ELABORATIVE STRATEGIES IN ASSOCIATIVE LEARNING[1]

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1. A speech delivered at the International Congress of Psychology, London, August 1969. Research reported here was supported by a grant, MH-13950, to the author from the National Institute of Mental Health.

For the past few years my research group has been studying the elaboration strategies which college students use in common verbal learning tasks, especially in paired associate learning. The first general conclusion to which we quickly came is that very little of the adult's learning in these situations is done by pure rote or by mere rehearsal. That is, it's not a matter of repetitive practice just wearing the right grooves between the corresponding neural structures. It rather appears that the typical subject is elaborating or adding to the material in such a way as to construct a comprehensible relation or to impose a familiar coding upon the material. In this respect, the common learning tasks are best viewed as confronting the learner with problems to be solved, where the person's problem is to find some way to relate or assimilate the new material to be learned to the knowledge he already has available in his long-term memory. The nature of the materials, and the type of memory performance required, set constraints on the methods and techniques the person uses to solve the problem, but the solution is nonetheless constructive in most cases. I will illustrate some of the methods used by subjects in constructing mnemonic relations and mention a few of their properties and implications for variables affecting memory performance.

If we consider paired associate learning of words, the main job for the person is to find or construct a comprehensible relation between the words of a pair. The number of possible relationships between two words is immense, of course. These may include relationships of formal similarity---that is, the two words have similar spelling or pronunciation, as in rhyming pairs. Or the relation may be semantic in the sense that both words belong to a common category, and this categorical information may distinguish this pair from other pairs in the list being learned. The benefit to be derived from such relationships is that if the person remembers the relationship, then when presented with the stimulus word he can restrict the range of responses to just those in the list which satisfy that relationship to the cue word. For example, if I know that the cue word has a rhyming response, that knowledge enables me to generate several candidate rhyming response-terms, and my recall is reduced to merely recognizing which of these candidates was in fact on the list being learned.

Another kind of relation depends on finding purely associative chains, starting with the cue word and ending with the response word. Thus, one can link BREAD to CUP by using the intermediary BUTTER, since BREAD-BUTTER and BUTTER-CUP are strong primary associates. The mediation literature leaves little doubt that these kinds of associative chains speed up learning. The only problem with the method is that it is seldom helpful with any arbitrary pair.

Two methods that seem of more general applicability with any arbitrary word pair are sentence predication and mental imagery. In predication, the pair of words to be associated are embedded in a sensible, linking sentence which the person makes up. With nouns, the linking predicate given by subjects is invariably a verb or a preposition. For example, to link the nouns DOG and

BICYCLE, subjects will produce verb sentences like "the DOG rides the BICYCLE", or "chases"it or "barks at" it, etc.; or they will give prepositional phrases like "the DOG on the BICYCLE", or "in front of" or "under" it, and so on. One might imagine that in our mental lexicon, verbs are organized for purposes of such predication: That is, a verb might be represented as a function with arguments, where the arguments may be filled with nouns having particular semantic features. Thus "X chases Y" is a relation into which we can substitute animate nouns for X and objects having motion for Y. Substitutions according to these semantic selection restrictions will produce permissible and comprehensible sentences; if we violate these restrictions, then the sentence is anomalous and useless as a mnemonic code. In associating pairs of nouns by this method, the problem is finding a predicate which has arguments corresponding to the semantic features of the cue and response words. Once found, that relation then welds the words into a highly integrated sentence unit which can be stored in memory.

It should be mentioned here that subjects will better remember word pairs embedded in sentences they generated themselves than they will word pairs embedded in sentences which they have merely read. That is, subjects presented word pairs and told to generate linking sentences will recall those paired associates about two-and-a-half times better than controls who simply read the words as emphasized subject and object nouns in declarative sentences. In requiring the subject to generate a sensible sentence, he is forced to search out and construct a linking relationship between the two words, so that he probably understands the constructed relationship much better than does the yoked control subject who merely reads the same sentence. Another way to say this is that it is quite possible for us to read or listen to sentences without understanding them---that is, without associating the necessary semantic concepts---whereas it is much less likely that we would fail to understand sentences we ourselves generated. And various experiments by us and others have shown that comprehension of a sentence aids its later recall. In those studies, the subject was preset by instructions to process sentences in ways designed to promote or diminish his comprehension of them, with the result that there was corresponding variation in his later ability to recall the sentence when cued with the subject noun of it.

Closely related to sentence generation is the method of mental imagery, which predominantly involves visualization for most people. Names of concrete objects can arouse sensory imagery of some particular referent, and pairs of such images can be placed into some imaginary interaction. For example, to link the DOG-BICYCLE pair, one would visualize a DOG riding on a BICYCLE, perhaps with many details filled in about the objects and the background scenery, possibly in a sequence of episodes as in a motion picture. If subjects instructed to use mental imagery are compared to uninstructed controls, the imagery subjects recall about one-and-a-half to two times more than the controls. The first figure illustrates the effect; this shows immediate recall of five successive lists of 20 concrete noun pairs, each pair studied once for five seconds. Recall of the imagery subjects after one trial is averaging around 80%, whereas the uninstructed controls average around 45-50% in this experiment.

Let me mention just a few of the properties of learning under imagery. First, it should be clear that words are first interpreted semantically before they arouse any imagery, since the imagery aroused by an ambiguous word like HAM is determined by whether the context leads me to interpret it as a food or an actor. Second, words differ considerably in the ease with which they evoke imagery, and large variations in paired associate learning arise from varying the imagery value of the words. The imagery value of the stimulus member of the pair seems particularly critical; and this is presumably because a high imagery word is likely to be encoded in the same way during recall-testing as during the study trial. Paivio and his associates have shown that imagery value is the most potent predictor of paired associate learning of nouns, when it is contrasted with similarly controlled variation in meaningfulness of the words, their familiarity or Thorndike-Lorge frequency, their emotionality, Semantic Differential ratings, or whatnot. When item-imagery is held constant, these other variables have only negligible effects on paired associate learning. A third fact is that when subjects are learning by imagery, the pattern of confusion errors changes in two understandable directions: first, different paired associates containing synonymous words like AUTO and CAR, or BOAT and SHIP, tend to be increasingly confused; and second, when imagery is attempted with abstract words, intrusion errors tend to be names of associated concrete objects, such as recalling CHURCH for RELIGION, or JUDGE for JUSTICE. A fourth fact is that an important ingredient of the imagery association method is the construction of significant interactions between the two imaginal objects; this is so because paired associate recall is very poor when subjects are instructed to imagine the two objects vividly but well separated in space, with no interaction, as though they were still photographs on two different walls of the room. Examining the types of sentences subjects use to describe their imagery, the separated images produce descriptions like "the DOG over here, and the BICYCLE over there" where the major connective is the conjunction AND; on the other hand, interactive imagery is described by verb or prepositional connectives like "the DOG is riding the BICYCLE" or "DOG on BICYCLE". An important parallel is that a similar pattern of recall is obtained if subjects are set to learn word pairs by generating verbal connectives consisting of conjunctions as opposed to verbs or prepositions.

This similar pattern of relationships between imagery and sentence generation is suggestive, leading one to ask whether imagery and sentence generation can be distinguished as methods for learning. I think a variety of evidence points to the validity of a distinction between these two methods. I would briefly mention just two relevant facts. First, the availability and speed with which subjects can generate verbal mediators for word pairs is unrelated to the imagery value of the words but recall nevertheless varies considerably with the imagery value of the words. Second, auxiliary tasks can be devised which will differentially interfere with learning under imagery but not with purely verbal learning.

For example, requiring the person to perform an auxiliary visual tracking task will selectively impair his ability to learn word pairs at the same time by visual imagery. Such results indicate that we should maintain a distinction between imagery versus sentence-generation methods for learning.

The more general point to be emphasized is that both these methods require active construction of comprehensible relations. I would say that the constructive process when we image is similar to that which takes place during perceptual apprehension of the corresponding scene. This view, that perception involves a constructive synthesis of a schema, has been proposed by many recent theorists, and is summarized in Ulric Neisser's recent book on <u>Cognitive Psychology</u>. I would suppose that successful perceptual constructions leave behind memory traces. and that upon appropriate command, large portions of the whole "scene" can be reconstructed from a part of it which is provided as a retrieval cue. In this way, the image of a DOG might enable me to reconstruct my scene of a DOG riding a BICYCLE by which I had learned this pair. Then simple recognition of other objects in this scene provides me with the associated response.

One may ask how this constructionist viewpoint deals with the learning of nonsense materials, such as the nonsense syllables so popular in the laboratory. The question is apt because there is increasing evidence, I think, which shows that adults learn those meaningless nonsense syllables by imposing a vast array of sensible constructions upon them. A defensible view is that adults don't really learn and recall nonsense syllables: rather they find some way to transform a nonsense trigram into a familiar word, and then they remember the word plus the transformation needed to get back to the original trigram. A current doctoral dissertation at Stanford by Luby Prytulak has filled in many of the details of this viewpoint with very favorable success. His basic idea is that the adult has a hierarchy or rank ordering of transformations which he will apply to a nonsense trigram, trying to convert it into a word; and furthermore, that most of the important psychological characteristics of a trigram are determined by how many and how complex are the transformations that have to be tried on the trigram before it converts to a word.

The basic operations on a trigram are adding, deleting, or replacing a letter or permuting letters. These operations can be concatenated in many different sequences, and the whole set may be further partitioned according to which letters in the trigram are involved. Although many hundreds of transformations are possible, as few as 30 account for about 90 percent of the encodings Prytulak observed with consonant-vowel-consonant trigrams. The second figure shows 17 of these transformations so you can get the general gist of what is done. These are also ranked in the approximate order that we believe they are tried out by the subject. This says that the person first tries an identity transform; if that fails to be a word, then he tries to suffix an ending to make a word; if that fails, he tries to double the middle vowel; and if that fails, then he tries to insert a consonant before the vowel and add a suffix;

and so on. The general scheme for encoding a trigram is shown as a flow diagram in the next figure and it simply describes the process of trying out the ordered list of transformations. We will suppose that if the person has time, he will eventually succeed in constructing a code word and he will store in memory his code-word plus the transformation that succeeded in converting the CVC into that code word.

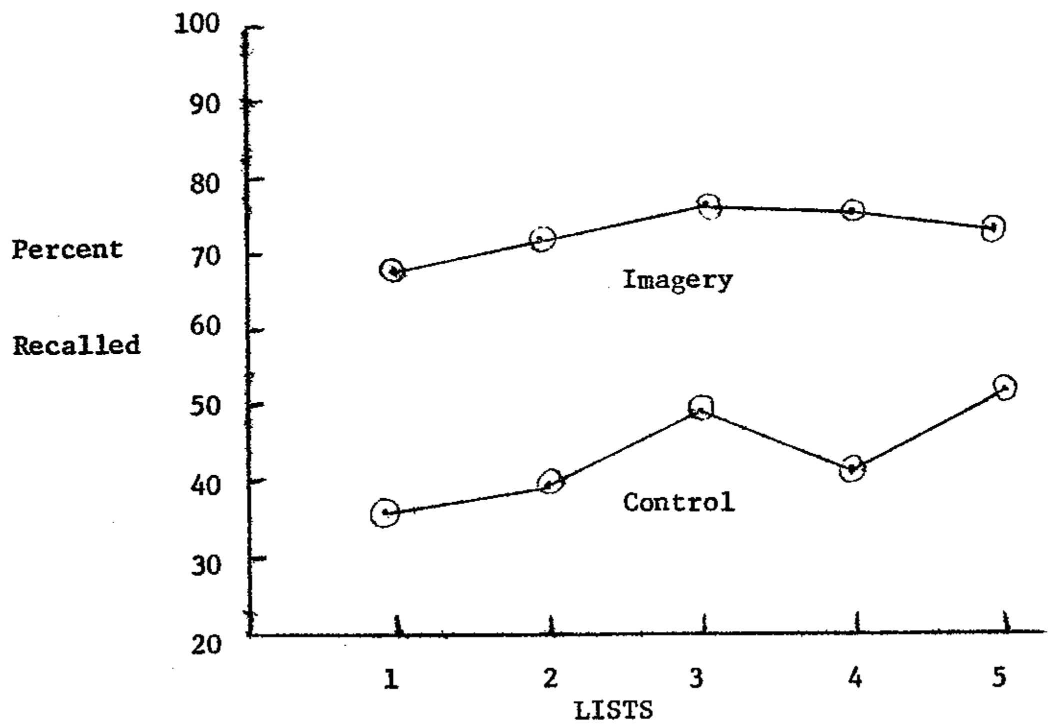
There are a host of implications of this way of looking at the matter. For one thing, we may suppose that when subjects are asked if they have any "associations" to a nonsense syllable, they in fact run through the list of transformations, trying to produce a familiar word; if they succeed before the time limit expires, they report an association; otherwise, not. Thus, the mean stack depth in the hierarchy at which a CVC succeeds should correlate with the latency and thus with the frequency of reported associations to the trigram. Prytulak indeed found a very high correlation (in the .70's) between his stack depth measure and the Kreuger association value of his nonsense syllables.

Secondly, the memorability of a CVC should be closely related to the stack depth of its first successful transformation and to a measure of the Thorndike-Lorge frequency of the words produced by that transformation. This frequency factor is included to roughly index the fact that a successful transform of a CVC will be more likely to be recognized as a word, and thus terminate the search process, if it is a familiar, high-frequency word. The flow diagram for recall is shown in the fourth figure. The recall cue may retrieve the code word and the transformation. If the code word is unavailable, then recall fails. If the code word is available, the transformation may have been forgotten, in which case the person selects a random but appropriate transformation, and then the word is decoded by applying the inverse of the transformation, yielding a CVC as the recall.

There is much scattered evidence which Prytulak pulls together in his thesis to make this story plausible. First, the memorability of a CVC in a short-term-memory task correlates in the 70's with a combined index of the CVC reflecting the stack depth of its first successful transformation, and the mean Thorndike-Lorge frequency of the words produced by that class of transformations on that CVC. Secondly, the type of intrusion errors made in recall often reflect forgetting of a complex transformation, replacing it with a simpler transformation at the time of decoding. Thirdly, in studies in which the experimenter provides an explicit code word to help the subject remember an embedded trigram, Prytulak's index correctly predicts how good will be the trigram recall produced by different code words, since this depends on the complexity of the decoding operations required to get back to the CVC.

These results and others support the general view that adults remember nonsense syllables by trying to construct words out of them. An attractive feature of this approach is that it provides a rational method for predicting the memorability of a nonsense syllable and its "association value" without having to rely upon a prior group of subjects providing normative ratings. That is, the theory provides an explanation of what causes variations in association value or meaningfulness of a trigram, as well as providing an account of the events likely to transpire during a memory experiment using nonsense syllables.

In closing, I would like to re-emphasize my general point in this talk. It is that associative learning usually depends upon the person finding or constructing comprehensible relations among the items to be associated, or in some way assimilating the new material to his current store of knowledge. Mnemonic devices ensure that such constructions take place, and in the absence of these constructions learning occurs slowly and haphazardly, if at all. I think it is unlikely that people store away complete images, sentences, or nonsense syllables in some memory warehouse from which such units are periodically delivered intact to consciousness for recall. I find more compatible the view that people store a few clues that are helpful guides for reconstructing the original perceptual or cognitive act. In computer terminology, these clues would be parameters of a generative program. This view of learning makes it very similar to current views of our perceptual abilities, which suppose that perception is an interpretive or constructive act, an elaboration of a stable schema of the world based on a few clues. My time is up now and I thank you for listening.



100
90
80
70
60
50
40
30
20
Percent
Recalled
Imagery
Control
1
2
3
4
5
LISTS

FIGURE 1

FIGURE 2

Rank Order	Transformation	Example
1	Identity	mud -- mud
2	Add suffix	fel -- felT
3	Double vowel	lok -- loOk
4	Insert initial consonant + suffix	wip -- wHipPING
5	Insert vowel + suffix	qic -- qUicK
6	Insert late consonant	det -- deBt
7	Insert extra vowel	ful -- fuEl
8	Insert vowel + consonant	deh -- deATh
9	Replace 1st with same sounding letter	kar -- Car
10	Insert late consonant + suffix	nih -- niGhT
11	1st sound + suffix	kas -- CasKet
12	Replace vowel	cit -- cAt
13	Add vowel + delete final consonant	dyl -- dAy_
14	3rd sound + suffix	laq -- laKE
15	Insert 2 late consonants	lit -- liGHt
16	Replace vowel + add late consonant	lut -- lOFt
17	Replace vowel + suffix	luf -- lOfT
.	. .	. .
.	. .	. .
.	. .	. .

FIGURE 3

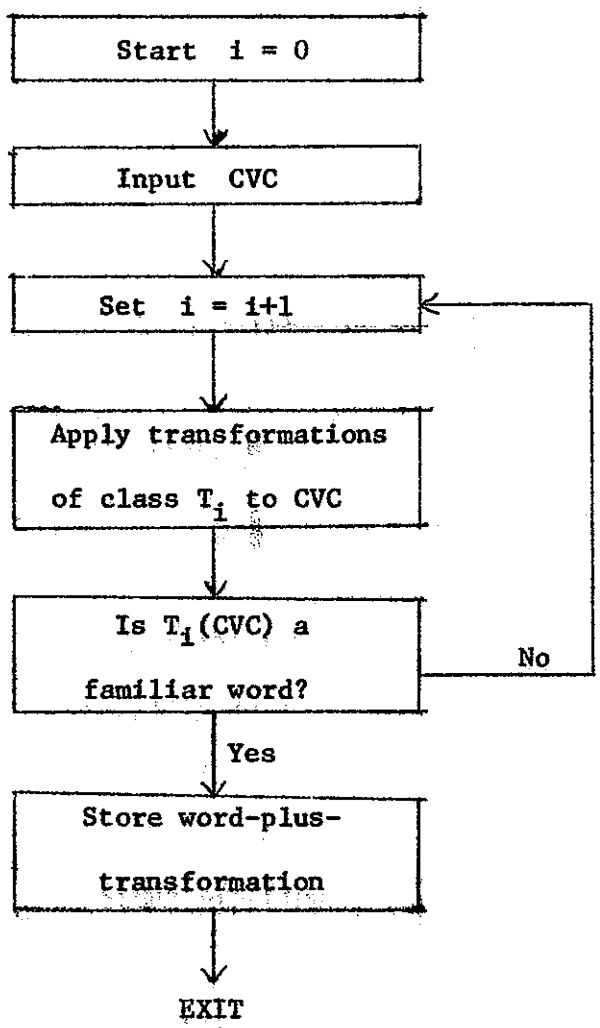
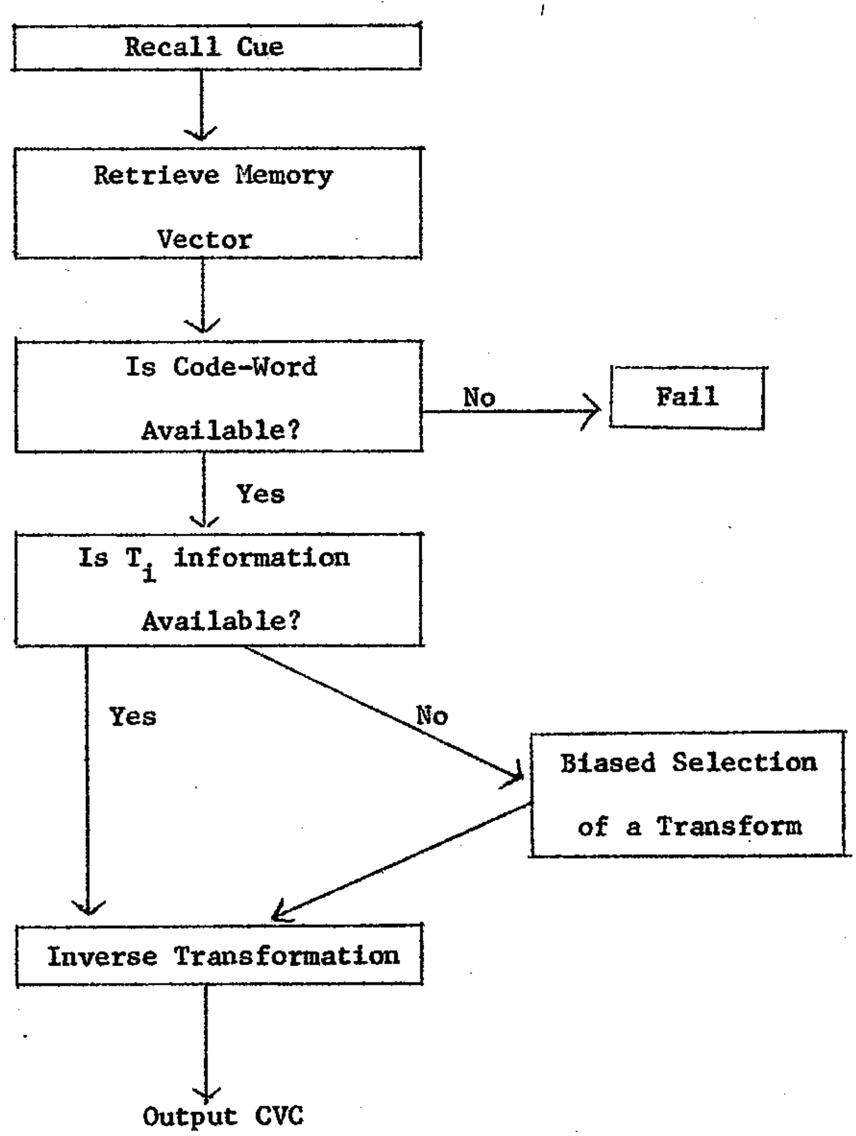

Start i = 0
Input CVC
Set i = i+1
Apply transformations of class T_i to CVC
Is T_i(CVC) a familiar word?
No
Yes
Store word-plus-transformation
EXIT

FIGURE 4


Recall Cue
Retrieve Memory Vector
Is Code-Word Available?
No
Fail
Yes
Is T_i information Available?
Yes
No
Biased Selection of a Transform
Inverse Transformation
Output CVC