Analysis of a Mnemonic Device

Modern psychology uncovers the powerful components of an ancient system for improving memory

It is in the nature of the mind to forget and in the nature of man to worry over his forgetfulness. Forgetfulness is the constant thorn in the side of the scholar and the scientist, the bane of every student's existence. Stories about such total memory catastrophes as amnesia, loss of personal identity, dissociated or multiple personalities have such a gut-level appeal and fascination for us that we will pay to see them dramatized. Similarly, we are sufficiently amazed by a spectacular memory that Walt Disney Productions can make a profit on a banal movie (The Computer Wore Tennis Shoes), whose weak plot revolves about an idiot savant who acquires and retains information with the speed and reliability of a computer.

Since time immemorial men have searched for various incantations, rituals, tricks, gimmicks, artifice, and methods to improve their memories. Incantations and prayer aside, the latter efforts have been partly successful, and by now a very few highly specific and reasonably successful methods are known. Collections of these mnemonic tricks are sold in commercial memory courses, which are usually advertised in the back pages of newspapers and pulp magazines. These typically lurid advertisements proclaim how success in life, love, school, and business is the sure-fire sequel of the super-powered memory that will issue from the reader's signing up and paying for the course. Although such hard-sell tactics are somewhat repugnant to respectable scholars (who view their grand proposals and fund-raising speeches in a different light), we should not be deterred by these commercial trappings from investigating scientifically some of the mnemonic devices. In this paper I will discuss one of these mnemonic devices, show how it works, begin some experimental analyses of its principal components, and show how these lead into scientific questions about the mind and language that are at the current frontiers of psychological research.

The mnemonic and its history

The particular mnemonic to be studied, called the "method of loci," has been known in Western civilization since ancient Greek times. Cicero (in De Oratore) claimed that the method originated in an observation by a Greek poet, Simonides, about whom he told the following story: Simonides was commissioned to compose a lyric poem praising a Roman nobleman and to recite this panegyric at a banquet in his honor attended by a multitude of guests. Following his oration before the assembled guests, Simonides was briefly called outside the banqueting hall by a messenger of the gods Castor and Pollux, whom he had also praised in his poem; while he was absent, the roof of the hall collapsed, killing all the celebrants. So mangled were the corpses that relatives were unable to identify them. But Simonides stepped forward and named each of the many corpses on the basis of where they were located in the huge banquet hall. This feat of total recall is said to have convinced Simonides of a basic prescription for remembering—to use an orderly arrangement of locations into which one could place the images of things or people that are to be remembered.

Cicero relates this story about Simonides in connection with his discussion of memory regarded as one of the phases of rhetoric. In ancient times rhetoric teachers provided memory instruction because, in those days before inexpensive paper and writing implements, public speakers had to memorize an entire speech, or at least the sequence of main topics. For this reason most references to the method of loci come down to us from treatises on rhetoric, such as Cicero's De Oratore, the anonymous Rhetorica ad Herennium, and Quintilian's Institutio Oratoria. Frances Yates tells the historical story in fascinating detail in The Art of Memory and provides a detailed description of how the method of loci was used in ancient times:

It is not difficult to get hold of the general principles of the mnemonic. The first step was to imprint on the memory a series of loci or places. The commonest, though not only, type of mnemonic place system used was the architectural type. The clearest description of the process is that given by Quintilian. In order to form a series of places in memory, he says, a building is to be remembered, as spacious and varied a one as possible, the forecourt, the living room, bedrooms, and parlours, not omitting statues and other ornaments with which the rooms are
The images by which the speech is to be remembered... are then placed in imagination on the places which have been memorized in the building. 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 demanded of their custodians. We have to think of the ancient orator as moving in imagination through his memory building whilst he is making his speech, drawing from the memorized places the images he has placed on them. The method ensures that the points are remembered in the right order, since the order is fixed by the sequence of places in the building [Yates 1966, p. 3].

To summarize, the prescription for memorizing a series of items is (a) first to memorize a list of "memory snapshots" of locations arranged in a familiar order; (b) to make up a vivid image representing, symbolizing, or suggesting each of the items of information that is to be remembered; and (c) to take the items in the sequence they are to be learned and to associate them one by one with the corresponding imaginary locations in memory. The associations are to be established by "mentally visualizing" the image of the items placed into the imaginary context of the locational snapshots. The same loci are used over and over for memorizing any new set of items. Without this feature—if an entire new set of loci had to be learned for each new list—the use of the method would be uneconomical.

To illustrate, the modern home dweller might have a series of loci, such as "my driveway," "interior of my garage," "front door," "upper shelf of coat closet," and "kitchen sink." The list is easily memorized because the places and their order in nature are familiar to the person. If he were to use these loci to remember a grocery shopping list—say, hot dogs, cat food, tomatoes, bananas, and whiskey—then he would try to imagine vivid mental pictures of the items at their respective loci. Examples, shown in the cartoons in Figures 1–5, might be "giant hot dogs rolling down the driveway," "a cat eating noisily in the garage," "ripe tomatoes splattered over the front door," "bunches of bananas swinging from the closet shelf," and "a bottle of whiskey..."
gurgling down the *kitchen sink*. The images may be elaborated in as much detail as desired, with movement and color, in unusual sizes and shapes, in any form to arouse interest. Then, when the person wishes to remember the shopping list, he need only walk mentally through his list of loci (see Fig. 6), asking himself, in effect, “What did I put in the *driveway*? What in the *garage*?” and so on. The loci on the list are well learned and are easily called to mind. Recall of the scene constructed at each locus enables him to recognize and name the other main object in it, thus appearing to recall the items in their correct order.

**Does the system work?**

The mnemonic system appears on the surface to be fantastic legerdemain, constructed by elves, and reasonable people are likely to believe that magical and occult powers of mentation are required to use the system effectively. Similar systems have also been associated in modern times with showmanship and magicians, and psychologists have tended to be rightly skeptical about the authenticity of spectacular memory performances. Is there any acceptable scientific evidence that such mnemonic systems are not simply elaborate systems for self-deception? Do they in fact really improve anyone’s memory?

There is much anecdotal evidence that the system does work. A recent case is recorded by A. R. Luria in his charming account, *The Mind of a Mnemonist*. The man, S., had a truly fantastic memory. Luria, who studied him periodically over a span of many years found that S. could remember volumes of information of all sorts rapidly and without effort and could retain it for years in some cases. He relied extensively on diverse idiosyncratic associations and ruses for converting most materials into visual images, and he seemed to have discovered for himself the method of loci. The following quotation relates one of his methods:

When S. read through a long series of words, each word would elicit a graphic image. And since the series was fairly long, he had to find some way of distributing these images in a mental row or sequence. Most often (and this habit persisted throughout

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**Figure 3.**

**Figure 4.**
his life), he would "distribute" them along some roadway or street he visualized in his mind. . . . Frequently he would take a mental walk along that street . . . and slowly make his way down, "distributing" his images at houses, gates, and in store windows. . . . This technique of converting a series of words into a series of graphic images explains why S. could so readily reproduce a series from start to finish or in reverse order; how he could rapidly name the word that preceded or followed one I'd selected from the series. To do this he would simply begin his walk, either from the beginning or end of the street, find the image of the object I had named, and "take a look at" whatever happened to be situated on either side of it [Luria 1968, pp. 31–33].

In recent years such personal anecdotes have been supplemented and amplified by controlled laboratory experiments testing mnemonic devices on "normal" intelligent adults (typically college students). A typical experiment might compare recall by subjects using the method of loci to recall by other subjects instructed to learn by their usual means, and the two groups might be compared on memory for lists of related or unrelated items, objects, events, persons, or words. The results are often striking and dramatic, the subjects using loci frequently recalling two to seven times as much as control subjects. This figure represents genuine improvement; the control subjects are not shamming. In fact, they are trying very hard to remember, but are using the hit-or-miss procedures college students have developed over the years (which, one would have supposed, should be fairly efficient learning strategies).

To cite one example, J. Ross and K. A. Lawrence (1968) asked their students to study many lists, each 40 items long, for one trial, using as loci 40 locations around the college campus. After each list of 40 items (nouns) had been presented once (at about 13 seconds per item), each student immediately recalled the list. He also came back the following day to recall again the list of the preceding day and to study a new list of 40 items. Recall immediately after studying the lists averaged 38 out of 40 in correct serial order; a day later, recall aver-
Compositional analysis of the mnemonic

The next step after a few such demonstrations is to begin more careful analyses of the components of the mnemonic device, so that one may better understand the method, decide which components are essential and which are inconsequential, and perhaps understand how memory works more generally. The method of loci contains a number of distinct components. The more salient ones are:

1. There is a known list of “cues.”
2. The cues are memory images of geographic locations.
3. Cues and items on the list to be learned are to be associated during input of the list items.

4. Associations are to be made in one-to-one pairings.
5. Associations are to be effected through imaginal elaboration, specifically by use of visual imagery.
6. The imaginal construction should be unusual, bizarre, striking.
7. If the list items are studied a second time, the same items should be placed at the same loci; even if ordered output is not required, constant ordered input is desirable.
8. At the time of recall the person must cue his recall of the list items.
9. The recall cues must be the same as or similar to those he thought of while studying the items.

Recent research provides information about each of these factors and its contribution to the overall mnemonic effect. I will briefly discuss the factors in turn.

1. A known list of “cues.” What is important is that the cues (loci) be available to the person at the time the list items are studied and at the time recall is attempted. The cues, in fact, could be actual pictures of locations, or objects, or unrelated words for that matter, shown by the experimenter as he reads the critical list words to the subject.

2. The cues are memory images of locations. Neither memory images nor locations are crucial for the mnemonic effect. First, presentation of external stimuli, such as pictures, by the experimenter can substitute for the person’s cuing himself with memory images. Second, the cues need not be images or pictures of geographical locations. Such loci have the advantage of being concrete, easily visualized, and already learned in a natural serial order; but various experimental comparisons suggest that any readily visualized object or context would supply as good a cue as do scenes of geographic locations (which, after all, are just coherent collections of objects). This conclusion is suggested by the equally good recall produced by the “numeric pegword” system.

The numeric pegword system is similar to the method of loci except that the memory pegs or pigeonholes are images of unrelated concrete objects associated in one-to-one fashion with the first twenty or more integers. Typical pegwords (shown in Fig. 7) are concrete nouns that rhyme with the numbers—like “one is a bun, two is a shoe, three is a tree,” and so on. To learn a new list of items, “one-bun” is used in the same way as the first location in the method of loci, “two-shoe” is used like the second location, and so forth. That is, the person is to visualize the first object in some interaction with a bun, visualize the second object interacting with a shoe, and so on.

The pegword and loci methods are identical except for the nature of the cues and for the fact that the pegword system provides direct access to numerical-order information. For instance, a person learning by the pegword system can directly recall in isolation that the seventeenth item was car; he can also say, retrieving in the reverse direction, that car was the seventeenth item; in contrast, the “loci” learner can only reconstruct such numeric information by counting from the beginning or end of his chain of cues.

3. Cues and list items are to be associated during list input. Formation of such
associations is critically necessary for the mnemonic effect. If the person is taught the locations or pegwords but is not told how and when to use them, there is no memory improvement whatever. A similar absence of effect arises if the person is exposed to external cues such as pictures while he is hearing the list items but does not attempt to connect them. Such external or imaginal cues become effective memory “retrieval cues” only if the person tries to associate or relate them to the list items at the time the items are studied.

4. One-to-one pairings of cue and item. Pairing appears to be an irrelevant and immaterial part of the method. Multiple items can be hooked onto the same pegword or can be imagined clustered together in the same location. No appreciable loss in recall occurs if the items hooked to a given pegword arrive simultaneously or in close succession and if the person elaborates one grand imaginal scene depicting some unitary interactions among the several items and the peg or location cue (see Bower, in press). Having the several items that are being associated to a given pegword simultaneously in mind seems to be the crucial matter. Without such cognitive simultaneity, retention of earlier items is disrupted somewhat by the learning of later items (see Fig. 8). By using the simultaneous method, therefore, a list of 40 items can be stored equally well as one-to-one pairings with 40 loci or as four-to-one pairings with 10 loci. What may be lost in the four-to-one pairings is information concerning the serial order of the items within the successive quartets of the list; that information may not be preserved in the simultaneous composite scene the person constructs for each quartet.

5. Use imaginal elaboration, especially visual imagery. Imaginal elaboration of the items—seeking out and depicting interacting relationships between the referents—appears to be critically important in producing the large effects typically observed. The imagery has to be of concrete objects or referents of the words, not of words themselves. (In fact, imagery of verbal symbols—words, digits, number arrays—is generally very poor.) Since construction of verbal relationships between cue and item can sometimes produce just as high recall as mental imagery of object interrelations (see Wood 1967), the specific claims for imagery require closer examination. But it is clear that various kinds of cognitive elaboration or construction of relationships lead to greater acquisition of associations (between cue and item) than does rote rehearsal or verbal repetition.

6. Unusual, bizarre imagery. The evidence for the prescription to use odd, bizarre imagery is, to date, entirely negative. That is, four laboratory experiments that have studied this variable have not demonstrated that “bizarreness of imagery” produces a consistent, significant effect on remembering. Subjects instructed to concoct bizarre associative scenes remember the cue-to-item associations no better than do others instructed to compose familiar, regular, sensible associative scenes. Differential effects are similarly absent when subjects study pictures of associative scenes that are bizarre versus regular as rated by other people (K. Wollen, personal communication, 1970). Little thought is required to see that bizarreness is itself a poorly defined dimension; any effect such prescriptions might have in naturalistic settings is probably due to incidental factors (for example, arousing or maintaining interest in learning by the novel association).

7. Repeating each item on the same locus. When the person receives two or more study trials on the same set of words, it is important to repeat each item on the same locus. If the items do not have to be recalled in a special serial order, then the training agent (teacher, experimenter) may vary the order of presenting the items from one trial to the next. If the subject automatically assigns each reordering of the items to his string of pegwords from start to finish, several items will be hooked to a given peg (with relatively long intervals between successive “hookings”), and a given item will be hooked to several pegs. Along this way lie trouble and poor performance. First, hooking item C to the same cue (A) to which item B was previously hooked may produce something like “unhooking” or unlearning of the prior association between the cue A and the item B. This is more likely if during A–C learning the person does not implicitly revive B and associate the simultaneous complex A–B–C (refer back to Fig. 8 and its associated text).

Figure 8. Immediate and 30-minute delayed retention of 1, 2, or 5 items associated to each cue, when studied all together (massed) or individually at separate times

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Further, if an item becomes hooked to several different pegs, the person has the problem of monitoring for and inhibiting repetitions of this item in his recall. During oral recall, as he goes through his pegs, he continually must be asking himself, “Is this an item I’ve already recalled on this trial?” Such discriminations require that a separate kind of occurrence information be stored in a working short-term memory; the discriminatory decisions based on that monitor memory may be mistaken, and the person may suppress his recall of some correct items, thus lowering his performance scores. For such reasons the subject will be much better off if he places a given item on the same peg at each trial (see Bower, Lesgold, and Tieman 1969).

8. At recall the person must cue himself. If the person associates items with a set of cues, those cues must be made available to him by some means if they are to aid his recall. The pegword and loci methods prescribe that the person should generate or present himself with his own cues by running through his well-known list. But if the cues are external, and manipulated by the experimenter, their presence vs. absence will produce effects similar to presence vs. absence of the imaginal cues.

9. Recall cues must be similar to those studied. If cue A has been associated at input with item B, then any effective cue A’ for retrieving B from memory must be “similar” to A. The main and significant dimensions of similarity are that cues A and A’ be close in semantic meaning (for example, synonymous) or consist of images of neighboring regions in space or belong to common perceptual categories. An important sort of similarity for practical reasons is that between imagining a situation (A) and actually being in that situation (A’). This similarity is traded on whenever we establish in imagination associations that we wish to have activated later in real life. One example is the “systematic desensitization” treatment for specific phobias, in which a patient in therapy learns to replace his anxiety reaction (aroused by the phobic object or situation) by calm relaxation (see Wolpe 1958). The breaking and replacement of the old object-to- anxiety association is all done in imagination, by visualization, in the therapist’s office, but the changed association transfers and occurs in real-life contacts with the formerly phobic object.

A second example is a recommended and effective way to remember future intentions, as when we think to ourselves, “Tomorrow morning when I leave home for the office, I must remember to bring that book for Sam,” or “After my class tomorrow I have to telephone the service station.” The best way to remember such future intentions is to visualize vividly some specific act usually done in the cue situation (for example, eating breakfast, gathering up lecture notes) and in imagination link performance of that cueing act to thinking about and performing the required act.

To summarize the discussion of the method of loci, the important ingredients appear to be formation of imaginal associations between known cues and previously unknown list items at input, and use of these cues for recall. The control subject, exposed to the same list of items to remember but not using the method of loci, is in what psychologists call a “free recall” experiment. His problem is that he does not know how or where to search in memory for the items just presented to him. For instance, he might know that they were words, but since he knows many thousands of words, how is he to begin searching for the ones he has tagged as having been on the list just presented? The magnitude of his problem would be similar to that of trying to retrieve a few specific books in the Library of Congress after all the books and documents had been dumped haphazardly and randomly in one enormous unsorted pile. The method of loci or pegword mnemonic solves this search problem by providing the learner with a known bank of pigeonholes or file cabinets in which he stores the list items. At recall, the person knows where to start his recall and how to proceed from one unit to the next; he has a way to monitor the adequacy of his recall; he knows when he has forgotten an item; and he knows when he has finished his recall. All of these are the good fruits of the retrieval scheme, and they mainly account for its effectiveness.

How psychologists conceptualize imagery

Although imaginal elaboration of the cue-to-item associations is an important factor in the effectiveness of the mnemonic, it would be satisfying to obtain better perspective on this prescription to use mental imagery. Talk about “mental images” is viewed with some caution and jaundiced disbelief by many behavioristic psychologists, for the very good reason that people utter an awful lot of nonsense about their mental imagery. There is little intersubjective agreement on the criteria for when a person is having a “genuine” mental image, or how to describe or compare imagery in different people. The normal person’s introspections are frequently neither very discriminating nor particularly valid, and they are easily influenced by loaded or leading questions. Further, people’s claims to see a memory image in vivid detail are often easily shown to be self-deception, since they are unable to perform certain operations that they could do if they really had a picture before their mind’s eye (to read the letters of words backwards rapidly, for example). The “seeing” by the mind’s eye is a sham seeing, a pretending to see or to depict something schematically; the information represented in the ordinary memory images is largely conceptual, generic, schematic—hinted-at “ghosts” of objects distributed about a schematic theater space.

To study imagery and its role in memory, however, one need not cut through a forest of philosophical and linguistic puzzles concerning our ordinary imagery talk (see Smith 1966). Perhaps all that is needed here is to specify some meaning of the term that is useful for scientific investigations.

For these purposes, and being very brief (see Bower, in press), it is perhaps best to say that a memory image presents to the experiencing subject some of the same structural information as was presented in one or more earlier perceptions of the object which the imagery is of.

Behavioristic psychologists (such as Sheffield 1961; Staats 1968) prefer to think about imagery in terms of perceptual or sensory responses aroused by the respective objects (or representative members of a generic class). Whole complexes of several different, modality-specific, sensory responses may become interassociated through contiguous experience—for example the sight, smell, feel, and taste of an

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would with This pie, "pomme" or "Apfel." Of course, the word apple also becomes associated with many other words, such as fruit, pie, jack. Instructions to the person to image the referent of the word apple would then selectively evoke associations to the complex of schematic sensory responses.

These basic ideas are ancient; they can probably be found in Aristotle and certainly appear in the writings of the British empiricist philosophers. The same ideas can be dressed in more modern garb, using the information-processing terminology currently fashionable. In those terms (see Grasselli 1969; Minsky 1968), semantic concepts would be represented as nodes or list names in a network of interconnected list structures; one of the sublists attached to a concept node would specify sensory-object information. This sensory list would contain a description of object parts and their interrelations in some basic picture grammar of features and spatial-relational predicates. This list would be used to recognize sensory patterns (to say, "That's an apple over there") and also as input parameters to a generative program for constructing a simulacrum, either in actual drawings or in the imaginal "drawings" we call images. Picture-generating programs of the latter sort are becoming increasingly familiar to scientists in such forms as Sutherland's "Sketchpad" program for man-computer interactions with pictorial materials, in computer graphics, and in computer artwork.

The behavioristic and information-processing views of imagery are complementary rather than contradictory. The computer analogies are conceptually richer and deeper, but the behavioristic views are so simple that they motivate much experimental research.

Imaginal associations and their properties

I wish to discuss now the properties of associations formed through imagination imagery, but first a brief word on how I will think and talk about them. **Imagination** is the name of the process by which we manipulate and combine memory images in a scene. For example, I can remember in imagery what the drain of my kitchen sink looks like, and I can also remember how someone appears when chug-a-lugging a bottle of whiskey. I can therefore combine these memory images in my imagination to form the composite scene of the drain gulping down the whiskey, even though I know that this corresponds to no event I shall ever witness. But the imaginative construction can apparently be stored away in memory nearly as well as can actual scenes we have witnessed. In fact, on many occasions it is difficult to distinguish between old memories of actual events and old memories of imaginings of plausible events that never actually happened. How people distinguish among veridical memories, memories of previous imaginings, mistaken memories, delusions, and hallucinations is a fascinating topic, but its allure cannot be followed here.

As I mentioned earlier, college students instructed to associate two concrete items, A and B, by imagination imagery will recall one and a half to two times better than will subjects learning by rote rehearsal or by whatever means students typically use. Psychologists have studied a few of the properties of learning produced by such imagery instructions; the properties or factors make good sense, and a few can be briefly mentioned.

A first important factor is the *imagery value* of the words that are to be associated. Words differ greatly in the vividness of imagery they evoke—compare such concrete words as "blood," "orange," and "tongue" with such abstract words as "interpretation," "difficulty," and "enterprise." Learning is very much faster with concrete than with abstract words, whether the learning is measured by associative pairings, by recalling sentences, by free recall, by serial recall, or by recognition memory (see Paivio 1969). People also report the spontaneous use of imagery to learn concrete materials. Moreover, the more vivid the person rates his imaginal scene at the time he constructs it, the more likely he is to remember it.

A further fact is that subjects will frequently make errors in recalling abstract words because they substitute an associated concrete object; instead of "religion," the person recalls "church"; instead of "government," he recalls "governor." Such errors are
entirely understandable in terms of the person's forgetting the linguistic tag on his concrete image, which tag was supposed to remind him to name the abstract concept, not the concrete exemplar.

Further, if the person can be induced by some means to form vivid interacting images, the degree of association established is about the same whether or not he intended to learn the material and whether or not he was highly motivated to remember it. The important ingredient appears to be the cognitive constructive activity itself, not the motivation or reward. These latter variables would appear to have their usual effects in real-life situations by inducing the person to try out an efficient learning strategy.

It appears likely, too, that some of the omnipresent individual differences in learning proficiency are attributable to use of different learning strategies (Rohwer 1970). "Smart" pupils tend also to use efficient learning strategies; for instance, there is preliminary evidence (Arthur Taylor, personal communication) that the customarily huge differences in associative learning between a group of normal and a group of mentally retarded children can be largely eliminated when both groups are trained to proficient use of mental imagery for learning. In a more general vein, now that results are available showing the efficiency of imagery and various types of mnemonic devices, we may expect an enthusiastic effort to apply this knowledge to improving the presentation and structuring of educational materials in the school setting.

A final and critical feature is that associative learning is facilitated by placing the two objects into an imaginable scene only if they are depicted in some kind of "interacting unity." Figural unity refers to the coherence or interdependence of the various parts of a figure (Asch 1969). Some examples are shown in Figure 10. Panels a and b depict unitary figures wherein the abstract shapes and the specific modes in which they are expressed exist in a unitary relation. The form and the mode naturally cohere in a primitive constitutive relation in the unitary figures. On the other hand, the nonunitary displays show the same two visual features separated, as independent entities. The

Figure 10. Left-hand figures depict a unitary relation between elements. In a, a parallelogram composed of pluses; in b, a teardrop composed of beads; in c, a doll in a chair waving a flag. Right-hand figures depict the same elements in a non-unitary manner.
reader's intuition doubtless can accurately predict that the several features of a picture are associated very much better in the unitary than in the nonunitary displays.

Similar results are obtained with distinct objects shown in some predicative sort of interaction. For example, the words "doll" - "flag" - "chair" are easily associated if the person is shown a doll waving a flag sitting in a chair (section c of Figure 10) or if he constructs that image or hears that sentence, as contrasted to hearing or seeing the three objects side by side, not interacting (see Bower, in press; Horowitz, Lampel, and Takanishi 1969). Simple juxtaposition or coniguity in literal, pictorial, or imaginal space is not a very strong "unitizing" relationship; some kind of interaction or interdependent activity helps the association.

For instance, the main nouns within such phrases as "man riding a horse while wearing a necklace" or "child eating an egg while typing on a typewriter" become highly interassociated, whereas those occurring within bland "neighborhood" statements such as "the man standing beside a horse beside which lies a necklace" or "child sleeping by a typewriter under which lies an egg" produce much weaker associations (Atwood 1969). The best association of the objects or nouns is produced by simple "actor-action-object" phrases or sentences or by pictures or images having that sort of natural description. Weaker associations are produced by connecting the two critical words by conjunctions (and/or) or by elementary spatial prepositions, such as "beside" and "to the left of" (see Rohwer 1966).

In this respect, associating the main elements within pictures or images or sentences reveal similar properties. These functional similarities have led to a search for some single factor responsible for these parallel associative effects produced by sentences, pictures, and imagery. A natural hypothesis favored at the outset is that verbal encoding is the critical factor and that unitary versus nonunitary pictures or images show their characteristic recall because of corresponding covert verbalization which the theory assumes is evoked in the perceiving subject.

Are imagery effects solely due to verbalization?

In recent years psychologists studying human thinking and memory have emphasized the profound and pervasive influence of man's linguistic or verbal system in encoding, representing, and remembering events and happenings in the world. Possibly because verbal behavior is accessible to public inspection and objective study in a way that mental imagery clearly is not, the emphasis on verbal processes has occurred at the expense of scientific development of imagery concepts. It is therefore understandable that some psychologists question whether alleged "imagery" effects in learning are explicable in terms of covert verbal processes. This is a plausible view, since the learning experiments cited previously used words or familiar objects with verbal labels as list items. Perhaps all that is accomplished by telling the person to visualize an interactive scene to link two words is to lead him simply to find and describe covertly a linguistic relation between the two semantic concepts. For instance, in linking two nouns, the usual linguistic relation is predication, so that actor-action-object or topic-with-comment types of propositions tend to be produced by the subjects. To link the concepts "cow" and "ball," the person will produce such phrases as "cow chases ball" or "cow kicks ball."

Now, instructing the person simply to discover and report such linguistic relationships between a pair of words (with no mention of imagery) happens also to promote extremely good associative learning of the word pair. In some cases, in fact, recall is almost as good as the learning produced by mental-imagery instructions. According to this extreme view, therefore, discovering and tagging (or storing) linguistic relationships between items would be assumed to be the basic operational processes in memory, and the "mental imagery" instructions would act only parasitically, deceptively, indirectly, but nonetheless inevitably through this verbal medium.

Criticisms of the strict verbal hypothesis

Diverse criticisms may be marshaled against this strict verbal hypothesis, and it may be instructive to mention a few. First is the largely anecdotal evidence that in many cases people remember sensory information that they did not or could not have described verbally—in fact, they may agonize acutely over their inability to express in words the exact information in or meaning of the remembered experience. The indefinite, impoverished reporting of such ill-defined experiences is, in fact, what makes such phenomena difficult to study in the laboratory.

A second argument against the strictly verbal explanation of "imagery" effects is the following fact. Concrete word pairs are learned much better than abstract word pairs, even when the person reads them in a sentence context or is asked to find and say a linking linguistic predicate for each word pair. (The "meaningfulness" and familiarity of the concrete and abstract words are equated in such comparisons.) If linguistic relations were all that is stored, then no difference would be expected between concrete and abstract noun pairs. One might suppose that the difference in memory arises because abstract word pairs are harder to relate or to weave into a sentence than are concrete pairs. As a matter of fact, that conjecture is false. J. C. Yuille and A. Paivio (1967) measured the time students took to come up with a linking verbal phrase or sentence; such linking sentences were produced just as quickly for abstract pairs as for concrete pairs. The conclusion from this research is that concrete sentences are probably remembered better than abstract sentences simply because the former evoke more imagery than the latter sentences.

In line with this counter-evidence, I and my coworkers have found (Bower, in press) that subjects who study "actor-action-object" sentences will give better cued recall of the sentences if at the time of hearing them they are told explicitly to visualize the described scene. For instance, in one experiment the percentages for recall (of object noun when cued with actor noun) was 42 percent for read-only subjects and 62 percent for read + image subjects.

Another nail in the verbal coffin is the fact that kindergarten children differ markedly in their associative recall of
Table 1. Proportion of paired associations recalled correctly when they were learned by visual imagery or rote repetition and when the auxiliary task was tactile or visually guided tracking (from Bower, in press).

<table>
<thead>
<tr>
<th></th>
<th>Tracking</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagery</td>
<td>66</td>
<td>55</td>
</tr>
<tr>
<td>Rote repetition</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

The conflict induced by the visual-memory–visual-report condition requires him to alternate as best he can between looking at the page and “looking at” his mental image of the spatial diagram.

S. J. Segal and V. Fusella (1969) reported sensory detection data consistent with the same idea. If the subject was instructed to image a sound like a ringing telephone, then his threshold for hearing a weak tone was substantially higher (that is, he more often failed to hear a weak tone); if he was imaging a visual scene, such as a tree, then his threshold for a weak visual signal was much higher. Such data imply that imaging something in a given modality makes it harder to detect a weak signal in that modality. This too would follow from the view that imaging a stimulus in a particular modality crowds the “limited capacity” of the analyzing mechanisms in that modality.

A memory experiment of ours (Bower in press) attempted to produce similar interference, specifically between visual perception (in performing a distracting task) and visual imagery (in performing a learning task). Subjects used one of two different strategies to associate word pairs, imagery or rote repetition, while at the same time they were engaged in one of two distracting tasks, one visual and the other tactile. The visual distracting task was to track with the index and middle fingers of the preferred hand a wavy line that moved rapidly and erratically from side to side in a twelve-inch horizontal slot one inch wide. Keeping the weaving line between the two fingers required considerable concentration to the visual cues, and this was expected to interfere with the subject’s attempt to visualize mnemonic scenes to associate the pairs of nouns, thirty of which were read to him at the rate of one pair every five seconds. The alternate distracting task was tactile tracking, in which the subject, with closed eyes, felt with his two fingers a raised string that woven back and forth across a horizontal slot; his goal was to keep the weaving string centered between his two fingers. This tracking required only tactile information and should interfere less with learning of the concurrent word pairs using visual imagery.

The results are shown in Table 1, which reports percentages of paired associates correctly recalled for subjects receiving either imagery or rote repetition instructions and having either the visual or the tactile tracking task during the study and later recall of a single list. A first obvious fact is that subjects who used imagery recalled very much better than did subjects who used rote repetition. More significantly, visual tracking significantly reduced recall in those people learning by visual imagery, whereas there was no difference in recall produced by visual versus tactile tracking for those subjects learning by verbal rehearsal. This pattern is what would be expected if visual perception interfered with visual imaging.

A similar experiment was performed by George Atwood (1969) in his doctoral thesis. He asked college students to learn associations that were either concrete and imaginable (for instance, “a pistol hanging from a chain”) or abstract and not readily imaginable (for example, “the theory is nonsense”). Such phrases were presented to the subjects at the rate of one every five seconds. One group of control subjects simply learned the pairs as they were read. Two other groups of subjects performed a distracting task during the learning trials.

Immediately after each phrase was read and when the subject was presumably processing that material into memory, he was made to react to a brief intrusive signal, which was either visual or auditory. This intrusive signal was produced by the experimenter showing (or saying) the digit 1 or 2, to which the student had to react immediately by saying two or one, respectively. This trivial auxiliary task would appear to be not very demanding, but Atwood’s subjects nonetheless reported that the visual reading of the digit did disrupt their
ability to image the episode described by the phrase they heard.

Later the subjects were tested by presenting the first noun—pistol or theory—for associative recall of the second noun—chain or nonsense. These recall percentages, displayed in Table 2, confirm the effects previously mentioned. Control (non-interrupted) subjects recalled the abstract material more poorly than they did the concrete material; in addition, either auxiliary task during the study trial detracted from the subject's degree of learning. Of crucial importance is the fact that the magnitude of disruption depended on the learning procedure and the modality of the disruptive signal. In particular, the visual signal was most harmful to learning of imaginable material that the person was trying to visualize mentally (compare -.24 to -.06), whereas the auditory signal caused greater disruption in learning of the abstract material (compare -.26 to -.10).

As before, therefore, the Atwood study confirms the main point about interference between simultaneous imaginal and perceptual processes in the same modality. That is, imaginary visualization is disrupted by the requirement to process incoming visual information at the same time. In the memory experiments the consequence of this disrupted visualization is that a "less vivid" picture of associative interaction gets stored during the time that the item pairs are to be studied, and poorer recall results later.

Lest anyone misinterpret these results as support for the hypothesis that imagery is a peripheral receptor process, it may be added here that while processing and reacting to incoming visual information reduced imagery, other studies show that explicit eye movements and pupil dilation are relatively unimportant to the amount of vividness of central imagery that can go on "in the head" (Bower, in press). College students instructed to stare fixedly at a small dot on a white wall while constructing their associative images will later recall just as many pairs as do other students instructed to close their eyes during visualization and to sweep their eyes (really "inner eyes") several times over the imaginary scene as they are constructing it.

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Visual</th>
<th>Auxiliary</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly imaginable</td>
<td>.58 (-.24)</td>
<td>.76 (-.06)</td>
<td>.82</td>
</tr>
<tr>
<td>Abstract</td>
<td>.60 (-.10)</td>
<td>.44 (-.26)</td>
<td>.70</td>
</tr>
</tbody>
</table>

### Dual processing systems

The evidence indicates that "imagery" effects in memory are not consonant with a strictly verbal encoding view. The viewpoint that currently holds sway (for instance, Atwood 1969; Bower in press; Paivio 1969) is that nonverbal imagery and verbal symbolic processes are the two major components of thinking. These components are distinguished by several properties. First, the imagery system is relatively more attuned to the task of representing and operating on concrete information, whereas the verbal system appears better suited for processing abstract information. Second, visual imagery has many of the properties of a spatially parallel system, whereas verbal processes are better suited for handling sequential, serial information. For example, if items (pictures or words) are shown serially one by one at a very fast rate (say, five items per second), the person can later freely recall or recognize more pictures than words, but his reconstructed *serial order* of the items is better when the items are words than when they are pictures (Paivio 1969).

We may think of the verbal and imagery systems as being richly interconnected. It is these interconnections that enable us to label pictures and sensory information generally and that enable imagery to be aroused by semantic interpretations placed on words or sentences. In this latter regard, we may recognize individual differences in the extent of the verbal-to-imaginal interconnections, as well as differences in the frequency of using imagery for interpreting language.

### Dual memory traces

Various memory experiments have compared peoples' recall of different types of items, and the probability of recall almost always comes out in the descending order: an actual object (highest recall); a picture of an object; the name of a concrete object; followed far behind by the name of an abstract concept (lowest recall). In other words, "concreteness" is a big determinant of the memorability of material, as has been demonstrated in a variety of tasks with all ages of verbally competent subjects. This elementary fact is explained by the plausible assumption that the subject will give an implicit verbal label to a familiar object or picture, so that both a pictorial engram (or memory trace) and a verbal engram will be established for that sensory object or picture. In contrast, when only a word is shown, especially if it is an abstract word, it will probably arouse no imaginal representative, so that only a verbal engram will be established by presentation of an abstract word. These memory traces decay over time, becoming less accessible or less supportive of recall. Later recall or recognition of the presented item will be better in the object/pictorial case because there are two different engrams to support the memory performance, and retrieval of either one of these suffices to perform the task. In brief, pictures or objects are remembered better than their names because the former establish two memory traces while the name alone establishes only one trace.

Various pieces of evidence are consistent with this dual-coding assumption. A further instance occurred in a recent experiment by Richard Freund at Stanford (personal communication, 1970). He found that people will have much higher recognition memory for a series of scenic pictures if they are required to describe or label each picture when they first study it. The interpretation is that requiring the person to label each picture insures that both a pictorial and a verbal memory code are established, whereas viewing the picture or word alone may establish only the
one memory trace. A similar argument may be used to explain why recognition memory is higher for concrete nouns than for abstract nouns (see Gorman 1961). The abstract noun is likely to be stored only in a verbal memory code, whereas the concrete noun will probably activate two memory traces.

Neurological evidence

This theoretical separation between imagery and verbal processes is also supported by observations on patients who have had parts of their brain surgically removed to cure severe epilepsy. These observations are consistent with the hypothesis that speech is interpreted, organized, and generated chiefly in the left hemisphere of the brain, whereas the right hemisphere tends to be more involved in performances utilizing nonverbal imagery (Kimura 1963; Milner 1968). Specifically, surgical removal of the left temporal lobe of the brain selectively impairs verbal but not pictorial memory, whereas removal of the right temporal lobe selectively impairs pictorial but not verbal memory. Pictorial memory was tested by recognition or recall of pictures shown earlier (such as photographs of faces, geometrical designs). Verbal memory was tested by recall or recognition of numbers, words, word pairs, and stories.

A second line of neurological evidence comes from patients following surgical removal of the corpus callosum, a large bundle of fibers connecting the two cerebral hemispheres. These cross-connections appear to function as communication links, so that each brain hemisphere can keep track of what is happening in the other hemisphere. Following removal of the corpus callosum (to control epileptic seizures), the patient appears to function quite normally in all respects in perceptual, motoric, and cognitive abilities. However, especially contrived tests by M. A. Gazzaniga and R. W. Sperry (1967) have shown that major psychological dysfunctions appear in these patients if they are prevented from handling an object with both hands when trying to identify it by touch.

The methodology for these experiments may be appreciated by reference to Figure 11, which shows schemat-
ically the "split brain" patient following cutting of his corpus callosum. Nerve fibers from the nasal half of the retina cross at the optic chiasm and project to the opposite cerebral hemisphere, whereas fibers from the lateral half of the retina project directly to the hemisphere on the same side. An experimenter can take advantage of this retina-to-cortex wiring diagram to project selectively a visual stimulus into the right or left hemisphere. The method is also shown in Figures 11 and 12. The subject is asked to fix his gaze upon a small black dot in the center of the field, whereupon a visual stimulus (a word or a picture) is briefly flashed to the left or right side of the fixation point (shown as gray and yellow fields in Figure 11). The flash is only one-tenth of a second long, too brief for the person to move his eye over the stimulus but long enough for a normal adult to identify easily a familiar stimulus.

In a normal adult visual information flashed into any one cerebral hemisphere will nonetheless be available to the other hemisphere because of the cross-connections provided by the corpus callosum. However, after these communicating pathways have been surgically removed, it is now possible to confine and isolate the visual information to one or the other cerebral hemisphere. In this way, therefore, one can project a verbal (printed), pictorial, or tactile stimulus to a particular hemisphere and ask that hemisphere to respond verbally or manually to a command. A further fact to be known about our innate wiring diagram is that the sensory and motor representations of any person's left hand are predominantly in his right cerebral hemisphere and those of his right hand are in his left hemisphere. That is, the chief hand-to-brain connections are crossed.

By a series of elementary tests, Gazzaniga and Sperry (1967) were led to conclude that the left hemisphere could both recognize and actively produce speech, whereas the right hemisphere had passive speech recognition but could not talk. Any visual stimulus (word or picture), or tactile object, projected to the left hemisphere was readily identified and labeled verbally; it could also be selected by touch by the right hand (see Figure 12). In contrast, if the same stimulus were projected to the right hemisphere, the patient could give no verbal or written report of it. However—and here is the curious finding—the patient was able to select the stimulus object by manual touch with his left hand even though he could not say what his hand was looking for nor say what object his hidden hand had picked up (correctly). The curiosity is the dissociation; here are two brain halves that are quite conscious, perceptive, and reactive, yet only one of them can verbally describe what it is doing, is aware or conscious of what it is about.

It appears that both hemispheres can understand and react intelligently to language, but only the left can produce it in speech or writing. Interestingly, if an object name is flashed to the left hemisphere and the person has to actually find that object with his left hand, he can not perform; in this case he can name what he is looking for, but his left hand cannot find it. The ruse that patients use to solve this problem with the left hemisphere is to say aloud or whisper the name of the object; that auditory feedback can then be recognized passively by the right hemisphere, which can then guide the left hand to the correct object.

Such observations show the dominance of the left hemisphere for active speech. In contrast, the right hemisphere appears somewhat better-skilled in nonverbal reasoning and spatial abilities. For example, a standard task was to show the patient a pattern of red and white blocks and then ask him to reproduce it from a scattered pile of blocks. This proved to be easy for his left hand, but impossible for his right hand (he was, incidentally, righthanded). Similarly, he could copy spatial drawings or pick out rotated transforms of a standard figure better with his right hemisphere (and left hand) than with his left hemisphere (and right hand).

These neurological studies show in extreme form a functional separation between the verbal and nonverbal spatial systems. Specific kinds of recognition-memory experiments have not been done with these callosal-sectioned patients. But one might expect better tactile recognition memory for unlabeled nonsense shapes in the right than in the left hemisphere,
better word memory in the left than in the right hemisphere, and no difference in recognition probability between concrete and abstract words projected to the left hemisphere. These and similar conjectures await further testing.

Looking ahead

The topics of language, cognition, and the higher mental processes have become a dominant focus of psychological research in recent years, and any prognostication of the future can only be in general terms. We can be reasonably sure that some future research will be aimed at providing a firmer and more extensive differentiation between the verbal and imagery systems, establishing their functional properties, showing how they are interconnected and how they have developed over the lifetime of an individual.

For one thing, we would like to know the unique operations or transformations that the imagery system can carry out on information provided to it. Some of its special operations (tapped by IQ tests) include the ability to rotate solid objects in imaginative space, to "walk around and inspect" all sides of an imagined object, to deform objects, to concatenate objects in diverse geometrical relationships or in bizarre combinations, and to shrink or expand relative sizes of objects. Many of these transformations would seem impossibly complex were the information represented solely in terms of strings in verbal form; postulation of some kind of "solid geometry program" in the head would seem to be required.

A second set of issues being researched extensively concerns the development in the infant of the imagery and verbal systems and how they are interwoven (for example, Bruner, Olver, and Greenfield 1966). For example, a plausible hypothesis is that very young children rely initially on sensory (and possibly motoric) imagery for representing the world, but this method becomes superseded and pushed aside by the child's developing linguistic competence. According to that hypothesis, linguistic encoding comes to be preferred because it frees cognition from the immediate sensory impression and concreteness of experience, enabling more abstract groupings, concepts, and relations to be used in structuring and communicating about the diversity in direct experience. On this account, then, the course of development in many cases leads to the gradual withering away of imaginal processes, which die from neglect and disuse. Visual impressions are no longer remembered in their full, vivid richness, but rather become conventionalized in terms of conceptual stereotypes.

In light of the research story told previously, that visual imagery improves memory, we may rue the general cultural deemphasis and decline of mental imagery and ask for research on techniques for developing imagery skills in adults. To end on a practical note, our prescription to the adult in approaching a new learning task is for him to become as a child again, to tap the wellsprings of his suppressed imaginative talents that have lain buried under years of linguistic development.

References


