R842-09 ERIC REPORT RESUME

ED 010 271 2-14-67 56
STUDIES IN MNEMONIC PROGRAMING.
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GFF21301 UNIVERSITY OF ILLINOIS, URBANA
NDEA-VIIA-1359
BR-5-0515
- -65 OEG-7-23-1020-268
EDRS PRICE MF-$0.09 HC-$1.44 36P.

*PROGRAMED INSTRUCTION, *PROGRAMED MATERIALS, *ENRICHMENT PROGRAMS, *MNEMONICS, *INSTRUCTIONAL MATERIALS, MATERIAL DEVELOPMENT, PROGRAMING, URBANA, ILLINOIS

THIS STUDY CLASSIFIED MNEMONIC STRATEGIES, EXAMINED THEIR THEORETICAL CHARACTERISTICS, AND REPORTED EXPERIMENTS INVESTIGATING THE RELATIVE EFFECTIVENESS OF MNEMONICS IN PROGRAMED INSTRUCTIONAL MATERIALS. THE FIRST EXPERIMENT INVESTIGATED THE COMMON MNEMONICS USED BY STUDENTS IN STUDYING A MEDICAL TEXTBOOK. THE SECOND EXPERIMENT TESTED THE EFFECTIVENESS OF MNEMONIC PROGRAMING. THE THIRD EXPERIMENT COMPARED THE EFFECTIVENESS OF THE PROGRAM WITH AND WITHOUT MNEMONICS. IT WAS CONCLUDED THAT THE USE OF MNEMONICS COULD BENEFIT THE STUDENT. (GD)

5-0515

(VII A-1359)

STUDIES OF MNEMONIC PROGRAMING* FINAL REPORT.

Final Report

OE - 7 - 23 - 1020 - 268

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* Preparation of this report was supported in part by a small grant ("Mnemonic Programing," OE 7-23-1020-268) from the U.S. Office of Education under Title VII of the NDEA.

Studies in Mnemonic Programing

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Abstract

This study classifies mnemonic strategies, examines their theoretical characteristics, and reports experiments investigating the relative effectiveness of mnemonics in programed instructional materials. Mnemonics were classified into four basic types -- simple association/partial codes, simple association/full codes, complex association/partial codes, and complex association/full codes. Mnemonic examples are given to support the classification, and a theory of mnemonics, based on standard learning principles is developed. Research is based on a selection from Gray's Anatomy of the Human Body, a program without mnemonics incorporating the material from Gray's Anatomy of the Human Body, and a program with mnemonics incorporating the material from Gray's Anatomy of the Human Body.

The first experiment investigates the common mnemonics used by students in studying Gray's Anatomy of the Human Body, specifically the anatomy of the trigeminal nerves. The second experiment compares the relative effectiveness of the program with mnemonics and the excerpt from Gray's Anatomy of the Human Body. The third experiment compares the effectiveness of the program with mnemonics with the program without mnemonics. It is concluded that mnemonics can work to benefit a student. Students need to be instructed in the use of mnemonics, and the mnemonic most suitable for student and material most suitable must be identified and used.

Problem

It is the purpose of this paper to classify mnemonic strategies, examine their theoretical characteristics, and to report studies which have investigated the relative effectiveness of mnemonics in programed instructional materials.

Mnemonics as a Construct

Mnemonic learning strategies (named for Mnemosyne, the Greek goddess of memory) are ancient cognitive devices developed to aid memory; examples are common and include "Thirty days hath September..." for remembering the number of days in each month, "FACE" for remembering the spaces of the musical staff, and "How I want a drink, alcoholic of course, after the heavy lectures in quantum mechanics" for remembering pi to 14 decimal places (the number of letters in each word corresponds to each digit.)

Arguments for the use of mnemonic stragegies have been advanced by more than 400 writers during the last 2500 years (Young, 1961) and three are discussed here. Cicero (Hunter, 1956) described his mnemonic system acquired from the Greek poet Simonides; prior to orating, Cicero associated each speech item with a specific locality in the room, and then, during the oration, he systematically explored the localities as a memory aid. Two vestiges of Simonides' system remain in the English language; we refer to units in a speech as topics (from the Greek topical meaning locality) and speakers still use the phrase "In the first place..." William James (1890) recorded his views on mnemonic strategies: "Of ingenious methods, many have been invented under the name of technical memories. By means of these systems, it is often possible to retain entirely disconnected facts, lists of names, numbers, and so forth, so multitudinous as not to be remembered in a natural way. The method consists usually in a framework learned mechanically of which the mind is supposed to be in secure and permanent possession. Then, whatever is to be remembered is deliberately associated by some fanciful analogy or connected with some part of this framework, and this connection thenceforward helps its recall." More recently, George Miller (1956) having cast some menmonic strategies in terms of modern information theory, wrote: "It is impressive to watch a trained person look at 40 consecutive binary digits presented at the rate of one each second and then immediately repeat the sequence without error. Such feats are called 'mnemonic tricks' -- a name that reveals the suspicious nature of psychologists. The idea thattrickery is involved, that there is something bogus about it, has discouraged serious study of the psychological principles underlying such phenomena. Actually, some of the best memory crutches we have are laws of nature. As for the common criticism that artificial memory crutches are quickly forgotten, it seems to be largely a question of whether we have used a stupid crutch or a smart one....When I was a boy I had a teacher who told us that memory crutches were only one grade better than cheating, and that we would never understand anything if we resorted to such underhanded tricks. She didn't stop us, of course, but she did make us conceal our method of learning. Our teacher, if her conscience had permitted it, no doubt could have shown us far more efficient systems than we were able to devise for ourselves... Another teacher who told me that the ordinate was vertical because my mouth went that way when I said it, and that the abscissa was horizontal for the same reason, saved me endless confusion...."

The history of mnemonics testifies their widespread use and clearly indicates the validity of the phenomenon. The problem for the psychologist is to treat mnemonics as a real psychological variable, rather than to explain it away. The mnemonic process can be treated as a hypothetical construct in an associative analysis of memory. This is the point of view taken here, in which mnemonic events are treated as mediating mechanisms which contribute to the retrieval of information, and produce responses which constitute recall.

A Classification for Mnemonic Strategies

A review of the literature (see references) discloses two basic mnemonics -- (1) associations and (2) codes.

Association Mnemonics

Association mnemonics depend on a coupling of the new response to be learned with an old overlearned response produced cue. The old established response provides reliable cues for the new response and thereby improves its retention. Two categories may be distinguished -- simple-association and complex-associations.

Simple-association mnemonics depend upon highly probable response chains. With them as the mnemonic process one, or more, mediating responses provide the prompting basis for a response and for a parity check between the mnemonic and the behavior it is supposed to control. The process consists of an intact, highly practiced association which can be readily made to the material being learned. Since it is well-learned, the simple-association mnemonic is readily recalled and can become the stimulus for the new and the less familiar response.

Complex-Association mnemonics depend on deliberately prelearned sets of associations that become mediating mechanisms with both response and eliciting properties. These mediating mechanisms typically require a great deal of practice and must be over-learned to be a useful aid in recall. Once established, these association chains can be elicited by a variety of explicit stimulus events; then, because of their prompting, or elicitation, value, they elicit particular responses, often in an independent order from that which the information was obtained. However, they may be designed to preserve the order and prompt the individual in that very aspect of recall.

Codes

Codes depend on artificial rules which automatically reduce unmanageable amounts of information into easily learned units. Two categories may be distinguished -- partial-codes and full-codes.

Partial-codes are those mnemonics which consist of rules that relate salient characteristics of the material to be learned; typically these are perceptual characteristics.

Full-codes are mnemonics which depend on the many-to-one correspondence between the elements to be recalled and a refined coding system. Full-codes permit the material to be coded into "information-rich" memory units which may be decoded later. Experiments have repeatedly shown that learning is almost independent of the information content of the learned elements as indicated. It is about as easy to learn five words of six letters each as it is to learn five random letters, although the words contain six times as much information. The rules of spelling are examples. Analogously we can remember five sentences, and in this case the linguistic rules provide a mnemonic. Full-codes apply to a specific set of materials. For example, phonic rules apply to vocal responses.

Association Mnemonics and Codes

Since association mnemonics and code mnemonics may be combined as aids in memorizing the same materials, the four-fold classification of Table 1 emerges. It is believed that almost all mnemonics described in the literature may be so classified. Examples follow:

Simple association/partial code. Shefter (1954) has given a mnemonic strategy based on the partial coding of these aspects of the material: (a) component, (b) orthographic, and/or (c) phonic associative responses. For example, three are involved in the spelling of "interrupt" learned

Table 1

Basic Types of Mnemonics

Simple association -- Partial codes	Simple association -- Full codes
Complex association -- Partial codes	Complex association-- Full codes

by noting that it contains the component word "err" <u>and</u> remembering "You err when you interrupt." The first two types of mnemonics are illustrated in the way of remembering the spelling of "judgment." It is learned by noting the orthographic component "gm" <u>and</u> remembering "General Motors (GM) always uses good judgment;" the first aspect (components) is involved chiefly in learning the English word for the German "Saal" by noting the similarity of "Saal" and "saloon" <u>and</u> remembering "Saal sounds like saloon which is a room. Simple associations/partial codes would seem to be most useful in learning to spell English words, the English equivalents of foreign words, and nomenclature of anatomy, etc.

<u>Complex Association/Partial Code</u> Lewis Carroll (Collingwood,1898) and Martin Gardner (1957) have given a mnemonic strategy for memorizing numbers based on the partial coding of complex associative responses shown in Table 2. Each digit is always represented by a consonant based on one of several principles -- the "downstroke" feature of the letters, the initial or terminal letter, the "look alike" feature, etc. The learner forms word phrases to establish an isomorphic set of consonants which are utilized in much the same way as the orthographic characters of the Hebrew alphabet. Table 3 illustrates the application of the Carroll-Gardner code for remembering several square roots. Complex associations/ partial codes would seem to be most useful in learning number arrays -- as roots, telephone numbers, dates -- and in learning cryptographic information -- as shorthand and the phonetic alphabet.

Table 2

The Complex Association/Partial Code Mnemonic

Given by Lewis Carroll and Martin Gardner

Digits	Consonants	Memory Aids	
1	T,D	T has one downstroke	t
2	N	N has two downstrokes	n
3	M	M has three downstrokes	m
4	R	R is the fourth letter in four	four
5	L	L is 50 in Roman numerals	50
6	J, soft G, SH, CH	J looks like 6 when reversed	J 6
7	K, hard G, hard C	K can be printed with two sevens	
8	F, V, PH as in photo	F in lower case script has two loops like the figure 8.	f, 8
9	P, B	P looks like 9 when reversed	P, 9
0	Z, S, soft C	Z is the initial letter of zero	zero

Table 3

Application of the Carroll-Gardner Mnemonic

for Remembering Square Roots

Number	Square root	Mnemonic key
2	1.444	RAT RACE. Think of two rats racing.
3	1.732	KIMONO. Three suggests triangle. Think of a kimono decorated with a pattern of small triangles.
5	2.236	ENMESH. Five suggests pentagon. Think of the pentagon hopelessly enmeshed in red tape.
6	2.449	RARE BEE. Six suggests hexagon. Think of the hexagonal cells of a beehive. Crawling over the cells is a two-headed bee.
7	2.645	SHEER LINEN. Seven suggests the dance of the seven veils. Think of the veils as made of sheer linen.
8	2.828	FUNNY FACE. Eight suggests "ate". Think of taking a bite and making a funny face.
10	3.162	TOUCH NOSE. Ten suggests the fingers. Think of touching your nose with all ten of them.

Simple Association/Full Code. Miller (1956) has given a mnemonic strategy for memorizing computer display lights based on the full coding of the simplest associations. Computer display banks of lights are either on or off, and must be read rapidly and accurately in terms of the "on-off" pattern which they display at any moment in time. The following octal code is pre-memorized: 000= 0, 000=1, 000=2, 000=3, 000=4, 000=5, 000=6, 000=7. To remember this string of lights 000000000000000000 after having learned it, the learner breaks the series into triplets 000 000 000 000 000 000, which are then converted to the octal code to give 627205 (000=6 etc.) easily remembered as a six-digit number and subsequently reconvertible to the 18 binary digit on-off light sequence. Simple association/full codes would seem to be most useful in learning such tasks as truth tables and syndrome patterns where the conventional symbols such as T/F present/absent can be recoded.

Complex Association/Full Code. Hill (1918) has given a mnemonic strategy based on the full coding of complex associations. This mnemonic is an often used magician's trick to remember as many as 100 disconnected words. The learner pre-memorizes a "standard" set of 100 words, each with its associated number. The words of the standard set have elegant ordering characteristics since the first and last letters designate a decimal notation so that each word is numerically "tagged", thus, Hill specified - = r, 1 = a, 2 = b, 3 = c, 4 = d, ...0 = n, so that his third word was "car", his thirtieth word was "can", and his one-hundredth word was "Ann." To learn the presidents of the United States, for example, the learner associates Washington with an image of an author, Adams with an image of a bar, Jefferson with an image of a car, etc.

The third president would be recalled by noting that the number 3 designated car, and imaging a car along with the previously associated Jefferson. More recently, Miller, Galanter, and Pribram (1960) have suggested a rhyming code for the "standard" set -- "one is a bun, two is a shoe, three is a tree..."; here Washington would be associated with bun, and so on. Complex associations/full codes seem to be most useful in the areas of language, history, social sciences and economics where the sequence of events is important but the words identifying such events are an arbitrary set -- as English kings, Civil War battles, export commodities of a country in rank order, etc.

A Theory of Mnemonic Memory

Contrasting Views

The classical view of memory states that all inputs are stored in a form such that they are retrieved as stored. From this point of view, memory is a storage and retrieval process. The assumption is that storage in the nervous system is in correspondence with the original stimulus input. The emphasis is upon capturing all the properties of the stimulus, and upon preserving the representation or trace of the stimulus.

The view here proposed assumes a central processing which first parses new material so those parts which are imortant can be identified readily, and second it stores only some of each new input cued to the requisit skills, e.g., those that produce grammatical structures. In this conception there are elements and processes which are stored, but the emphasis is upon the skill, or response, aspects of recall. Both recall and recognition are seen as active processes involving both specific or general skills. These processes generate the stimuli that are observed at the time of recall and are used to compare with the original stimulus. An example may help to clarify. It is remembering how to catch a ball. The set of elements can be represented by a set of objects, balls, such as baseballs, softballs, etc., and the processes or skills, fielding and batting. Each time the subject fields a ball, he uses skills he previously learned; he does not learn new ones at the time while storing the information regarding trajectories. Similarly, one learns attention habits and uses them again and again to read new printed material. In the same way, the processes of remembering a concept or principle can be considered as an active, generative process, involving a set of skills associated with classes or sets of materials. At the time of input, the learner stores elements which, when combined with appropriate, overlearned, processing skills already in the learner's repertoire, permit him to remember the material at another time. Retention is assumed to be an active synthetic process in which the individual uses overlearned skills that are either general or special skills that are peculiar to the material involved in generating a stimulus output that is intended to match the input.

Mnemonics and Processing Skills

From the present position, a mnemonic is a processing skill. It is a means of producing a response output that matches a previously presented input. Since all recall is the manufacturing of the response patterns from stored elements by means of overlearned processing routines, mnemonica are a special case of a general phenomenon. Mnemonics are not anomalies, but are exemplars of the basic processes that are necessary in all manifestations of retention. Mnemonics appear to be anomalies simply because of their properties as algorithms and heuristics which emphasizes their function as guides in the assembly of materials and responses. This position is consonant with modern conceptions of linguistics which consider language behavior to be a synthetic activity; the proposed view assumes that learning and recall of natural language is a synthetic process in which basic skills that are increasingly over-learned generate an output from a set of minimal elements. The rules of language are an organized set of labels for the elements of a verbal output that results from a processing skill. Each rule represents a different skill for producing a type of output, or an arrangement of exemplars from the classes of elements represented by the labels.

It is assumed that with over-learning, the processing skills become increasingly better associated with the specific elements of a reproduction. With high degrees of over-learning of material, the required processing skills that produce the recalled material become more reliable in eliciting elements that were in the input. The request for recall including the context in which it occurs, acts as a cue for the type of processing skill needed to produce a facsimile of the original stimulus input. This describes direct retrieval. It is distinguished from indirect retrieval which consists of cueing two or more types of processing skills that are sequenced so as to generate a facsimile of the stimulus input. One type of available overlearned processing skills is cued by the request to recall and it cues others that are also necessary.

Direct and indirect retrieval have been misunderstood historically. The first (direct) might be called Pattern Storage and Retrieval (PSR); it is the storage of perceptual patterns for later retrieval. PSR occurs with high degrees of repeated exposure. The second can be called Component Storage and Generative Retrieval (CSGR); it is the storage of PSR elements and skills for combining the elements to reproduce the input. The skills for combining the PSR elements are called rules. These skills exist in the learner's repertoire; they are learned as a result of consistencies in classes of inputs. For example, in the structural consistencies of grammar, the pattern in the input serves as a cue for the skill required of the learner to produce that pattern of verbal elements. These cues to the processing skills are associated with the critical elements of the input. Thus they are elicited by the request to recall.

Most of the literature on retention has been conceived in terms of the PSR position which is essentially a "stimulus error." Interpretations of results from the manipulation of the classic variables such as meaningfulness and stimulus similarity, presume PSR -- ignoring the possibility of CSGR. For example, in the usual treatment of meaningfulness in which the learning of words is contrasted with the learning of nonsense syllables, the subject takes longer to learn the latter; it is not generally assumed, however, that this difference may be due to the lack of learned processing procudures for dealing with novel disconnected letters.

Mnemonics have long been used to supply needed processing rules. They are particularly helpful in domains where the individual learner is deficient in the processing rules that are required. Sets of materials, to be learned by rote, are the principal situations in which mnemonics can be useful processing skills. They are not in competition with any other processing skills since these tasks usually have unique processing requirements. In a complete accounting of the total effort required to learn such materials with mnemonics, the mastery also must be assessed. The mastery of the mnemonic may be either easy or hard. Mnemonics become efficient as the number of situations to which they can be applied is increased; they also are efficient if, in learning them, the time required to learn the total set of new associations is lessened sufficiently to compensate for the time taken to learn the mnemonic. Taken that the mnemonic is well established as a processing skill, then recall consists of its elicitation which then generates the output that is desired.

Theory in Relation to Data

Some significant implications of mnemonics depend upon research findings concerning the relationship between learning and retention; namely, that the degree of original learning, rather than the nature of the material, determines the level of recall. It has been observed frequently that material high in meaningfulness is recalled better than material that is low in meaningfulness when both have been studied for the same length of time. This is not a contradiction of the present position. Rather, it is assumed that the material of high meaningfulness is associated with more highly established processing skills which explains why it was learned more rapidly so that in the same period of time it was either learned better or more overlearned; this also explains its better recall. Further support is given by the empirical fact that both high-and low- meaningfulness materials are remembered equally well when both are learned to the same criterion. This means that the required processing skills are at an equal level of proficiency.

From these findings, one may hypothesize that mnemonics affect the individual's rate of learning and, therefore, the degree of recall; but for this to be true, the same mnemonic or processing skill has to be involved in learning and retention. This hypothesis could be tested by determining whether the learning and recall task can be accomplished by the same processing skills. It is probably true that partial learning identifies a phase of acquisition that requires different processing skills from those required at mastery or in overlearning. When separate mnemonics are used in learning and in recall, each can be taught to different groups and their performance compared at different stages of practice and recall. A design also could be used in which the same individuals are required to learn two tasks to the same criterion, each task under one condition, and then are tested for recall. In such an experiment, one mnemonic would serve as the explicit processing procedure to be used in learning and another in later retrieval.

One characteristic of materials that are said to be meaningful is that they elicit processing skills. The existence of consistencies in the structure of materials previously experienced promotes the establishment of particular processing skills that permit the individual to use these skills with new materials. Meaningful materials are learned more rapidly than non-meaningful materials, when the same amount of time is invested, because there are consistencies in their organization or structure. This is revealed by the rules that can be used to describe them. Meaningful materials are retained better because the learner has already mastered a processing procedure which he can use. In CSGR the components that are stored are the novel materials, and the processing skill represented by the structure is the cue for the skills that generate the output which is the recall.

A REINTERPRETATION OF SOME EXPERIMENTAL STUDIES

Verbatin and Substantive Memory

The effectiveness of recall is usually determined by the extent to which the product produced at the time of recall matches the original stimulus configuration. When recall is evaluated in this way, it is verbatim recall and can be contrasted with memory for substance. Substantive memory is probably more ubiquitous than is verbatim recall. A study by Cofer (1941) is relevant wherein he compared the repititions and the time taken to learn prose passages of four different lengths both verbatim and for substance. The learning of the ideas was more rapid than was verbatim learning -- roughly three times as fast with the longer passages. This same finding has been reported by others. Collectively, these data support the hypothesis that recall consists of storing unique elements and the cueing of a set of processing procedures for generating the recall. When the material is ordinary prose, the processing skills are those associated with the formation of language, and they are generally well established in the adult, and fairly well established at quite an early age in the child. A request for verbal recall, for example, elicits sentence forming skills which generate the observed language. It may not be the identical language of the input, but it will be well formed language. The problem that this illustrates is one of a failure to associate the correct processing skill with the representation of the components that are part of the input. At the time of recall even if the critical elements of the component storage cannot be retrieved, the individual often can reproduce the substance of the ideas (elements). This suggests that component storage, rather than the verbatim statements, are in use. To generate the verbatim statements, it would be necessary to repeat the material over and over, to practice it, so that each specific encoding of the concepts is associated with the required processing skill.

Pattern Learning

Another type of experiment that might be cited in connection with this orientation is represented by the work of Guilford (1927). The learning of items, of little meaning and arranged in a "pattern" not immediately discernable, was compared with the learning of the same items arranged randomly. Examples of Guilford's "patterns" are number-series arranged in numerical progression and lists of syllables with meaningful initial letters. Since the set of stimulus elements used in his study were objectively the same in both sequences, it is argued that the observed performance difference is due to differences in the required processing skills. In one case, the subject could utilize processing skills that were already learned and in his repertoire, whereas in the other he had to develop a new set. The ability to capitalize on the previously stored processing skill results in more rapid learning and better retention.

Support comes from another type of study. In it, subjects are instructed to utilize processing skills, that is "to look for meaningful relations" or "to try to organize the items into a logical sequence." This type of experiment differs from those peviously described; here the subjects must organize (by themselves) the material into a meaningful pattern; the subject is asked to utilize, at the time of learning, processing skills which he has already acquired. Balaban (1910) reported that subjects so instructed displayed superior performance to those asked to memorize the material in a rote fashion.

The study by Carmicheal, Hogan, and Walter (1932) can also be interpreted from the present position. All subjects were required to remember several forms but different groups of subjects were given different labels for the forms. The subjects, when asked to recall, reproduced the stimulus material in terms of the label they were given at the time of learning rather than in terms of the objective stimulus. Since the graphic stimulus was the same for all subjects, the differences in reproduction can be interpreted as differences in the processing skills elicited by the labels.

Interference

The present position can explain certain kinds of interference. If a student is well practiced in reading in a left-to-right manner, as is typical of English and is then transferred to Hebrew, written in a right-to-left manner; then the processing skills he has available for reading are at variance with those required for the new task. Learning as well as recall of Hebrew by English speaking subjects as contrasted with Japanese subjects, is likely to be poorer until the new processing skills are highly developed. Another example of interference presumably due to processing skills was reported by Luchins (1942). He used a consistent format in presenting a set of problems to students and required them to employ a processing skill, or algorithm, to a number of these problems. Then he shifted the subjects to other similar problems presented in the same format but the elements in which a different and simpler processing skill could be utilized. Here the stimulus materials as a set are indistinguishable from one another as stimuli, but highly distinguishable as responses. The critical difference among the problems is in the processing procedures that can be applied to them. Students tend to persist in the use of the processing procedure they need to use initially when, in fact, another alternative procedure is possible and simpler in number of steps to solution.

The explanation of interference in verbal memory due to similarity, from the proposed point of view, is that similarity of elements elicits processing which is sufficiently interfering to retard learning. There are two conditions of interference and each involves a processing rule. Here are some examples: (1) Given a serial list of 10 words to learn in one order as a first task, and the same 10 words to learn in a different order as the second task, interference will result; (2) Given two different sets of words and the same processing rules for each set, the amount of intereference that will result will be small. In the first case, the combination of identical elements with a different skill leads to interference between the processing skills. In the second case, the combination of different elements with an identical skill leads to very little interference as indicated by intrusions. The amount of interference associated with the former is much more significant than that associated with the latter, however, in fact, the latter may have a net facilitation.

Age and Memory

The CSGR synthesizing-capability appears to be a function of age; adults have had more exposure to the structured consistencies of materials and therefore the processing skills are more highly developed than are those of children. The adult has a larger vocabulary of components for storage and cues for the processing skills used in generative retrieval. One possible explanation of why one learns more rapidly with increasing age is that he has already learned the required processing skills for producing correct grammar. The young learner needs to master not only the component symbolic elements of each new task but also the processing skills for generating acceptable grammatical structures. This suggests that recall is different at different levels of skill. At the low level of skill found at an early age, recall consists of the retrieval of the entire set of symbols; the processing roles for spelling words as well as for forming sentences need to be mastered as an interrelated set, whereas at a later age recall is the retrieval of the novel component elements and of previously overlearned processing skills for producing the grammatical structures. Individual differences in memory among adults are due probably to differences in the component storage since the overlearning of grammatical units is likely to be high for all of them.

The adult's procedure for storage appears to be analytical; it is decoding which specifies a set of components, or new elements, for storage and these serve also as cues for an appropriate processing skill that produces grammatical structures. In the encoding at recall, the component elements are retrieved and are formed into sentences by the processing skills. For example, one memorizes a large number of addends, but not all of them. Instead of memorizing the infinite set of sums, one learns a processing procedure that produces any sum as needed. Then, when given a new set of numbers, he uses those procedures to get the sum. While some highly practiced sums are reproduced without processing, this is a result of short circuiting due to practice (Osgood, 1958).

In reading, one stores the individual ideas or concepts expressed in the material and the fact that they were expressed in particular English prose forms (e.g., Jones and English, 1926; English and Edwards, 1939). When asked to recall the information, the adult retrieves the novel elements -- concepts, ideas or facts -- and utilizes his existing and already well mastered English language processing skills or structures to generate a verbal statement that communicates or expresses the content of the material originally presented in a similar, but not necessarily identical, prose form.

RESEARCH

The work accomplished under this project consisted of three studies, all but one of them utilizing a programed learning sequence of frames designed to teach students; (1) to name the trigeminal nerves; (2) to draw the relationships among the trigeminal nerves; (3) to answer questions about the location of branches; and (4) to report the number of branches of each nerve. The technical accuracy of the material was determined by using Gray's _Anatomy of the Human Body,_[2] in particular the section dealing with the neuroanatomy of the trigeminal nerve. Each of the studies will be reported separately in the order in which they were conducted.

Study I. The Relative Frequency of Mnemonics

Purpose. The objective of this study was to determine the relative frequency with which students used the four types of mnemonics when asked to memorize material. The findings were to be used in the preparation of new program materials. The assumption being that the mnemonics used by the sample of students would represent a set of already learned, and therefore available, associative devices used by students to reproduce neuroanatomical information.

Subjects. Thirty-three female undergraduate students enrolled in general psychology were used as subjects.

Procedure. The task of the subjects is defined by the following instructions.[3]

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[2]Reproduced with permission of Lea and Febiger, Publishers.

[3]See Appendix 1 for material.

INSTRUCTIONS

I

"This pamphlet is an excerpt from Gray's Anatomy of the Human Body. Gray's Anatomy of the Human Body is the text usually used for anatomy courses in dental and medical schools. You will have 60 minutes. Read the first page and the material beginning with the heading "Maxillary Nerve" on the second page. Read all of the third, fourth, and fifth pages and as far as the heading "Mandibular Nerve" on the sixth page.

"While you are reading, try to learn as much as you can.

II

"It has been found that people use memory devices to help them learn facts. An example of such a device is the poem --

Thirty days hath September
April, June, and November
All the rest have 31
Excepting February.....
.....

"As you know, this is used to help remember the number of days in the months.

"As you are reading and learning this material, try to recognize and remember any memory devices you use."

The subjects were given one hour in which to perform the task, and there were no restrictions on the number of responses.

Results. The responses were classified first in terms of the four basic types of mnemonics in Table 1. It was found that all 62 were simple association/partial codes.

A finer analysis was made in terms of the following varieties: spatial associations (topographical location and relationship to each other); ideosyncratic (personal history) and (verbal associations). Most of the associations were orthographic, but there were some codes, for example, MOM for mandibular-ophthalmic-maxillary.

It was also noted that there was a "Zipf-like" effect in that students shortened words, for example, meningeal was encoded as "men." The tabulated results are shown in Table 4.

Study II. Programming vs. Text. The Relative Effectiveness of Mnemonic Self-Instruction.

Purpose. The objective of this study was to compare the relative effectiveness of a self-instructional program containing mnemonics with excerpts from Gray's *Anatomy of the Human Body* covering the same information.

Subjects. Students from two first-year classes in Chicago dental schools were divided equally and randomly into two groups in each school.

Procedure. One group was given a mnemonic programed version of the trigeminal nerve (see Appendix 2, 3) and the other was given excerpts from Gray's *Anatomy of the Human Body* (see Appendix 1) which covered the same material.

All students were given a pretest (15 minutes) and were allowed to read the program for 110 minutes and then they were given an immediate post-test (see Appendix 2). They were allowed 45 minutes for the post-test.

Results. The means and standard deviations of the four groups are presented in Table 5. On the pretest, no significant differences at the .05 level were obtained. All groups learned significantly.

Using the post-test data, there were several significant findings. One significant difference was found between the means of the group who studied the mnemonic program and the group who studied the text, favoring the mnemonic program at the .01 level ($F = 20.10$ for 1 and 152 df).

The schools were found to differ significantly at the .01 level ($F = 18.42$ for 1 and 152 df.)

There was no significant interaction between schools and treatment.

Study III. The Relative Effectiveness of Adding Mnemonics to a Self-Instructional Program.

Purpose. This study compared the relative effectiveness of two self-instructional programs -- one with and one without mnemonics. (See Appendices 3 and 4). Both programed texts were compared with each other and with the standard text from Gray's as a control (see Appendix 1). Differences were sought in the immediate retention of the material presented.

Subjects. A total of 25 male and female students at the University of Illinois volunteered and were paid for their time. They were assigned to the experimental conditions as indicated in Table 6.

Procedure. The procedure was like that in Study II. Students were given a pre-test lasting for 15 minutes, a maximum study time of 2.25 hours, and a final test of up to 45 minutes. The time taken by each student in each of these phases of the study was recorded. Table 6 shows the means and standard deviations of the several groups.

Results. All groups showed a significant amount of learning, judging from their pre-test and post-test mean scores. However, the groups did not show significant differences in the amount they learned. Since the maximum possible score on the post-test was 131, this cannot be attributed to a ceiling effect.

Table 4

Mnemonics or Memory Aids Reported by Students in Study I

Classification: simple association/partial code for all mnemonics and memory aids listed

Type of mnemonic	Forms by mnemonic types	Number of Ss reporting using a given type
Spatial		Total = 14
	a. Items related to each other (e.g. outlines, figures, and diagrams)	10
	b. Topographical (e.g. use a face as a "map", associate meaning of nerve name with area supplied.	4
Linguistic		Total = 13
	a. Within-word associations (e.g. zygomaticofacial" and "zygomaticotemporal" both start with "zygomatico-"; meningeal/men)	9
	b. Between-word associations (e.g. MOM/mandibular, ophthalmic, maxillary)	2
	c. Familiarity of words	1
	d. Pronunciation of words	1
Idiosyncratic		Total = 4
	a. Personal history associations	3
	b. Remember previous test questions	1

Table 5

Study II. Means and Standard Deviations of Two Dental School Groups on Two Methods of Learning Neuroanatomy of The Trigeminal Nerve - - Mnemonic Programing and Text

Group	N	Test	Mean	S.D.
Dental school I program with mnemonics	39	pretest	4.31	3.04
	39	posttest	60.40	20.10
Dental school I program with Gray's text	39	pretest	3.68	2.72
	39	posttest	44.94	15.39
Dental school II program with mnemonics	39	pretest	3.91	4.44
	39	posttest	67.87	14.77
Dental school II program with Gray's text	39	pretest	4.01	3.82
	39	posttest	59.88	14.33

[1]Correlation of pretest and posttest: .21 (significant at the .01 level with 163 degrees of freedom).

Table 6

The Relative Effectiveness of Material

Programed with Mnemonics, Material Programed

without Mnemonics and Text Material

(Study III)

Group	N	Test	Mean	S.D.
1. Program with mnemonics	9	pretest	7.81	7.91
	9	posttest	56.89	26.77
2. Gray's text	9	pretest	6.56	5.42
	9	posttest	60.13	16.99
3. Program without mnemonics	8	pretest	1.56	2.35
	8	posttest	78.50	-7.11

It should also be noted that the standard deviations of the three groups differed significantly, as revealed by Bartlett's test. The group without mnemonics had the smallest standard deviation (7.01). Furthermore, the group who studied with the mnemonic program had the largest standard deviation (26.77). The control group standard deviation was in between (16.99)

This result suggests that the effect of mnemonics is highly idiosyncratic. Some students will be greatly benefitted by having simple association mnemonics presented to them, while they are learning, and other students will be unaffected or possibly even hindered by the same mnemonics. Furthermore, the presence of mnemonics does not necessitate their being used; thus there may be some students who develop reading habits which permit them to deliberately avoid using the mnemonics given them. This could occur for the reason given by Miller (1956), namely that students were discouraged in the use of mnemonics by teachers, and discussed in the first part of his paper. For addition, a curriculum that encourages rote memorization could teach students to memorize by rote if it does not teach them to use mnemonics.

SUMMARY

The findings indicate that mnemonics can work to benefit a student. The problem seems to be twofold: (1) students need to be instructed in the use of mnemonics, and (2) the bases for selecting the type of mnemonics which is most suitable to a student and the material he has to learn, need to be identified.

These conclusions are based upon three studies which utilize a total of 239 students at three different universities. Self-instructional materials covering the anatomy of the trigeminal nerve were developed along with tests measuring the objectives of the program.

The first study provided the mnemonics used in developing the programed materials in later studies.

The second study compared the program with mnemonics and a standard text, and revealed the superiority of the programed materials.

A third study compared (1) a program with mnemonics and (2) a program without mnemonics, and (3) the standard text. The results indicated that the students learned more from the programs, but that there are greater individual differences in learning when mnemonics are used than when they are not. This suggests that students need to be instructed in their use.

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