal, appositional functions, and the corpus callosum matures and interconnects the two more completely. If any of these growth or developmental processes do not occur properly, a reading problem will appear.

Even if these processes occur normally, stimulation of the processes of the brain in interaction with each other would still be important in facilitating the learning of language and reading, as has been found in several empirical studies. Moeser and Bregman (1973) successfully used pictures to improve the teaching of syntax. Yarmey and Bower (1972) used imagery instructions to raise the performance of educable retarded children to the level of normal children on paired-associate tasks. Levin (1973) found that both good and poor readers improved their comprehension after imagery instructions. Children with vocabularies more than one year below grade level were helped most with the pictures.

Although it is only a beginning at understanding the complexities of reading, the above conception suggests one interesting analysis of the facilitation of reading: Children may need practice at associating the sounds and semantic meanings of words, primarily on the left side, with the recognition of their shapes, primarily on the right side.

In addition, the research summarized in this book should help us to develop new diagnostic tests of sequential verbal-auditory processes and of simultaneous visual-spatial ones and, perhaps someday, measures of their connectedness. The recent research should elucidate the need to tailor reading methods to the aptitudes or disabilities of the learners. The long quest for a universally superior reading method, one that was to be better for nearly all students, may have been a futile one. It now seems more advantageous to study methods in relation to aptitudes and to the processes used by the brain to construct meanings and representations for printed words.

For my third implication, let us discuss recent research which may suggest new concepts about methods of presenting subject matter. As Krashen mentioned in Chapter 6, one of the graduate students at UCLA, Dayle Hartnett (1974), hypothesized and found an interaction between brain hemispheric dominance and effectiveness of inductive and deductive methods of teaching Spanish. Inductive learning, which involved synthesizing parts into wholes was presented in the curriculum prepared by Dr. J. Barcia. Inductive learning was as effective or more effective than deductive learning for right-hemisphere-dominant students. Deductive learning, which proceeds from the rules to the examples, was more effective for left-hemisphere-dominant learners studying the curriculum prepared by Dr. W. Bull. This interesting study indicates a way to theorize about how instructional treatments may interact with aptitudes or with brain processes.

In matching teaching methods to aptitudes or processes, there is the issue of which mode should be the dominant or pri-

mary mode of instruction and which mode should be the elaborative mode. Instruction may often be better when multiple modes are used, not just the learner's dominant mode. One important educational issue seems to be, not the determination of a single mode for a learner, but rather the selection of which primary mode is to be excited simultaneously with which secondary one to stimulate an interaction between the hemispheres.

The issue is complicated by the realization that in the design of instruction the nominal stimuli—for example, pictures—must be understood in terms of the type of processing, verbal-semantic or imaginal, they stimulate among learners. Although pictures are normally processed imaginally, an instructional method using pictures might stimulate the learners to describe these pictures with sentences. In that sense, what appears to be a pictorial method of instruction might better be understood as a verbal-semantic one, or perhaps an interactive one, involving imagery and semantic-verbal processes. The mode of instruction may not be important. The important point is that the treatment must be understood in terms of the types of processing of information it stimulates, not only in terms of its nominal characteristics.

Summary

The theme of this chapter is that learning and memory are generative processes. The major educational implication of the theme is that the methods of teaching should be designed to stimulate students actively to construct meaning from their experience, rather than stimulating them to reproduce the knowledge of others without relating that knowledge to their own experience.

From ancient times through modern days the theme of learning and memory as constructive processes recurs. Simonides viewed remembering as a constructive process. By having students use their previous experience to construct imaginal representations for verbal concepts, he taught them how to improve their memories. His ingenious procedure, in itself not important today, becomes significant when it is related to the subsequent events of the Middle Ages and the Renaissance and to current research findings. In these contexts, I suggest that we may not fully appreciate the pedagogical and mnemonic value of imagery concretely represented in architecture, painting, and sculpture.

The findings of the recent research on the lateralization processes of the human brain provide scientific evidence which indicates that learning and memory are processes that often involve constructing representations in both brain hemispheres. Zaidel and Sperry (1974, p. 270) summarize their related findings as follows:

> Taken collectively, the results support the conclusion that the inter-hemispheric commissures are important to memory especially in the initial grasping and sorting-for-storage of perceived information, and at later stages in the retrieval and read-out of contralateral or bilateral engrams.

Láter, on the same page, they conclude their article as follows:

> In particular the data suggest that processes mediating the initial encoding of engrams and the retrieval and read-out of contralateral engram elements involve hemispheric co-operation and depend upon the functions of the inter-hemispheric commisures.

In one sense we are where we started with this chapter, with Simonides and his discovery of the facilitating effect upon memory of constructing imaginal representations for words and sentences. In another sense, we are far ahead of Simonides. The findings

of recent research from several lines of inquiry indicate that we can facilitate learning with understanding and comprehension by stimulating the brain to process information generatively.

* * *

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