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A REVIEW OF THE LITERATURE ON MEMORY ENHANCEMENT: THE POTENTIAL AND RELEVANCE OF MNEMOTECHNICS FOR MILITARY TRAINING.

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This report reviews the literature on memory enhancement and assesses the potential of techniques designed to enhance memory (mnemotechnics) for military training. An overview describes a wide range of mnemotechnics. After a review of the empirical literature on mnemotechnics, a research strategy is offered for applying mnemonics and mnemotechnics to military training. Mnemonics and mnemotechnics have the potential to significantly enhance training effectiveness. However, if they are not carefully researched and implemented, it is likely that their training potential will be mitigated, if not entirely lost.

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Item 20 (Continued)

This report is intended primarily for professional researchers to identify areas of needed research. It can also be used by the military training community to assess the training potential of mnemonics and mnemotechnics.

Technical Report 436

A REVIEW OF THE LITERATURE ON MEMORY ENHANCEMENT: THE POTENTIAL AND RELEVANCE OF MNEMOTECHNICS FOR MILITARY TRAINING

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Memory Enhancement

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FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences conducts research to develop a technology base in support of field testing. Part of this research is to identify learning technologies which have the potential to enhance training effectiveness and the operational proficiency of the soldier. As effective memory is vital to the performance of many military tasks, techniques for memory enhancement, i.e., mnemotechnics, constitute a promising learning technology. This report, directed primarily to a research audience, provides a review of the technical literature on mnemotechnics. A research report to accompany this technical report will be directed primarily to management and will provide examples of how mnemonics and mnemotechnics can be incorporated into military training.

This entire project is responsive to special requirements of the Office of the Deputy Chief of Staff for Personnel and to Army Project 2Q762722A765.

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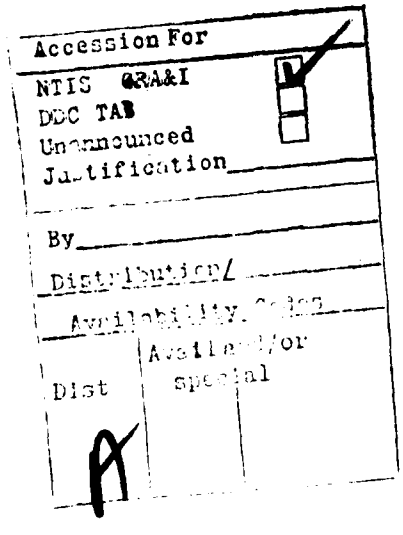

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A Review of the Literature on Memory Enhancement: The Potential and Relevance of Mnemotechnics for Military Training

BRIEF

Requirement:

To review the scientific and popular literature concerned with specific techniques for enhancing memory, i.e., mnemotechnics and to assess the potential of these mnemotechnics for military training.

Procedure:

An extensive review was conducted of the scientific literature on memory enhancement. A representative sample of popular books on memory training was also surveyed. Conclusions were based upon both rational and empirical analyses.

Findings:

(1) Mnemotechnics can clearly increase the rate at which new information is acquired. Accordingly, their potential for increasing military training effectiveness and consequent operational proficiency is obvious. (2) A wide range of mnemotechnics currently exists. Mnemotechnics are already available for such tasks as code learning and the acquisition of foreign and technical vocabulary. Moreover, the potential for developing new mnemotechnics for specific training problems is considerable. (3) Only a limited amount of research has been done on mnemotechnics in applied contexts. Given the large number of factors (e.g., personnel characteristics, motivational considerations, type of training task) that can impact on mnemotechnic effectiveness, mnemotechnics need to be carefully researched and implemented if their military training potential is to be fully realized.

Utilization of Findings:

This report will be used by researchers to identify areas of needed research on mnemotechnics. The military training community will use the report to assess the training potential of mnemotechnics.

A REVIEW OF THE LITERATURE ON MEMORY ENHANCEMENT: THE POTENTIAL AND RELEVANCE OF MNEMOTECHNICS FOR MILITARY TRAINING

CONTENTS

CONTENTS (continued)

INTRODUCTION

Techniques designed to improve memory can be traced back to the ancient Greeks (Yates, 1966). In ancient times training in specific techniques to enhance memory (i.e., mnemotechnics) was an integral part of rhetoric. Prominent persons were known for their memory feats. Pliny the Elder (Yates, 1966, p. 41) writes of the Roman Cyrus who knew the names of all the men in his army. Another Roman, Lucias Scipio, was said to have known the names of all the Roman people. Mithridates of Pontas was reported to have known the languages of all the twenty-two peoples in his domain. The Greek Charmudas was supposed to have known the contents of all the volumes of a library. Yates (1966) documents the role played by the art of memory from the ancient Greeks and Romans through the Middle Ages up to the time of the German philosopher and co-inventer of the calculus, Leibnitz. Given this grand tradition, one wonders about the demise of memory training. One could speculate that memory training is obsolete in the age of the computer and the Xerox machine. Research regarding how good students study, however, has indicated that many of the better students spontaneously use mnemotechnics of their own (Carlson, Kincaid, Lance, and Hodgson, 1976).

Indeed, contemporary psychological research and theory does provide support regarding the utility of mnemotechnics. The notion of modifiable processing strategies has developed within theories of human information processing (e.g., Atkinson and Shiffrin, 1968; Shiffrin and Atkinson, 1969). The practical implications of this notion are quite profound; if the manner in which individuals process information can be modified, then individuals might be trained to process information in an optimal manner. Consequently, the rate at which individuals acquire information and the amount of information they retain could potentially be enhanced. In fact, it has been amply demonstrated that the rate at which individuals acquire and retain information can be enhanced through the use of mnemotechnics. A review of these mnemotechnics and the empirical evidence bearing upon their effectiveness is provided in this review.

Given that mnemotechnics have been around for literally thousands of years, and given that modern psychological research has resurrected interest in these mnemotechnics, the immediate question arises regarding the potential of these mnemotechnics for the military. A technology which increases the rate at which individuals learn has obvious training benefits. In turn, these training benefits should be reflected in operational effectiveness. The first contract research done for the military on memory enhancement was a report, done in 1957, by Wallace, Turner and Perkins (Note 1). Using a mnemotechnic at a self-paced rate their subjects were able to recall up to 300 items perfectly. Even with

700 pairs of items, recall was of the magnitude of 95%. Several years later, Senter (1965) produced a report for the Aerospace Medical Research Laboratories which argued strongly for the application of mnemotechnics to training. In 1977, the Interservice Procedures for Instructional Systems Development called for the use of memory aids (mnemonics) in curriculum development. To address the issue as to how mnemonics could be incorporated into training materials, the Navy's Training Analysis and Evaluation Group (TAEG) developed a guidebook for technical writers to assist them in incorporating mnemonics into training materials (Braby, Kincaid, and Aagard, 1978). By using this approach Ainsworth (1979) was able to develop mnemonics which increased the rate of acquisition of Morse Code.

In spite of the above, very little use is made of mnemonics in training, and there is practically no formal mnemotechnical training in any of the services. Moreover, it is mistake to think that the application of mnemotechnics and mnemonics is a straightforward matter. Questions regarding what training materials should employ mnemonics and who should be given mnemotechnical training are very important. The final chapter of this report presents a research strategy for applying mnemonics and mnemotechnics to military training. The basic position of this report is that mnemonics and mnemotechnics represent a promising training technology. However, if this technology is not carefully researched and implemented, this potential will be either lost or greatly mitigated. Prior to discussing this research strategy, a chapter will be devoted to a discussion of most of the common mnemotechnics currently available, followed by a chapter reviewing the experimental literature bearing upon these mnemotechnics.

To understand how memory enhancement works, it is first necessary to understand what constitutes successful remembering. Generally speaking, successful remembering requires what Bartlett (1932) termed "an effort after meaning." That is, memorable information is meaningful information. When the information to be remembered is meaningful to the potential learner, then use can be made of the meaningful structure of the material itself as a mnemonic device. For example, most prose materials should be meaningful to the potential learner. Questions regarding optimal methods of processing prose materials constitute an important research area in their own right. (see Dansereau, Collins, McDonald, Holley, Garland, Diekhoff & Evans, 1979; Higbee, 1977; O'Neal, 1978). The current paper, however, is also concerned with a somewhat more intractable problem; i.e., the retention of materials that are not initially meaningful to the learner. Examples of essentially meaningless materials include lists, dates, most numbers, basically anything which appears arbitrary. At the outset of many different courses of instruction potentially meaningful material often appears meaningless. For example, for beginning

students, foreign words, and many principles and procedures are apparently meaningless. As a result, many students experience difficulty trying to learn such information.

Mnemotechnics are processing strategies developed specifically for remembering information which is apparently meaningless. They are special techniques which impose meaning and organization on apparently meaningless material. As a consequence of this imposed organization and meaning, the retention of nominally meaningless information is enhanced.

Although the terms mnemonics and mnemotechnics are often used interchangeably, in this paper they will have definite and distinct meanings. The distinction employed in this paper is essentially identical to that made by Senter (1965). Basically the term "*mnemonic*" will refer to a specific aid to memory. For example, the name Roy G. Biv is a *mnemonic*, a first letter mnemonic, for the colors of the spectrum. All acronyms are mnemonics, or at least purport to be mnemonics, their efficacy sometimes being in doubt. Any specific mediator, be it verbal, imaginal, or whatever, will also be regarded as a mnemonic. In distinction, a *mnemotechnic* is a system for generating mnemonics which attempt to solve a memory problem.

This paper will provide a description of common mnemontechnics. It will then review the experimental and other empirical evidence bearing upon the effectiveness of mnemotechnics. Finally, the paper will provide a focus for further research and development.

OBJECTIVES

1) To provide a list and description of the most common mnemotechnics.
2) To provide an assessment of the general utility of mnemotechnics.
3) To provide a research strategy for applying mnemonics and mnemotechnics to military training.

AN OVERVIEW OF MNEMOTECHNICS

The following list, while not claiming to be exhaustive, does present a fairly comprehensive description of mnemotechnics. Before discussing individual mnemotechnics, however, it would do well to enumerate a few basic principles common to all techniques.

Basic Principles

Retrieval Cues: If no, or few, retrieval cues for recall are provided in the to-be-remembered material, the mnemotechnic will supply specific retrieval cues. Typically, the retrieval cues of the mnemotechnics are systematic, thus allowing the individual to ascertain whether he has recalled all the required material.

Elaboration: All mnemotechnics involve some sort of mental elaboration whereby the to-be-recalled material is linked to the retrieval cue. The most commonly recommended type of mental elaboration is visual imagery. For example, say that the retrieval cue was "shoe" and the word to be remembered was "tire." The visual image linking these two words might be a mental picture of a shoe kicking a tire. Later, when the term "shoe" is presented, it should elicit the image of the shoe kicking the tire, allowing the recall of the term "tire." Although visual imagery is the most commonly recommended form of mental elaboration, other means of linking (e.g., sentences, phrases) are also sometimes recommended.

Recoding: Very often some recoding is required before the mnemotechnic can be employed. When abstract materials are encountered it is almost always necessary to recode them into a more concrete form before an image can be generated. Say, for example, that the word pair, government-religion was to be learned by forming a visual image. As both terms represent abstract concepts, they must each be recoded into concrete representations before an image can be formed. Accordingly, government could be recoded as the Capitol Building and religion could be recoded as the Pope. Then an image relating the two terms might consist of the Pope climbing up the Capitol Building. Very often the success in the implementation of a mnemotechnic will be dependent on an individual's ability to recode. One mnemotechnic to be discussed, the number consonant alphabet, is concerned primarily with the recoding of numerical information.

Method of Loci

Perhaps the oldest mnemotechnic, dating from the ancient Greeks (Yates, 1966), is the method of loci. In this technique the retrieval cues are the loci, which are especially selected well known places. The information which one desires to recall is mentally placed in the different loci by means of visual imagery.

Say, for example, that the task is to remember the following list at the grocery store: milk, hot dogs, beer, asparagus, bananas, popcorn, and bread. One might use the following areas of his house as loci: sidewalk, front door, mailbox, garage, chimney, roof, and patio. One then places mentally via visual images, the milk on the sidewalk, the hot dogs on the front door, the beer in the mailbox, the asparagus in the garage, the bananas around the chimney, the popcorn on the roof, and the bread on the patio. At the supermarket, the individual needs only to conjure up the images of the house to remember what was needed at the store. Greek and Roman orators used this same technique for somewhat more esoteric purposes. Columns in the halls where they spoke were sometimes used as the loci. The various parts of their speeches, recoded as concrete representations, were then placed at the different columns. The speaker would then use each column to remind himself of the successive topics of his speech.

Pegword Mnemotechnics:

The numeric pegword technique is essentially the same as the method of loci except that numerical pegwords replace familiar locations as the retrieval cues. The most popular and easiest to learn version of the numeric pegword technique is commonly called the one bun rhyme mnemonic. To use this technique the individual must first memorize rhyme pegwords for the digits one through ten. For example, one is a bun, two is a shoe, three is a tree, four is a door, five is a hive, six is sticks, seven is heaven, eight is gate, nine is wine, and ten is hen. Each item to be remembered is then linked to the rhyme pegword, typically by a visual image. Accordingly, if the following list of items was to be learned:

1 - Helicopter
2 - Rifle
3 - Jeep
4 - Desk
5 - House
6 - Religion
7 - Poverty
8 - Bravery
9 - Law
10 - Wealth

one might form the following images:

1. a Helicopter enwrapped in a bun
2. a Rifle stuck in a shoe
3. a Jeep up in a tree
4. a Desk blocking a door
5. a House underneath a beehive
6. the Pope (religion) picking up sticks
7. a group of poor people (Poverty) in heaven
8. some outnumbered soldiers (Bravery) defending a gate
9. a judge (Law) drinking a jug of wine
10. a hen laying a golden egg (Wealth)

It should be noted that because the last five concepts were abstract, they were recoded as concrete representations. It should also be noted that as the retrieval cues are numbers, information so encoded can be recalled either in or out of sequential order. By knowing how many items are to be recalled, the technique also provides a means of ascertaining whether all the desired information has been recalled.

The Navy's Training Analysis and Evaluation Group (TAEG) has employed the rhyme pegword mnemotechnic to train recruits on "Orders to the Sentries." After instruction on the rhyme pegword the recruits were given illustrated booklets. On each page was an illustration of the pegword and an image representation of the order appropriate to the numerical pegword.

Although rhyme words can be developed for as many digits as desired, proficient mnemonists tend not to use rhyme words as pegwords. In more advanced systems the numeric pegwords are based on the phonetic alphabet. The phonetic alphabet is discussed in more detail in a following section.

It is also useful to have pegwords based on the letters of the alphabet. Consider the following:

A - Ape	J - Junk	S - Sailor
B - Bum	K - King	T - Talk
C - Cat	L - Lemon	U - Uncle
D - Dog	M - Million	V - Vasoline
E - Egg	N - Nephew	W - Woman
F - Fox	O - Ox	X - Xylophone
G - Guy	P - Prisoner	Y - Yak
H - House	Q - Queen	Z - Zebra
I - Indian (American)	R - Rear	

In a military context consideration should be given to using the military's phonetic alphabet. The military phonetic alphabet is presented below:

A - Alfa	J - Juliett	S - Sierra
B - Bravo	K - Kilo	T - Tango
C - Charlie	L - Lima	U - Uniform
D - Delta	M - Mike	V - Victor
E - Echo	N - November	W - Whiskey
F - Foxtrot	O - Oscar	X - X-ray
G - Golf	P - Papa	Y - Yankee
H - Hotel	Q - Quebec	Z - Zulu
I - India	R - Romeo	

One disadvantage to using pegwords based on the military phonetic alphabet is that some of the pegwords are abstract, thus, theoretically at least, increasing the difficulty of generating interactive images based upon them. Nevertheless, with sufficient imagination, these pegwords can be used successfully. By employing multiple systems of pegwords (e.g., the two systems based on the alphabet presented here, plus the one numeric system presented here and the one to be presented later), one is simply enhancing one's flexibility for dealing with memory tasks.

Linking

Linking can be employed whenever a serial list or chain of associations is to be learned. Basically the technique involves using each recalled item as the retrieval cue for the succeeding item. Take, for example, the task of learning the following chain of command; President, Secretary of Defense, Secretary of the Army, Chief of Staff, FORSCOM Commander, Corps Commander, Division Commander, Brigade Commander, Battalion Commander, and Company Commander. One could link these elements as follows: the first image could be of the President talking to a secretary who is acting defensively and who has a big "D" on her sweater (Secretary of Defense); this secretary could, in turn, be pictured speaking to another secretary who is wearing an army uniform (The Secretary of the Army); then one could imagine this secretary speaking to an Indian Chief holding a staff (the Chief of Staff); one could then imagine this Indian Chief with a staff trying to halt a large mass of forces coming (FORSCOM); then one could mentally picture these forces coming (FORSCOM) and overrunning a commander leading some apple cores (Corps Commander). Next, these apple cores could divide into divisions with commanders (Division Commander). One division could then be herded into a brig (brigade); then one could imagine battalion colors being (Battalion Commander) placed outside the brig. Finally, one could imagine these battalion colors being placed outside a company store (Company Commander).

The foregoing might seem somewhat bizarre. It should be realized, however, that these mental gymnastics accomplish two purposes. First of all, they focus attention on the learning of the task at hand; and secondly, they recode abstract verbal information into a more readily accessible visual memory. It should also be noted that the pegword method could also be used to learn the chain of command simply by placing each level of the chain of command with its appropriate pegword. Although the pegwords might appear somewhat superfluous in the present case, they do offer one advantage. When the linking technique is used if one link in the chain is lost, it is possible that the entire chain might be lost. This danger does not present itself when pegwords are used.

Sometimes the linking mnemotechnic is referred to as the story mnemotechnic. Essentially, the linking aspect of the technique is maintained, except that in the story mnemotechnic the emphasis is placed on using a story to link successive items rather than on visual images. In the case of highly imageable items, it is very likely that the result of the two techniques is equivalent. In the case of abstract items, however, the use of a story to link items can eliminate the need to recode items as visual images.

Number-Consonant Alphabet

Any advanced system of mnemotechnics requires a technique for remembering numbers. The number-consonant alphabet represents the most common mnemotechnic for remembering numbers. According to Higbee (1977, p.136) the origin of the number-consonant alphabet can be traced back to 1648 when a mnemonist named Winckelman is purported to have introduced a digit-letter system. The technique involves the recoding of numbers as consonant sounds. Take the following recoding scheme: 1 = t,d,th; 2 = n; 3 = m; 4 = r; 5 = l; 6 = j, g (soft), ch, sh; 7 = k, c (hard) g (hard), ng; 8 = v, f, ph; 9 = p, b; 0 = c (soft), s, z. This technique, when mastered, allows the ready memorization of strings of numbers. Consider, for example, the task of memorizing the following serial number: 007423480. The number-consonant alphabet could be used to recode the digit string as follows:

s e e s	a	c o w	r u i n	m y	r o o f s
(0) (0)		(7)	(4) (2)	(3)	(4)(8)(0)

This phrase could in turn be elaborated further by forming an image of yourself watching a cow (presumably the same one who jumped over the moon) ruin your house and garage roofs by jumping on them. Or consider the task of learning the following phone numbers: 532-9826 and 532-1316. The 532 prefix can be recoded as "lawmen." The phrase "buff Nash" can be used to recode 9826, and the phrase "time dash" can be used to recode 1316. Accordingly one could form images of lawmen buffing a Nash and timing a dash to remember the respective phone numbers. One can link these images in turn to the images of the person or activity the numbers belong to.

One can similarly employ the number consonant alphabet to memorize the effective ranges of different weapons. For example, to remember that the main gun range of the T-55 tank is 1,500 meters, one could recode the T-55 tank as "Lulu (55) doing the tango" and firing her gun at "two lasses" (1,500); or to remember that the main gun range of the M-1970 medium tank is 2,000 meters one could imagine "Mike", the "top cuss" (M-1970) firing at some "nice sauce" (2,000).

As was mentioned above, all advanced mnemotechnics tend to make heavy use of the number-consonant alphabet. Numeric pegwords in advanced systems are based on the number-consonant alphabet. Below are listed numeric pegwords, from 1 to 100 which are based on the number-consonant alphabet.

1. Tie
2. Noah
3. Ma
4. Rye
5. Law
6. Shoe
7. Cow
8. Ivy
9. Bee
10. Toes
11. Tot
12. Tin
13. Tomb
14. Tire
15. Towel
16. Dish
17. Tack
18. Dove
19. Tub
20. Nose
21. Net
22. Nun
23. Gnome
24. Nair
25. Nail
26. Notch
27. Neck
28. Knife
29. Knob
30. Mouse
31. Mutt
32. Man
33. Mummy
34. Mare
35. Mail
36. Mush
37. Mug
38. Movie
39. Map
40. Rose
41. Rat
42. Rain
43. Ram
44. Rower
45. Rail
46. Rush
47. Rack
48. Roof
49. Rope
50. Louse
51. Lot
52. Lawn
53. Lamb
54. Lair
55. Lulu
56. Lush
57. Lake
58. Lava
59. Lap
60. Shoes
61. Shot
62. Shin
63. Sham
64. Chair
65. Jail
66. Choo Choo
67. Shuck
68. Shave
69. Ship
70. Case
71. Cat
72. Cane
73. Coma
74. Car
75. Coal
76. Cash
77. Cook
78. Cave
79. Cab
80. Vice
81. Vat
82. Fin
83. Fun
84. Fear
85. Fool
86. Fish
87. Fig
88. Fife
89. Fop
90. Puss
91. Pot
92. Pin
93. Bum
94. Beer
95. Pail
96. Bush
97. Buck
98. Beef
99. Bee Bee
100. Doses

Mnemotechnics for Spelling

A variety of mnemotechnical approaches can be taken towards the problem of spelling. At one level, an attempt can be made to develop specific mnemonics for each problem word. For example, the phrase "piece of pie" can serve as a mnemonic for remembering that "i" precedes "e" in "piece." However, at a more general level, mnemonics can be used to prescribe rules of spelling. For example, one could remember that "i" precedes "e" in "piece" from the rhyme mnemonic rule,

> "i" before "e" except after "c"
> or when sounded a
> as in neighbor and weigh.

Some of the general mnemotechnical systems can also be applied to spelling problems. The basic tactic is to employ words denoting letters of the alphabet (e.g., the cue words from an alphabetic pegword system). Theoretically, one could then use these words in conjunction with either a linking mnemotechnic or a numeric pegword mnemotechnic. In all likelihood, however, such an approach would prove too cumbersome to be practical. It would appear more feasible to use the alphabetic cue words on an ad hoc basis. For example, to remember that separate is spelled separate rather that seperate, a mnemonic image could be formed of an Ape separating some bushes.

Mnemotechnics for Speeches

Mnemotechnics for speeches are as old as the art of memory itself. It will be remembered that the method of loci was initially developed as an aid for remembering speeches and was a fundamental rhetorical skill in ancient times (Yates, 1966). Although the method of loci has historical precedence, both pegword and linking mnemotechnics were appropriate for the memorizing of speeches. The method is quite simple. First images are formed for each of the key ideas in the to-be-memorized speech. Then those images are either linked together in their appropriate order or are placed in their respective loci or with their respective pegwords. It should be noted that these mnemotechnics are not intended for memorizing speeches verbatim. Rather they are intended for remembering all the successive topics of a speech in appropriate order. The topics are then to be "talked."

Substitute Word or Keyword Technique

The substitute word or keyword technique is a mnemotechnic designed for the acquisition of new vocabulary words. This mnemotechnic consists of two component steps. The first step

requires the development of a substitute word or keyword based on the sound of the vocabulary word. The second step involves linking the keyword or substitute word to the meaning of the target word via a visual image. Before illustrating the technique it would be useful to make a distinction between substitute words and keywords. Although each technique involves the recoding of the target word in terms of its sound, a substitute word is based on the entire sound of the target word, whereas a keyword is based on only part of the sound of the target word. Although books on memory development (e.g., Lorayne & Lucas, 1974) have recommended using substitute words, the limited experimental work on the topic (e.g., Raugh & Atkinson, 1974, 1975) has indicated that keywords are preferable.

The technique could be used to learn the Spanish word for horse, caballo (pronounced cab'eye o), as follows: first a substitute word or phrase (a cab eyeing an "o") or a keyword (eye) would be developed based on the sound of the target word. Next, an image would be generated linking the meaning of the target word to the substitute phrase (a cab eyeing the (o) mark on a horse), or keyword (a cyclopean horse).

It should be noted that this mnemotechnic is not applicable solely for foreign vocabulary. It can also be used for learning new or technical terms in one's native vocabulary. Essentially, the mnemotechnic, as do all others, provides a way of imbuing meaning to apparently nonsensical material. And most unlearned vocabulary, native, technical, or foreign, is initially nonsensical.

Mnemotechnics for Morse Code

Harry Lorayne, a renowned memory expert, has developed a mnemotechnic for acquiring Morse Code. As he tells the story (Lorayne & Lucas, 1974), he developed the technique when he was serving as a private in the Signal Corps. He approached his commander with the mnemotechnic claiming that by using the technique, the men could learn Morse Code in thirty minutes. He says his commander turned him down, asking what would he do with the men for the remainder of the cycle.

Lorayne's (1957) technique involves the recoding of the dots as "r" sounds, and the dashes as "t", "th", or "d" sounds (e.g., a, .-, could be recoded as rat). However, Dr. Edwin Smutz has suggested that the recoding scheme would be more phonetically compatible if Lorayne's scheme were revised (i.e., dots as "t", "th", or "d" sounds and the dashes as "r" sounds). After all, the r sound is broader and, accordingly, more approriately recoded as a dash. Consider the following recodings based upon Dr. Smutz' scheme.

A	.-	tar	N	-.	rout
B	-...	rotted	O	---	rah rah rah
C	-.-.	retread	P	.--.	throw rod
D	-..	red day	Q	--.-	rear tire
E	.	tee	R	.-.	tired
F	..-.	tight ride	S	...	dud day
G	--.	roared	T	-	ray
H	....	toot toot	U	..-	tot chair
I	..	tutu	V	...-	tooted horn
J	.---	terror	W	.--	dear rye
K	-.-	rater	X	-..-	rudder
L	.-..	dear tot	Y	-.--	rat roar
M	--	rear	Z	--..	rare dude

These recodings of the Morse Code can then be linked to their respective alphabetic representations by using alphabetic pegwords. Vivid images can be generated to form these links. Printed below is a set of descriptions of images, linking letters of the phonetic alphabet to the recoded Morse Code.

A	.-	The Greek letter alpha dripping with tar
B	-...	Spectators yelling Bravo from a rotted stadium
C	-.-.	Charlie buying a retread
D	-..	A red day over the Delta
E	.	A tee shot sounding an echo in the woods
F	..-.	Doing the foxtrot on a tight rope
G	--.	The crowd roared at the golf shot
H	....	A hotel whistling toot toot
I	..	India wearing a tutu
J	.---	Juliet being in terror for her life
K	.-.	A rater evaluating a Kilo
L	.-..	A dear tot in Lima, Peru
M	--	A mike at the rear of the studio
N	-.	a 56-0 rout in November
O	---	Oscar cheering rah rah rah
P	.--.	Papa throwing a rod
Q	--.-	Having a flat rear tire in Quebec
R	.-.	A tired Romeo after a hard night
S	...	A dud day in the Sierra Mountains
T	-	Ray doing the tango
U	..-	Your uncle fixing a tot chair
V	...-	Celebrating a Victory with a tooted horn
W	.--	Drinking whiskey and dear rye
X	-..-	A rudder being x-rayed
Y	-.--	A Yankee hearing a rat roar
Z	--..	A Zulu, a rare dude

Of course, the above image mnemonics are idiosyncratic to the author. Different individuals should generate whatever images work best for them. If the images are to be supplied as part of the training materials, then the best images, in terms of learning efficiency, should be determined empirically.

The Naval Training Analysis and Evaluation Group (TAEG) have developed a set of pictorial mnemonics for learning Morse Code. Their mnemotechnic incorporates the dots and dashes directly into the mnemonic picture, (e.g., 3 SIERRA Mountains  ; 4 HOTEL windows  ; TANGO dancers ).

In short, there is no dearth of mnemotechnics for the learning of Morse Code.

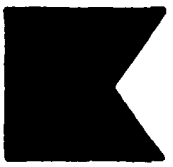
A Mnemotechnic for Remembering Names and Faces

The most commonly heard lament about memory failures is, "I can never remember a name, but I always remember a face." According to some notions, this discrepancy is a result of visual information, the face, being inherently more memorable than verbal information, the name. Lorayne (1975) has devoted an entire book to this problem. A solution to this problem is to recode the verbal information into a visual image. The retrieval cue in this mnemotechnic is a salient feature of the to be remembered individual's face. Say, for example, that Mr. Van Cott has a very large nose. One might form an image of a Van with a cot and a man sleeping in it, his big nose snoring. Or, consider Mr. Liebowitz who has a furrowed brow. One might imagine liverwurst covering his brow. Or, consider Ms. Goldstein who has sensuous lips. One might imagine her lips drinking from a golden stein. For those who might experience difficulty forming picturable equivalents of names, Lorayne has published lists of common names recoded so as to form picturable equivalents.

Mnemotechnics for Pictorial Symbol Referents

In a sense, the need for mnemotechnics for pictorial materials presents somewhat of a paradox. Typically, a mnemotechnic involves recoding verbal material into a picturable equivalent, as visual information appears to be superior, mnemonically speaking, to verbal information. However, in the use of pictorial symbols we begin with visual information which is presumably highly memorable. The resolution to this apparent paradox is that the memory problem usually does not concern the memory of the symbol itself, but rather the referent of the symbol, that is, the verbal or semantic information.

All mnemotechnics for pictorial information involve some sort of elaboration based on the sign relating it to the meaning of the sign. The Naval TAEG group at Orlando, Florida has developed a mnemotechnic for learning the meanings of Navy signal flags (Braby, Kincaid, & Aagard, 1978). They have developed specific mnemonics for each signal flag. In certain cases the mnemonic consists simply of a meaningful elaboration relating the flag to its meaning. For example, the flag for "B" (Bravo) is colored red and shaped as follows:

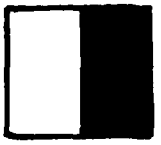


The mnemonic is that the Red flag is a Bullfighters cape and the crowd is yelling BRAVO for him.

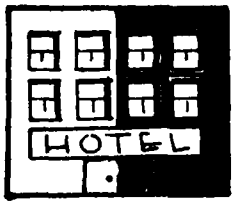
Or, the flag for "E" (Echo) has a blue top and a red bottom and is shaped as follows:

Here the mnemonic is "Blue sky - Red Earth."

Sometimes the mnemonic also consists of an elaboration of the picture itself. For example, the flag for "H" (Hotel) is as follows (the right half is colored red and the left half white):

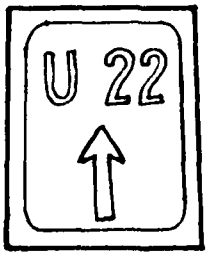


The mnemonic is comprised of the following:



Red light district Hotel

Griffith and Actkinson (1978) developed a mnemotechnic for instruction on international road signs which employed mnemonics for individual signs which elaborated specific features of the signs relating these features to the sign's meaning. For example, the sign for Autobahn Detour was:



The mnemonic was, "...concentrate on the "U" in the sign. Think of the "U" detouring you around something."

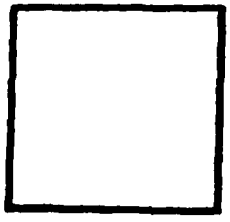
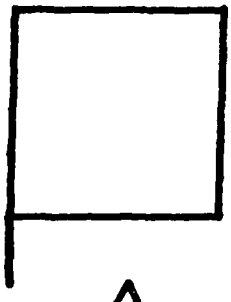
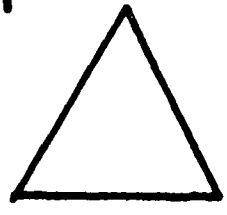
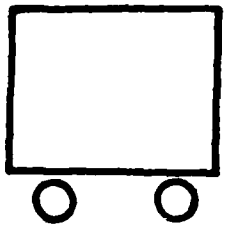
Weinstein (1978) has employed a similar mnemotechnic in which individuals are encouraged to develop their own mnemonics in which they use a feature of the sign to relate the sign to its meaning.

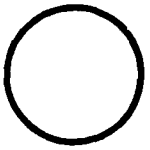
The problem of remembering the meaning of pictorial symbols is widespread. In fact, written Chinese consists solely of ideographs,

i.e., pictorial symbols. The Chinese do not employ a phonetic alphabet (i.e., an alphabet based on the sounds of the language), but use, rather, a unique pictorial representation for each word in the language. Presented below are some Chinese characters, their meanings, and some mnemonic cues which might prove useful in remembering the meanings of the symbols.

Characters	Meanings	Mnemonic Cues
日	Sun	Think of the sun coming through the window
月	Moon	Think of a ladder to the moon
火	Fire	Think of a man running from fire
水	Water	Think of a cockeyed spider thirsty for water
木	Tree	Think of a tree growing through the top of a mountain
金	Gold	An arrow planted in the earth with a carat on top marks the place where Gold is to be found
土	Earth	Think of a cross planted in the earth

Military symbols provide another instance in which there is a problem regarding remembering the meanings of pictorial symbols. Although FM21-30 (Military Symbols) does present something in the way of mnemonic cues for a few of the symbols, by and large, the student is left to fend for himself in learning military symbols. Presented below are some of the basic military symbols, their meanings, and some mnemonic cues which might prove helpful.

Symbols	Meanings	Mnemonics
	A unit	Picture a unit standing in a rectangular formation
	A headquarters or element of headquarters	Imagine a flag flying above a headquarters
	An observation or listening post	Imagine a lookout climbing to the top of a hill to observe or listen
	A combat service support element of a U. S. combat unit	Imagine a boxcar carrying combat service support



A combat service installation or activity

Think of trying to keep the ball rolling at a combat service support activity

Mnemotechnics for Remembering Times and Places

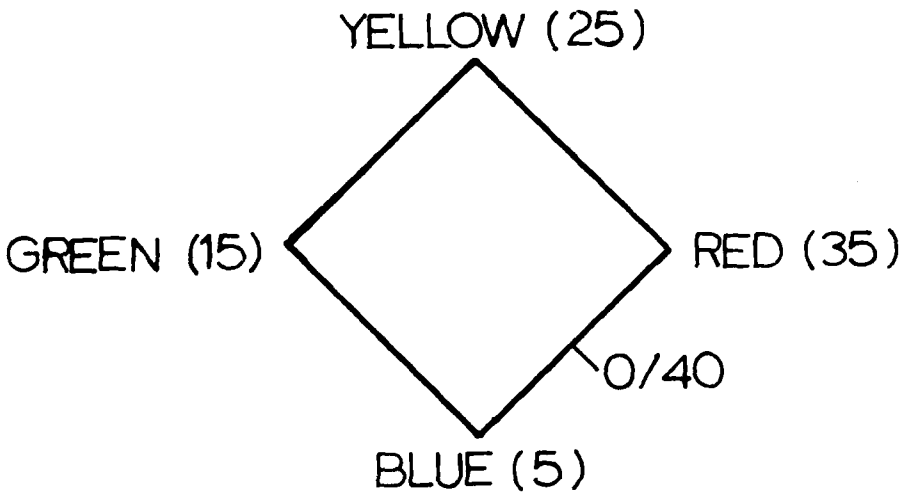
Mnemotechnics for remembering times and places requires a thorough profiency with the number-consonant alphabet. Say, for example, you have to remember that you have a dental appointment at 1430. First, you would need to recode the time by using the number-consonant alphabet. Fourteen thirty could be recoded as "tire mouse". Tire mouse could then be elaborated further into a mental image of a mouse sleeping in a tire. This mental image could then be transported to the place of your appointment, e.g., Dental Clinic #4. (By the way, if you needed to remember the number of the dental clinic you could simply imagine the dentists drinking a bottle of rye). Or suppose you needed to remember Colonel Sanders at the airfield at 1610. You need only imagine Colonel Sanders and you at the airport while you drop a dish on your toes (1610).

Mnemotechnic for Recognition

Practically all mnemotechnics are concerned with recall. In recall the target information must be retrieved from memory. Basically mnemotechnics provide a system of retrieval cues and a means of readily accessing memory via the retrieval cue. In recognition memory, the target information is presented again and the task is to identify the target information as old. A basic mnemotechnic for recognition memory is to mark mentally the to-be-recognized information. This mental marking can consist of recoding the information as an image and then, perhaps, further marking the information by setting fire to it, tearing it up, etc.

Mnemotechnics for Remembering Colors

An obvious means of improving memory for colors is to provide names for the colors. Indeed, it appears that naming a stimulus array assists memory (Bartlett, 1932). A somewhat more intractable problem involves the matching of hues from memory. This problem is difficult in that the color vocabulary of most people is impoverished relative to the richness of their color experiences. To compensate for this deficiency Siegel and Siegel (1976) have developed a mnemotechnic to improve memory for color. The first part of the mnemotechnic is to learn the following hue diamond:



The numbers in parentheses were used to represent the four psychologically distinct hues. Individuals then interpolate appropriate numerical values for various mixtures of the corner colors (e.g. 10 for a precise 50-50 blue green mixture).

Summary

A wide variety of mnemotechnics has been discussed. Although they are capable of dealing with an impressive range of memory problems, they have all been developed from the basic principles introduced at the beginning of this section, i.e., the provision for retrieval cues, mental elaboration, and recoding. The linking and pegword mnemotechnics are fundamental to even the most rudimentary system of mnemotechnics. The loci mnemotechnic appears to offer fewer advantages than the pegword mnemotechnic, and, therefore appears to be mainly of historical interest. Besides providing a means for readily memorizing numbers, a knowledge of the number-consonant alphabet is required for many advanced mnemotechnics.

Some of the remaining mnemotechnics, e.g., those for Morse Code learning and those for symbol memory, have obvious applications to military training. The direct application of some other mnemotechnics to military training might not be readily apparent. However, there was a purpose for discussing such mnemotechnics. And that purpose was to demonstrate the wide variety of tasks to which mnemotechnics are applicable. It should be appreciated that most mnemotechnics have been developed by professional mnemonists and stage magicians for the express purpose of entertaining audiences with their mental prowess. However, in the course of developing these "stunts" they employed, albeit informally, sound principles of human factors engineering. Essentially, they performed a task analysis of the feat they wanted to perform and then designed a strategy to accomplish that end. Memory problems became exercises in problem solving. The solutions to these problems were the development of specific mnemotechnics. Basically, this same approach can be followed with respect to military training problems. Training tasks need to undergo task analysis. The memory component of the training task needs to be delineated, then mnemotechnics can be developed to address the particular memory demands of the task. Only recently has the problem of developing mnemonics and mnemotechnics for training materials even been addressed (see Braby, Kincaid & Aagard, 1978). One may contend that the surface of this problem has only been scratched.

The next section will review the experimental research, what little there is of it, that directly addresses the utility of the mnemotechnics discussed in this section.

Although each of the above mnemotechnics will be discussed individually, it will be seen that little or no research has been directly addressed to many of the specific mnemotechnics.

Utility of Mnemotechnics - Experimental Evaluation

In the typical experimental paradigm employed to assess the utility of mnemotechnics, the performance of a group instructed in the use of a mnemotechnic is compared against one or both of the following control groups: (1) a noninstructed control, i.e., a group merely instructed to perform a task and given no clue as to how they might best perform it, and/or (2) a rote rehearsal control, i.e., a group instructed to learn material merely by repeating it over and over again to themselves. When assessed in this manner the group instructed in the mnemotechnic typically outperforms the control group(s). This type of experiment can be found ad nauseam in the literature. A comprehensive review can be found in Paivio (1971).

Typically the central focus in research on mnemotechnics has not been on the mnemotechnic per se, but rather upon some underlying theoretical process or construct that the mnemotechnic putatively involves. As mnemotechnics tend to rely rather heavily on imagery processes, it is not too surprising that mnemotechnics have been used extensively to investigate the theoretical construct of imagery. Paivio's monumental Imagery and Verbal Processes (1971) reports many studies on mnemotechnics, but they all are reported to validate the imagery construct or to elucidate Paivio's dual process coding theory.

Consequently, out of the multitude of research studies that have employed mnemotechnics, only a handful have focused on the effectiveness of the mnemotechnic per se. In fact, most of the research has employed standard learning paradigms from experimental psychology, e.g., paired associate, serial learning, free recall, recognition, verbal discrimination, rather than a specific mnemotechnic, e.g., pegword, loci, number-consonant alphabet. All the mnemotechnics listed in the preceding section will be discussed in this section. Where there is experimental evidence bearing upon the mnemotechnic, it will be discussed; where there is no experimental evidence, the lacuna will be duly noted. After each specific mnemotechnic has been discussed, experimental evidence bearing upon which mnemotechnics are most effective for list learning will be reviewed. The following section will discuss principles of effective mnemotechnic implementation. Next some additional considerations regarding mnemotechnics will be discussed, followed by a summary and conclusion section.

Method of Loci

One of the most frequently cited experimental references on the method of loci is that of Ross and Lawrence (1968). Subjects instructed in the method of loci were able to recall 38 out of 40 items presented once at a 13 second/item rate. One day later they were able to recall 34 out of 40 of these same items. Unfortunately, Ross and Lawrence did not employ a control group. Subsequently, Groninger (1971) did employ a control group. He found that not only did the subjects instructed in the method of loci learn a list of 25 words faster than the control group ($\bar{x}$ = 13 min 49 sec vs. 17 min 11 sec), but they also exhibited superior recall one week and five weeks later. The Groninger study, as do most studies on mnemotechnics, employed college students as subjects. Robertson, Tchabo, Hausman, and Arenberg (1976) used senior citizens sixty years or older as subjects. Using a pretest-postest design they found that the control group demonstrated lower pretest-postest improvement than did the experimental group using the method of loci.

Crovitz did a series of studies examining specific issues regarding the method of loci. In one study Crovitz (1969) claims to have found that memory loci did not have to be memorized to be effective. He found that when memory loci (i.e., locations on an artificial map) were shown to subjects average recall was thirty-four correct out of forty items. Crovitz did not employ a control group. It should also be noted that Montague and Carter (Note 2) found that learners should make up their own loci in order for them to be effective. In another study, Briggs, Hawkins, and Crovitz (1970) found that not only is it unnecessary for the loci to be memorized, but that it is also unnecessary that the association between the loci and the to-be-recalled items be generated by the learner. They found that average recall was seventeen out of twenty items. This conclusion needs to be regarded with some skepticism as again, no control group was included. Moreover, research using paired associates (e.g., Bobrow and Bower, 1969, Griffith, 1976) indicates that subject-generated mediators are superior to experimenter supplied mediators. Crovitz's (Note 3) third study indicated that a list of loci does not help subjects unless the subjects are trained in making effective visual associations.

Pegword Mnemotechnics

Compared to other mnemotechnics, the experimental evaluation of pegword mnemotechnics has been extensive. The first experimental analysis, reported in the United States at least, of a commercial memory technique was done by Smith and Noble (1965). They investigated the effectiveness of a hook (pegword) technique, based on the number-consonant alphabet, for learning serial 10-item lists of low, medium, and high scaled meaningfulness. Experimental

subjects received a one hour lecture on the technique and were given four days to practice the technique in private. Control subjects learned the serial lists, without any specific instructions regarding mnemonic techniques. In addition to the instructions provided the experimental group, the experiment proper consisted of a learning phase followed by a recall and relearning phase 24 hours later. Although the two groups did not differ significantly[1] during the initial learning phase, the mnemotechnic did significantly enhance performance during recall and relearning. The mnemotechnic did interact with item meaningfulness in that no differences occurred for lists of high meaningfulness, large differences in favor of the mnemotechnic under medium meaningfulness, and small differences in favor of the mnemotechnic for lists of low meaningfulness. One might attempt to explain these results by arguing that high meaningfulness materials could be readily learned and hence did not require a mnemotechnic, and that low meaningfulness materials were too difficult to use a mnemotechnic effectively. Besides being ad hoc, such an explanation finds no support elsewhere in the literature.

Senter and Hauser (1968) obtained somewhat different results from Smith and Noble (1965) using a very similar technique. Senter and Hauser provided a combined demonstration and training session on the hook (pegword) technique which lasted for 1/2 hour and was given one week before the experiment proper. Subjects learned a list of 20 CVC trigrams by the method of serial anticipation; i.e., individual CVC's were presented sequentially and subjects were to provide the next CVC in the sequence. Feedback was provided and they were to anticipate the next item, and so forth. The CVC list alternated items of 0% association value with items of 100% association value. The hook (pegword) mnemotechnic proved effective at both levels of association value.

A criticism of the two preceding studies was that control subjects received less pretesting practice than did the experimental subjects. This criticism was avoided somewhat in an experiment by Berla, Persensky, and Senter (1969). In their experiment control subjects were given the same amount of pretest training, i.e., they learned the pegword, and the practice lists, although they were not instructed as to how to employ the pegwords in the mnemotechnic. The primary dependent measure in this experiment was the time required to learn the list of 20 words. The list was learned significantly faster by individuals employing the peg mnemotechnic. This experiment also compared the performance of subjects for whom

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[1]Whenever the term significant difference is employed it refers to an alpha level of .05. Sometimes, however, the obtained "p" values were less than .05.

the pegwords were provided during recall against the performance of subjects who had to provide the pegwords themselves during recall. Interestingly enough, individuals who were provided with the pegword during recall took longer to learn the test list than did individuals who had to provide the pegword implicitly. Persensky and Senter (1969) performed a similar study using recall accuracy as the dependent variable. They also compared the performance of the following three groups: a drill, or control group, which was given practice learning serial lists; a lecture group which was provided a lecture demonstration on the hook (pegword) method; and a lecture-drill group which was provided a combination of the two preceeding treatments. Although no significant difference was obtained between the lecture and the lecture-drill groups, both of these groups performed significantly better than the drill only (control) group. These findings obtained both on an immediate recall test and on a delayed test administered 24 hours later. This experiment also contrasted performance when the pegword was and was not explicitly presented. In contrast to the Berla, Persenky, and Senter (1969) study no significant differences were found between these two conditions. As another study by Delprato and Baker (1974) found no difference regarding the effectiveness of pegwords as a function of whether or not the pegwords were explicitly presented, it is likely that this factor is not important to mnemonic effectivensss provided that the implicit pegwords are sufficiently learned.

Up to this point the pegwords that have been employed have been based on the number-consonant alphabet. For most experimental purposes an easier pegword system to employ is the one-bun rhyme mnemonic. The rhyme scheme makes the acquisition of the pegwords much easier. In an experiment (Foth, 1973) which compared the effectiveness of rhyme pegwords as retrieval cues versus the effectiveness of pegwords based on the number-consonant alphabet, the results were essentially equivalent.

Bugelski, Kidd, and Segmen (1968) reported an important parametric investigation of the one-bun rhyme mnemotechnic. They compared the performance of their mnemonic group against both a standard noninstructed control group and a rhyme control group which learned the one-bun rhyme, but was not instructed in imagery elaboration. Presentation rates of two, four and eight seconds were employed. No significant enhancement for the mnemonic group was obtained at the two second rate. Significant enhancement was obtained at the four second rate, however, and even greater enhancement was obtained at the eight second rate. The performance of the rhyme control was essentially equivalent to that of the standard control.

Bugelski (1968) addressed the issue of interference when the pegwords were used to learn successive lists of items. Bugelski had

rhyme pegword mnemonic and control subjects learn six successive lists of ten items each, self-paced ($\bar{x}$ seconds/item : mnemonic = 8.11; control = 6.11). At the end of the experiment subjects were to recall as many items as possible in their correct ordinal position (e.g., all number one items, all number two items, etc.) from all six lists. During the initial recall of each of the lists the mnemonic subjects exhibited uniformly high recall, whereas control subjects presented a pattern of recall in which performance alternated high, low, high, low, etc. On the final recall of all the lists, the average recall for the mnemonic group was 63% as compared with 22% for the control group. Although the recall for the mnemonic group was representative of all lists, recall for control subjects tended to be greatest on the last two lists learned.

Keppel and Zavortink (1969) partially replicated Bugelski's (1968) findings. Although they did find an absence of proactive and interference effects across four successive lists, both the mnemonic and control groups exhibited pronounced retroactive effects during the final recall of all four lists. Perhaps a significant difference between the two studies is that Bugelski (1968) employed a self paced procedure, whereas Keppel and Zavortink (1969) employed a six second/item presentation rate.

Bower and Reitman (1972) compared two means of employing pegwords in a multilist situation. One group (SI) was to form separate images for each pegword for each list. The other group (PE) was to elaborate progressively their images for each pegword across the lists. That is, as each new list was learned, items were added to the composite image for each pegword. Thus at the end of the five lists that were learned, the PE groups were to have one composite image of five items and the pegword, whereas the SI group was to have five separate images for each pegword. There were no significant differences on the immediate recall of each list. However, at the end of session test and at the one-week delay test the PE group was significantly superior to the SI group. On the one week test, however, there was a tendency to recall better the items from earlier lists, thus suggesting some effect of cumulative rehearsal. Bower and Reitman employed a 10 second/item presentation rate. The literature suggests, then, that proactive interference does not present a problem with the pegword mnemotechnic, and that there are at least two ways of mitigating or eliminating retroactive effects, i.e., through self-pacing or progressive elaborations.

Apart from the use of explicit-presentation versus implicit generation of pegwords, little attention has been given to what constitutes an effective pegword. This question is important apart from applied considerations, for it gets at the issue of what constitutes an effective retrieval cue - an issue at the very heart of memory theory. One aspect of this issue which has been

addressed, but not answered, is that of the relative effectiveness of concrete versus abstract pegwords. According to Paivio's (1969) conceptual peg hypothesis, item concreteness is more potent on the stimulus side than on the response side of paired-associates. Standard paired-associate research, with the stimulus terms presented explicitly, has corroborated this hypothesis. Paivio (1968) found, however, that recall did not vary as a function of pegword (stimulus) concreteness when subjects were using a rhyme pegword mnemotechnic. Subsequent investigators (Delprato & Baker, 1974; Wortman and Sparling, 1974) who have purported to address the issue of pegword concreteness have clearly not addressed the issue as both studies confounded pegword concreteness with response concreteness. Thus far all studies have dealt exclusively with numeric pegwords; pegwords based either on the number-consonant alphabet or upon rhyme schemes. No studies have been found regarding pegwords based on other systems, e.g., the alphabet.

Another question which has received scant attention regards the characteristics of individuals that influence effective use of the pegword mnemotechnic. Most of the reported studies have used college students as subjects. At one extreme Higbee (1976) demonstrated, to his own satisfaction at least, that two young girls (age 7 yrs. 2 mos., 5 yrs. 3 mos.) were able to use the rhyme pegword technique to learn the Ten Commandments. At another extreme, however, Griffith and Actkinson (1978) found that, in the army at least, only individuals with General Technical (GT) scores 110 and over were able to use the rhyme pegword techniques effectively. Griffith and Actkinson did use an eight second presentation rate. It may be that at a slower presentation rate and/or with more practice time, low and moderate GT aptitude individuals could use the mnemotechnic effectively.

Linking Mnemotechnic

Wood (1967) compared a linking mnemotechnic against a noninstructed control group on the learning of a list of forty words presented aurally and found the recall of the linking group to be superior. Delin (1969a) instructed experimental subjects to learn a serial list of sixteen items by using bizarre images to link successive items. Delin stressed, however, that each pair of images was to be unique and that the successive images were not to be linked together in a string. He found the recall of this experimental group to be higher than the recall of a control group given standard serial anticipation instructions. In another study Delin (1969b) attempted to determine what components of the linking mnemotechnic were responsible for improved recall performance by employing the following successive approximations to a linking mnemotechnic: (a) to treat each item as paired with the previous one; (b) to make a mental image of each item paired with the previous one; (c) to make a vivid mental image of each item paired with the previous one; (d) to make a vivid active image of each item paired with the previous one; (e) to do (d) using as many sensory modalities as possible; and (f) to do all the preceding and to make the images bizarre. Delin found that with the exception of (a) simple pairing and (f) bizarreness, each successive approximation significantly incremented recall. Another researcher, Bugelski (1974), also found that instructions to use a linking mnemotechnic resulted in serial recall superior to that of a standard control group. Moreover, he obtained this result with both college students and eighth graders.

Bower and Clark (1969) have reported a study demonstrating the effectiveness of a type of linking mnemotechnic, the story technique. Subjects were required to learn 12 serial lists of 10 nouns each followed by a final recall of all the lists. Experimental subjects were instructed to learn the lists according to a narrative-chaining technique in which each noun was linked to each succeeding noun in terms of a narrative story. Experimental subjects were allowed as much time as they needed to learn each list. Each control subject was yoked to an experimental subject in terms of time allowed to learn each list. Although the immediate recall was essentially equivalent for both groups, on the final recall the experimental group outperformed the control group by a factor close to four.

Murray (1974) extended the findings of Bower and Clark (1969) by varying the interitem associative strength of list items (high, low, and zero) and by assessing retention immediately after each list was studied, at the end of the session after the ten word lists had been learned, and at retention intervals 7, 14, and 28 days after list learning. Murray confirmed Bower and Clark (1969) by finding no significant differences between the experimental and control groups,

and in finding a significant difference in favor of the experimental group during the recall test administered at the end of the session. Moreover, Murray found recall at the end of session test and at the seven day retention interval to be higher for the experimental condition regardless of the interitem association strength. The retention difference between the experimental and control conditions did not maintain for the 14 and 28 day intervals, however.

Herrman, Geisler, and Atkinson (1973) explored the effectiveness of a narrative story mnemonic by having subjects alternate telling and listening to stories linking the 8 nouns for each of the lists. They did not employ a control group in their study. They found the narrative-story mnemonic had the apparent effect of elevating recall for items in the middle of the lists, resulting in flat recall functions and thus the elimination of the typical serial position effect (i.e, the elevated recall of the ends of lists).

Although the preponderance of studies clearly indicate mnemonic enhancement as a result of employing a linking mnemotechnic, two experiments by Gamst and Freund (1978) revealed negative results. Gamst and Freund had subjects learn one list of thirty words under one of the following sets of instructions; (1) to recall the list however they wished; (2) to generate a story linking the list items (i.e., a linking mnemotechnic) and during recall, to write the stories they had devised and then to circule list items; or (3) to generate a story linking the list items (i.e., the linking mnemotechnic again) and, during recall, first to write all the list items they could remember and then to write the story they had devised, circuling the list items. Half the subjects under each condition learned a list with high imagery items, whereas the remaining subjects learned a low imagery list. All subjects were given five minutes to study their respective lists. Although, there was a main effect of item imagery (high>low), there was no significant effect of instructional set nor was there a significant instructional set by item imagery interaction. The second experiment compared a free recall condition, with a story generation (linking mnemotechnic) condition, with a third group whose subjects were given one of the linking stories from a set of linking stories which had been generated by other subjects. A second variable was study time; subjects were given 1, 3, or 5 minutes for study. Again, although there was the expected significant main effect of study time, there was neither a significant main effect of the type of study condition, nor was there a significant interaction effect. Gamst and Freund listed some methodological differences among studies to account for why their findings were discrepant from other researchers. One reason offered was that the Gamst and Freund study employed a single list of thirty words. Most previous studies employed a successive series of shorter lists. Accordingly Gamst and Freund hypothesized a practice effect in some of the other studies. That is, subjects might have become more proficient in the

technique across lists. Gamst and Freund employed no practice list in their experiments. They also presented the whole list to the subjects, rather than presenting the items sequentially.

Number-Consonant Alphabet

Although the number-consonant alphabet is central to any advanced system of mnemotechnics, no studies were found in the literature regarding the number-consonant alphabet *per se*. Issues regarding how long it takes to become proficient with the number-consonant alphabet, and to what extent the use of the number-consonant alphabet enhances the retention of digital information have simply not been addressed. Apparently trained mnemonists can use the number-consonant alphabet in a most impressive manner. However, to the best of this writer's knowledge, there have been no systematic analyses regarding how effectively mnemonists do use the number-consonant alphabet. There has been anecdotal evidence reported. The famous mnemonist Roth is said to have learned the hundreds of names and phone numbers of the members of the San Francisco Rotary Club (Hoffman & Senter, 1978). Bower (1973) writes about a 96 year old man who would memorize lists of 50 three-digit numbers shouted out to him by an audience at the rate of one three digit number every five or ten seconds.

Data which do address the central feature of the number-consonant alphabet, i.e., recoding, were reported in George Miller's classic article, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity For Processing Information" (1956). He reported a study by Sidney Smith in which Smith demonstrated that the memory span for binary digits could be greatly enhanced by recoding the binary digits into higher order chunks of octal digits. After Smith had practiced extensively on the system itself he was able to recall a sequence of forty binary digits read to him once.

Slak (1970) did a series of experiments in which he used a letter-number system of his own invention. Slak's system was designed specifically for the learning of three digit numbers. In his system the first and third letters were represented by consonants and the middle digit was represented by a vowel. Approximately twenty hours were required to learn this system. The system was reported to be useful for a memory-span task, and serial learning task, and a free recall task. Because of the amount of time required to learn the system, the subject pool was restricted to Slack himself and one assistant. He taught a simplified version of his system to twenty undergraduates who used it to learn the numbers about twice as fast as a control group that had not been taught the system.

Chase and Ericsson (Note 4) have recently reported an extensive study of a single individual who is attempting to increase his digit

span. After seven months of training this individual increased his digit span from seven to forty-two. The mnemotechnical coding strategy this individual has developed is quite interesting. Taking advantage of his own interest in competitive running, he recodes digit sequences in terms of what constitutes good, poor, and average times for different distances.

Mnemotechnics for Spelling

No research was found bearing upon the utility of mnemotechnics for spelling. This absence of research on mnemotechnics and spelling is remarkable as spelling difficulties in English are noteworthy, even among the highly educated. Within the realm of Army training, a spelling subtest is one of the criteria against which the Basic Skills Education Program (BSEP) is assessed. It would be interesting to determine whether BSEP participants given mnemotechnical training in spelling would perform appreciably different on the spelling subtest than BSEP participants given no mnemotechnical training.

Mnemotechnics for Speeches

In spite of their historical precedence, no research was found, in the psychological literature at least, bearing upon the effectiveness of mnemotechnics for speeches. One interesting comparison would concern which of the following mnemotechnics is more effective: loci, pegwords or linking. In an instructional situation it would be interesting to compare the respective performances of instructors using one of the three following methods: reading a lecture verbatim; delivering the lecture from notes; and delivering the lecture with a mnemontechnic. These same comparisons would also be interesting in comparing formal speeches.

Substitute Word or Keyword Technique

The reader will remember that the distinction between the substitute word or keyword technique is that the substitute word is based on the entire word or phrase to-be-learned, whereas a keyword is usually based on only a fragment (e.g, syllable) of the to-be-learned material. The substitute word or keyword is then related to the meaning of the to-be-learned material by forming an interactive image involving the substitute word (keyword) and a visual representation of its meaning. All published research has dealt with the keyword technique to the exclusion of the substitute word technique. Apparently the substitute word technique was discarded as a result of pilot research which indicated that keywords were either more effective or practical (Raugh & Actkinson, 1974).

The first published experiment on the effectiveness of the

keyword technique is by Ott, Butler, Blake, and Ball (1973). They studied the acquisition of the English translations of 24 one syllable German nouns and adjectives. Four treatment groups were employed: Treatment 1, in which the keyword was presented as an interactive picture relating the keyword and the to-be-learned word meaning (e.g., a picture of an eye peering out of an egg as a mnemonic for the German word, Ei, meaning egg); Treatment 2, in which subjects only saw the English interpretation of the German word that was being pronounced on the tape (These subjects were instructed to select an English word which sounded similar to the German word they were hearing and to generate an interactive image associating the English sound-alike word and the meaning); Treatment 3, in which subjects learned the English translation of the German words according to their own strategies; and Treatment 4, in which subjects were to learn the meanings of the German words according to rote repetition. Words were presented to all subjects at a 12 second rate. Subjects were given a retention test eight minutes after they learned the list (the interval was filled with an interpolated task); they were subsequently tested two weeks later. Statistical analyses indicated that Treatments 1 and 2 were significantly superior to Treatments 3 and 4 which were indistinguishable from one another on all three tests. Although Treatment 1 was significantly higher than Treatment 2 during the learning test and the retention test, this difference disappeared in the delayed retention test.

Raugh and Atkinson (1974, 1975) conducted four experiments regarding the effectiveness of the keyword mnemotechnic for the acquisition of the meanings of Spanish vocabulary words. In their first experiment all subjects were taught the keyword for each word of a 60-word Spanish vocabulary. After learning the keywords, the experimental group was trained to use mental imagery to associate each keyword to its corresponding English translation, whereas the control group was trained to use a rote rehearsal method to associate each Spanish word directly to its English translation. The final test score for the experimental group was 88% correct versus 28% correct in the control group. In their second experiment the keywords were not prelearned. Rather, the subjects in the experimental group learned the keywords simultaneously with their formation of imagery links, whereas the control subjects used rote rehearsal to make direct associations between the Spanish words and their English translations. Here the final test score was 59% correct for experimental subjects and 30% correct for control subjects. Subsequent experiments were run under computer control. Keywords were presented on the computer's CRT while the Spanish word was heard from audio tape. Subjects used the keyboard to type their responses. The third experiment employed a within subjects design. Under the control condition subjects were told to use any learning strategy except the keyword strategy. Again a significant difference was obtained with final test scores averaging 54% under

the keyword condition versus 45% for the control condition. The fourth experiment added a free-choice condition, under which the subject could request a keyword if desired, to the strict keyword condition, in which a keyword was always supplied, and an anything-but-keyword control condition. The final test scores averaged 59%, 57%, and 50% correct for the free-choice, strict keyword, and anything-but-keyword control conditions, respectively. Whereas the free-choice and strict keyword were not significantly different, both of these conditions were significantly better than the anything-but-keyword control condition. Under the free-choice condition, subjects requested a keyword at least once for 92% of the items. Moreover, the frequency of keyword requests increased with the scaled difficulty of the items.

Atkinson and Raugh (1975) expanded the generality of their conclusions in an experiment involving Russian vocabulary acquisition. Subjects were to learn the meanings of 120 words presented over three days. One group was instructed in the keyword mnemotechnic. They were told to learn the keyword first and then to picture an imagery interaction between the keyword and the English translations; they were also told that if no such image came to mind, they could generate a phrase or sentence incorporating the keyword and translation. Control subjects were not given instructions on the use of keywords or mental imagery, but were simply told to learn the meanings in whatever manner they wished. The average percentage correct on a comprehension test was 72% for the keyword group and 46% for the control group. On a delayed comprehension test (range 30 to 60 days later, $\bar{x}$ = 43 days), the keyword group recalled 43% whereas the control group recalled 28%.

All the preceding studies were psychology experiments. That is, subjects were not language students struggling with the acquisition of their respective vocabularies. Raugh, Schupbach, and Atkinson (1977) have reported a study involving second year Russian students. These students studied a large (675 words) basic vocabulary over an 8 to 10 week period. Unfortunately, no control group was employed in this study and only thirteen subjects were involved overall. Most subjects did find keywords useful, however, and tended to use them when they saw no roots or cognates they could employ.

Willerman (1977) examined the utility of the keyword mnemotechnic for first year college French students. Moreover, she examined French vocabulary production as well as English translation as dependent variables. Willerman found no facilitating effect for the keyword mnemotechnic under any conditions. In fact, some students were hostile to the keyword mnemotechnic. A close examination of her instructions and procedure, suggests that the instructions and procedures are likely reasons why she did not obtain effects. Her instructions were minimal and very little was provided in the way of training and feedback to assure that the

students understood the technique.

Morse Code Mnemotechnics

Ainsworth (1979) reported on the effectiveness of the pictorial mnemonics developed for the learning of Morse Code by the Naval Training Analysis and Evaluation Group (TAEG). During the acquisition phase mnemonics resulted in superior performance when compared to a traditionally trained group with respect to both sending and receiving skills. The mnemonics enhanced sending skills more than receiving skills. These tests administered during acquisition were paper and pencil tests. At the end of the fourth and fifth weeks of training subjects were tested during a performance phase on their skill in receiving flashing light messages. The type of instruction employed did not have significant differential effects during this performance phase.

No published reports were found bearing on the effectiveness of other mnemotechnics in Morse Code learning.

Mnemotechnics for Remembering Names and Faces

Although the issue of facial recognition has received some attention (e.g., Winograd, 1978, Bower and Karlin, 1974), no research has examined the utility of recoding names into concrete representations and then forming an interacting image between a salient facial feature and the concrete representation of the name. Again, as with other mnemotechnics, there is anecdotal evidence regarding its effectiveness. For instance, the mnemonist, Harry Lorayne, before appearing on the Jack Paar television show associated the names of each person in the studio audience, numbering around 400, to their respective face. During the show he recalled each name as the person stood up in the audience. Lorayne, however, has devoted his life to the performance of feats of memory. The general utility of this mnemotechnic remains an open question.

When one considers the common lament about memory, "I can never remember a name, but I always remember a face," the dearth of experiments concerning the association of name to face is most remarkable. In fact, only one published experiment was found regarding the problem of associating names to faces. That study by Landauer and Bjork (1978) examined the effectiveness of different practice schedules for associating names to faces. They found that by expanding the time between successive tests, name recall was significantly enhanced.

Mnemotechnics for Pictorial Symbol Referents

Griffith and Atkinson (1976) reported on the effectiveness of mnemonic cues for the learning of the meanings of international road

signs. Although they found no significant evidence for mnemonic enhancement, they argued that the conditions were far from optimal. They suggested that with further refinements mnemonic cues might prove useful.

Higbee (1977) reported a masters thesis (Chuang, 1974) and a doctoral dissertation (Bennion, 1974) bearing upon the utility of a mnemotechnic for learning the English translations for Chinese ideographs. In the Chuang study high school and college students learned twelve Chinese-English word pairs. Half of the students were told to learn the pairs by means of rote rehearsal, whereas the remaining students were instructed to form a mental image which would help them remember the English meaning of the Chinese ideograph. Retention was tested by means of both recall and recognition. Although the differences were consistently in favor of the students employing the mnemotechnic, a statistically significant difference was only obtained for high school students under recognition testing. The experiment by Bennion involved the same twelve word pairs, but the subjects were all high school students. Bennion compared the mnemotechnic against a control condition in which the students were to note the geometrical features of the Chinese characters. The same pattern of results was obtained in the Bennion study as in the Chuang study. Again, only the recognition test was statistically significant.

The above studies exhaust the available research on the utility of mnemotechnics for learning the referents of pictorial symbols. Clearly a great deal more research needs to be done.

Mnemotechnics for Remembering Times and Places

No reports were found in the literature bearing upon the issue of the effectiveness of specific mnemotechnics for remembering times and places.

Mnemotechnics for Recognition

No research reports were found in the literature regarding the effectiveness of mental marking per se on recognition memory. However, an experiment by Griffith (1975) does suggest that imaginal elaboration can enhance recognition memory. In an incidental learning task, subjects were to rate individual words presented aurally in terms of their imageability. Subjects performing this imagery incidental task were superior on a subsequent recognition test to subjects who categorized these same words, and to subjects who were intentionally set for the recognition test. As mental marking typically involves imaginal elaboration it is reasonable to expect that explicit instructions to mark mentally to-be-recognized information would result in similar enhancement. Obviously, a good deal more research must be done, however.

Mnemotechnics for Remembering Colors

An experiment by Siegel and Siegel (1976) assessed the utility of the mnemotechnic using the hue diamond with numerical interpolation. Subjects trained for ten minutes on this color coding mnemotechnic performed more accurately and more consistently in a task requiring the matching of hues from memory than a control group not instructed in the mnemotechnic.

Relative Effectiveness of Mnemotechnics for List Learning

The linking, loci, and pegword mnemotechnics can all be used for learning lists of items. A central question is whether any one mnemotechnic is better than the others. Pegword mnemotechnics do have an advantage in that they not only allow the strict serial learning of a list, but they also provide for the rapid recall of list items by their precise serial position. That is, if someone had employed either the method of loci or a linking mnemotechnic and was asked to recall the fifth item on the list, he would likely have to run through the list to retrieve the fifth item. If that person had used a pegword mnemotechnic, however, he would simply recall the pegword for five, and retrieve the appropriate item.

Suppose the task is that of free recall or serial recall and that rapid recall of list position is not important. Under these conditions is it desirable to use a pegword technique? Three experiments suggest a negative answer to this question. With respect to free recall, Wood (1967) found a linking mnemotechnic superior to a pegword mnemotechnic for the learning of a list of forty words. Similarly, Santa, Ruskin, and Yio (1973) found a story technique (linking) to be superior to a pegword technique with respect to the final recall of six lists of ten words each. With respect to serial learning, Borges, Arnold, and McClure (1976) found a story mnemotechnic superior to a pegword mnemotechnic for the

delayed recall of four lists of ten items each. It would appear, then, that unless it is desirable to recall rapidly by list position, that a linking story mnemotechnic should be preferred for list learning.

Principles of Effective Mnemotechnic Implementation

All mnemotechnics involve the generation of mediators. These mediators usually take the form of visual images. The discovery, then, of principles of good mediator generation has direct relevance for the effective implementation of all mnemotechnics. With regard to the problem of mediator effectiveness, the following issues have been investigated.

Item Attributes (Imagery Value, Concreteness, and Meaningfulness) Norms are available (e.g., Paivio, Yuille, and Madigan, 1968) which rate individual words in terms of their imagery value (how easy it is to form a mental image for a referent of the word), concreteness (how directly the word refers to something tangible as opposed to something abstract), and meaningfulness (the number of associations that can be generated to a word within a prescribed time period). One of the most robust and significant findings to come out of all the literature on verbal learning and memory is that these attributes correlate very highly with learning and retention. Paivio (1969,1971) has argued and provided empirical support for the position that of these three attributes, imagery value is the most important. It is much easier to employ mnemotechnics when the to-be-remembered material is readily imaged. Indeed, most mnemotechnics provide for the recoding of abstract information into an imageable representation. Generally speaking, the less recoding that is involved, the more effective is the implementation of the mnemotechnic.

Bizarreness, Interaction, and Emotionality of Mediators One of the most fundamental precepts of the ancient mnemonists (Yates, 1966) was to make images as bizarre (implausible, incongruous, or ludicrous) as possible. Presumably, bizarre images were regarded as more memorable. This same principle is advocated by modern mnemonists (Furst, 1957; Lorayne, 1957). Some experimental work, however, has tended not to support this principle. Research by Wood (1967), Perensky and Senter (1970), Nappe and Wollen (1973), and Senter and Hoffman (1976) found not only that bizarre imagery was no more effective than common images, but also that subjects required more time to form bizarre than common images. Hauck, Walsh, and Kroll (1976) essentially replicated the Nappe and Wollen experiment with more experienced subjects. Although subjects improved their speed of image generation across five days of experimentation, it still took longer to generate bizarre as compared to common images. Again no difference in recall performance was obtained.

Wollen, Weber, and Lowry (1972) argued that the dimensions of bizarreness and interaction were probably confounded in the typical experiment. Accordingly, they attempted to separate the dimensions by providing pictures for each of the word pairs. Each word pair had the four following pictorial representations: interacting, nonbizarre; interacting, bizarre; noninteracting, nonbizarre; and noninteracting, bizarre. Within this paradigm they discovered that it was the interaction rather than the bizarreness dimension that had a facilitating effect on recall. Subsequently, these results were replicated by Senter and Hoffman (1976).

Sadalla and Loftness (1971) examined the question of the effect of emotionality on images. They had subjects construct images of positive, negative, or neutral emotional content for use as mnemonic aids in a paired-associate task. They found that the emotional mediators were more effective than neutral mediators, but that it did not make any difference whether the mediators were positive or negative in content.

Both the issues of bizarreness and emotionality were re-examined by Andreoff and Yarmey (1976). They argued that bizarreness might enhance long term retention and, accordingly, employed a delayed test 24 hours after an immediate test. They found a significant effect of bizarreness on both the immediate and the delayed test. That is, bizarre imagery instructions were more effective than common imagery instructions. The main effect of emotional instructions was not significant. In fact, on the delayed test instructions to form emotional images tended to suppress the effect of bizarreness.

Although the preponderance of data indicates that bizarreness does not impact on immediate recall, delayed recall appears to be another matter. In addition to the Andreoff and Yarmey (1976) experiment cited above, Webber and Marshall (1978) also found that bizarre imagery facilitated delayed recall. An earlier study by Delin (1968) found that recall fifteen weeks after initial learning was positively correlated with the rated bizarreness of the mnemonic image. The only experiment which employed a delayed recall test and still failed to find a recall-enhancing effect of bizarreness is that by Hauck et al. (1976).

Supplied vs. Generated Mediators Using what is essentially a paired-associate paradigm, Bobrow and Bower (1969), Pelton (1969), Bower & Winzenz (1974), Schwartz (1971), and Griffith (1976) have found that when individuals form their own mediators recall is higher than when mediators are supplied by the experimenter. Schwartz and Walsh (1974) failed to find a difference in recall between experimenter supplied and subject generated mediators. Their experiment was especially contrived, however, for the mediators in the experimenter-supplied condition were identical to

those in the subject-generated condition. It is possible that their findings are restricted to their limited situation. Blick and his collegues have found either no difference between experimenter-supplied or subject-generated mediators (Buonassissi, Blick, and Kibler, 1972) or a significant difference in favor of experimenter-supplied mediators (Gartman and Blick, 1974; Kibler and Blick, 1971; Pines and Blick, 1974). Blick and his colleagues have employed the free recall of either individual words or of word pairs as the criterial task. In short, the empirical data do not provide clear support for either supplied or generated mediators. It may very well be that there is a complex interaction between mediator type, task type and individual differences.

All the above presupposes that subjects are motivated to form mediators. The work of Griffith (1976) suggests that mediator formation requires mental effort. Accordingly, if an individual is not sufficiently motivated to form his own mediators, and the mediators are not supplied, instructions in the use of a mnemotechnic will be to no avail. Even if the individual is sufficiently motivated to generate his own mediators, if he lacks the facility to form mediators quickly, he may not be able to employ effectively a mnemotechnic for a given task. In the typical training situation, then, practical constraints might dictate that mediators be supplied to the trainers. To this end the Navy Training Analysis and Evaluation Group (TAEG) has published a guide for technical writers to use in incorporating mnemonics into training material (Braby, Kincaid, and Aagard, 1978). In another report (Ainsworth, 1979), the acquisition of Morse Code was significantly enhanced by supplying graphic mediators to signalmen trainers.

Rehearsal Although advertisements for commercial memory courses directly imply that mnemotechnics instantly "burn" information permanently into memory, the ancient Greeks and Romans (Yates, 1966) realized that the images generated by mnemotechnics needed to be rehearsed if the required information was to be retained. The empirical question concerns how often the material needs to be rehearsed and at what intervals. Lorayne and Lucas (1974) recommend that the material be rehearsed at one, three, and seven days following original learning if the individual desires to retain the information permanently. Senter (Note 5) recommends rehearsal a few hours after original learning, then once the following day, and once again several days later. Although no empirical research on the question of the effects of the spacing of practice and mnemotechnics is available, a general finding throughout the verbal learning and memory literature is that distributed practice is superior to massed practice (Melton, 1970). For example, Landauer and Ross (1977) found that simple instructions to employ spaced practice in trying to remember a telephone number resulted in retention superior to that of individuals given no instructions regarding practice.

Further work (Landauer and Bjork, 1976) has indicated that increasing the time between successive repetitions results in retention superior to that associated with either uniform or contracting repetitions.

Although general prescriptions to rehearse, to space the rehearsals, and to increase the time between successive rehearsals are useful, it is clear that a good deal of empirical work needs to be done. Parametric investigations need to be undertaken in which different mnemotechnics and different classes of materials are studied. Until precise parametric work is completed, valid prescriptions for using mnemotechnics to optimal effect cannot be given.

Additional Considerations

Keeping Memories Current Generally speaking, mnemotechnics have been designed for long term retention. However, many memory tasks require that information be constantly updated. Different jobs that require updating of information range from that of the short-order cook to that of the intelligence anaylst. Pilots of aircraft as well as individuals in command positions cannot avoid the burdensome task of updating their memories. Even though new technologies, i.e., computer systems, provide a means of lessening this burden on memory, modifications of computer hardware or software, themselves, require the updating of skills and procedures.

Research does seem to indicate that mnemotechnics have potential utility for updating memories. Mnemotechnics seem to be resistant to practice and interference effects (Bower and Reitman, 1971; Bugelski, 1968; and Keppel and Zavortink, 1969), and that retroactive effects can at least be mitigated, if not eliminated (Bower and Reitman, 1971; Bugelski, 1968). In a keeping track task in which subjects must keep track of the current values of a number of variables it has been found that subjects tend to develop their own mnemotechnic in which the subjects mentally picture a set of windows or bins corresponding to each variable. Individual "tallies" are then kept in each window and rehearsed (Monty, 1968).

Recently Bjork (1978) has evaluated some specific strategies with respect to the updating of memory. The first strategy he evaluated was a visual-erasure strategy. This visual-erasure strategy was reported by a mnemonist for whom proactive inhibition was essentially nonexistent (see Hunt and Love, 1971). This visual-erasure strategy consists of imagining several little blackboards, each with the name of a stimulus above it. Whenever information needs to be updated the old information is mentally erased and the new information is mentally written in its place. An experiment (reported in Bjork, 1978) employed four stimulus words (BOAT, ROPE, HILL, FROG) printed on 5 by 7 cards mounted in a

horizontal array on a wall directly in front of a subject. Response to these stimulus cards had to be constantly updated. The visual erasure strategy proved unworkable for the typical subject. Typical subjects simply did not have the facility to do the mental writing and erasing. Consequently, Bjork and his colleague, McClure, developed several alternatives to the visual erasure strategy. One alternative was the ordered-rehearsal strategy. According to this strategy, the four current response words were to be rehearsed in a fixed, rote order corresponding to the order of the stimulus words on the wall. A second alternative strategy evaluated was a story construction strategy. Using essentially what was a linking story mnemotechnic, subjects were to construct a continuing narrative based on each stimulus word. A third alternative strategy evaluated was an image-replacement strategy. Here subjects were to form an image for each stimulus response connection. Wherever information was updated they were simply to replace the image. These strategies were evaluated with respect to recall after the initial updating and on the final total recall of all items at the end of the task. Overall, the story mnemotechnic proved to be the best. Not only was recall as good as ordered rehearsal for initial updating (around 80% correct) but recall was also highest on the final total recall (around 67%). Whereas the ordered rehearsal was superior to image replacement for initial updating (~77% to~67%), image replacement proved superior on the final total recall (~ 45% to~ 22%).

Clearly, mnemotechnics are potentially useful for updating memories. However, it is also clear that more research, particularly with real world tasks, needs to be done.

Transfer to New Situations A critical issue for mnemotechnics and other learning strategies is whether training in one situation will transfer to another situation. Moreover, it is desirable to know the extent of generalization from one situation with another. For mnemotechnics, or other learning strategies, to have any real general utility, they must be readily generalizable. Given the criticality of these issues of transfer and generalization, it is most remarkable that so little has been done in the way of empirical examination of these issues. What little research that has been done has mainly employed either children or the educable mentally retarded as subjects (see Weinstein, 1975, 1978 for a review). Moreover, the training programs have not provided extensive training. Although one or two examples might illustrate how to employ a mnemotechnic or learning strategy, it is likely that a fair amount of practice is required before any real facility is developed. To be able to generalize to new situations might require even more training.

Although no research was found regarding the issue of the transfer of mnemotechnics per se, an experiment by Weinstein (1975; 1978) did examine the related issue of the transfer of elaboration skills training. Weinstein used ninth grade high school students in

one of the three following groups: experimental, control, and posttest only. The experimental group received five 45 minute training sessions administered about one week apart. Over the course of their training sessions the experimental subjects were to generate mediators for nineteen different tasks. Examples of the tasks included having subjects read a passage on how arteries differ from veins, and then to generate elaboraters to emphasize the distinctions, e.g., veins are thinner than arteries, so a thin hollow tube can be used as an image for a vein; having subjects provide mental elaborations for the frequent meanings prefixes such as inter, mis, sub (e.g. thinking of a submarine going under the water); having subjects memorize a home economics shopping list by using what is a story mnemotechnic. While the experimental subjects were performing their tasks, instructors were available to provide feedback on the subjects' elaborations and to provide suggestions as to how the subjects might improve their technique. Control subjects also attended five training sessions and were exposed to the same tasks. However, the control subjects were given no clues as to how best they could perform the tasks. The postest only group provides another control baseline by attending only the two postesting sessions.

The postests were administered to all groups four weeks apart (during the sixth and tenth weeks of the experiment). Each postest consisted of the following criterion tests: a reading test, a free recall test, two trials of a paired-associate learning test, and two trials of a serial learning test. Although the experimental group consistently outperformed the control group and the postest only group on all criterion tests on both the immediate and the delayed posttest, the magnitude of the differences were such that statistically significant differences were obtained on only the following criterion postest: free recall and trial 2 of paired associates learning on the immediate postest, and reading and trial one of the serial learning delayed posttest. Although these results suggest that elaboration training does generalize, they also underscore the problem of developing adequate training programs so that cognitive skills do readily generalize to new training situations.

Effects on Other Cognitive Activities. Mnemonics and mnemotechnics have achieved eminent success with respect to the enhancement of memory. A question of both practical and theoretical import is whether mnemonics or mnemotechnics will have a negative, positive, or a neutral impact on other cognitive skills. It might be argued that individuals might become so preoccupied with the mnemonics and mnemotechnics that other cognitive skills might suffer. On the other hand, the enhancement of memory might reduce memory demands such that other aspects of cognitive performance are benefited. There is correlational evidence, at least, that Chess experts and Go (an oriental game of comparable complexity to Chess)

experts evidence phenomenal memories for their respective games (Chase and Simon, 1973a, 1973b; Reitman, 1976). In an academic situation, Carlson, Kincaid, Lance, and Hodgson (1976) have found a significant positive correlation between the reported use of spontaneous mnemonics and college grade point average. Of course, it is still possible that the effects of mnemonics and mnemotechnics are specific to memory performance and that they have negligible impact on other aspects of cognitive performance.

With respect to concept learning it is reasonable to assume that a learner should be able to solve a concept more efficiently when not required to maintain instance or hypothesis information in memory. Research (Bruner, Goodnow, and Austin, 1956, p.92) has found that external memory aids do enhance concept learning performance. Research has also indicated that internal memory aids can enhance concept learning. McVaugh (1973) has found that simple verbal rehearsal can facilitate concept identification. Katz and Paivio (1975) have found that manipulations of the imagery construct can also facilitate concept attainment. With respect to the effect of a specific mnemotechnic on concept attainment, only one experiment was found in the literature. Dyer and Meyer (1976) examined the effect of the one-bun pegword mnemotechnic on concept attainment. They varied mnemonic instructions (pegword technique vs. no instruction) and the memory requirement of the concept task (successive vs. concurrent presentation) in a factorial design. An interaction was obtained such that the pegword mnemotechnic did enhance concept identification, but only under the condition with high memory demands (i.e., concurrent presentation).

This rarely cited experiment by Dyer and Meyer (1976) is highly significant, because it demonstrates that a mnemotechnic can have a benefical effect on another cognitive task. These findings also lead to another important question. And that is, what are the advantages of having ready access to information, "in the head," versus having external sources providing the information?

Summary and Conclusions

Although the experimental research on mnemotechnics appears quite promising, the gaps in the research surface are most conspicuous. Many mnemotechnics have not even received experimental scrutiny. Given the importance of the number-consonant alphabet, this absence of experimentation is most regrettable. Even when there is research bearing upon a particular mnemotechnic, the range of research is limited. Very often the subject sample is restricted to college students, the amount of training is quite limited, and the retention intervals tested are limited. Within the context of mnemotechnics, the issues of the optimum amount and distribution of practice are typically ignored. Perhaps the most critical research issue that has been largely ignored is that of the question of the transfer and generalization of mnemotechnical skills. With the exception of the limited research done with children and retarded individuals, the research by Weinstein (1975,1978) constitutes the only empirical attack on the problem Obviously, if mnemotechnics do not readily transfer to new situations, they are of limited utility. Finally more research needs to be done in real training situations rather than in contrived laboratory settings.

A Research Strategy for Applying Mnemonics and Mnemotechnics to Military Training

Even given the tremendous shortcomings in research on mnemonics and mnemotechnics, the preceding review has indicated that there are a large number of mnemotechnics suitable for a wide range of memory problems. Experimental evidence has indicated enough potential in a laboratory environment to merit testing in realistic training situations. Indeed, a basic criticism is that mnemotechnics have typically not been evaluated in realistic situations. Moreover, with the exception of Weinstein's (1975, 1978) research, little has been done in the way of the assessment of the transfer and generalization of mnemotechnical training to new situations. What follows are some suggested lines of research and implementation, as well as some considerations paramount to mnemonics and mnemotechnics. It should be remembered that mnemonics and mnemotechnics date back to the ancient Greeks (Yates, 1966). The first military sponsored research on mnemonics dates back to 1957 (Note 1). In 1965, another favorable report ensued (Senter, 1965). Recently, both the Army (Griffith and Actkinson, 1978) and the Navy (Ainsworth, 1979; Braby, Kincaid, and Aagard, 1978) have reported some very promising work. If further research is not pursued intelligently, however, and if implementation is left to work itself out, it is extremely likely that the potential training value of mnemonics and mnemotechnics will be lost.

Direct Incorporation of Mnemonics into Training Materials

The Interservice Procedures for Instructional Systems Development (1977) calls for the use of mnemonics in curriculum development. To this end the Navy's Training Analysis and Evaluation Group (TAEG) has developed a guidebook for technical writers to assist them in incorporating mnemonics into training materials (Braby, Kincaid, and Aagard, 1978). This guidebook is an excellent source for technical writers. First, it provides guidance on when, and when not, to employ mnemonics. Then it outlines nine ways of incorporating mnemonics into training materials. For each of these nine techniques an explicit example of how that technique can be applied to Navy training is provided. Exercises are also provided so that technical writers can practice each technique. This Navy TAEG guidebook is an excellent product, and the other services might want to consider developing their own versions of the guidebook. Even given the excellence of this product, however, if dedicated training is not provided to technical writers, and if proper quality control is not maintained to assure that mnemonics are being employed appropriately, it is likely that the full training potential of mnemonics will not be realized.

It should also be recognized that the direct incorporation of mnemonics into training materials constitutes but one means of

applying mnemonics and mnemotechnics to training. It requires the development of mnemonics by technical and course writers. Students are not required to develop their own mnemonics. At this time, it is not even clear whether the direct incorporation of mnemonics into training materials constitutes the best approach. Although, the Interservice Procedures for Instructional Systems Development (1975) should be followed and mnemonics incorporated wherever appropriate in training materials, other approaches also need to be pursued.

Effective Mnemonics in System Design

A related concern regards the use of mnemonics in complex systems. It would appear that in certain computer systems the use of the term mnemonic (i.e., something which aids memory) is a misnomer. For example, the Tactical Fire Direction System (TACFIRE) command and control system for the field artillery employs 905 different mnemonics in its formats. Moreover, there are 177 additional legal entry mnemonics which operators must recall to enter in the various fields of the formats. Although not all operators need to recall all formats, the memory demands are staggering. Quite frequently during the course of operations operators must thumb through manuals looking for needed mnemonics. There is an additional problem of redundant mnemonics. For instance, there are seven different mnemonics denoting fuses. Whether such redundancy is convenient from the point of view of software design is not the point. The human factors implications and the concomitant training problems are obvious, however. It is ironic that mnemotechnics and higher order mnemonics should be required for mnemonics which are supposed to aid memory. Unfortunately there exist neither guidelines for developing system mnemonics, nor military standards concerned with human factors aspects of computer software. That experimental work designed to enhance system mnemonics pays off is evidenced by the TOS^2 system (Nystrom and Gividen, 1978). By designing system mnemonics carefully, training problems can be reduced significantly. Similarly by incorporating highly imageable material in training materials, training effectiveness can be greatly enhanced.

Employment of Task Specific Mnemotechnics

Examples of task specific mnemotechnics that have been discussed in this paper include those mnemotechnics provided for Morse Code learning and those mnemotechnics provided for the learning of the referents of pictorial symbols. Some of the more generally applicable mnemotechnics can also be applied to specific tasks. For example, a linking mnemotechnic can be used to learn the chain of command or a pegword mnemotechnic could be used to train sentries in their general orders. Finally, specific mnemotechnics can be developed on an ad hoc basis. That is, on the basis of an analysis of the memory demands of a given training task, a new mnemotechnic

could be developed to facilitate the learing of the task. It should be realized that it was essentially in this manner that other mnemotechnics were developed in the first place.

In the training situation, then, the student would not simply be given a specific task or some information and told to learn it. In addition, he would be given instructions into how to go about learning the material, i.e., the mnemotechnic. This approach is compatible with a standard lecture format as well as some form of individualized instruction (e.g., computer assisted instruction or a programmed text).

General Mnemotechnical Training

Yet another approach is to develop the general mnemonic proficiency of individuals. The idea is to provide formal mnemotechnical training, perhaps in the context of a general learning strategies course. Here individuals would be provided training in the mnemotechnics presented in this paper as well as being trained to develop ad hoc mnemotechnics of their own. The amount of training required to become a proficient mnemonist is an empirical question.

If any real use is to be made of mnemonics and mnemotechnics in military training, general mnemotechnical training would be a prerequisite at some point in the training system. Anyone, technical writers, instructors, charged with incorporating mnemonics into training materials should be given general mnemotechnical training. Whether other individuals should be given general mnemotechnical training is another empirical question. Perhaps general mnemotechnical training would have the same beneficial effect that general physical training has in physical tasks. Then again, perhaps, it would not. The question is an empirical one. The next issue to be addressed concerns what type of individuals can potentially benefit from mnemonics and mnemotechnics.

Personnel Characteristics

Research needs to focus constantly on the characteristics of individuals who are able to benefit from mnemonics and mnemotechnics. Although, since it has been shown that some mental retardates can benefit from mnemonics (Wanschura and Borkowski, 1974), it is reasonable to assume that some sort of mnemonics should be beneficial for all military personnel, there still are boundary conditions. It should be remembered that in the paired-associate task employed by Griffith and Actkinson (1978), only personnel with GT Scores 110 or over were able to benefit from a rhyme pegword mnemotecnnic. Perhaps lower aptitude personnel would not benefit from general mnemotechnical training but need to have specific mnemonics supplied to them in their training materials. Perhaps

higher aptitude personnel benefit more if they are provided general mnemotechnical training. The preceding are merely conjectures awaiting experimental validation. Attention needs to be paid to the aptitude levels of personnel participating in mnemonics research.

Motivational Considerations

The generation of mnemonics requires mental effort. Experimental evidence exists to this effect (Griffith, 1976). There is anecdotal evidence that people knowledgeable of appropriate mnemotechnics do not always employ them. And it is a truism that human beings do not always behave in a optimal manner. Thus, it is possible that even given good mnemonics or good mnemotechnical training, individuals would not employ them. Individuals must be convinced of the utility of mnemonics and mnemotechics if they are to be maximally effective. For individuals who are not motivated to learn, memory aids are unlikely to make any difference. Moreover, mnemonics and mnemotechnics can be easily parodied and ridiculed. A good attitude is needed for mnemonics and mnemotechnics to be effective. In short, motivational factors must not be overlooked.

Mnemonics, Mnemotechnics, and Research on Learning Strategies

At the beginning of this paper mnemotechnics were introduced as techniques for learning apparently meaningless materials. They were distinguished from learning strategies, in that learning strategies were techniques for learning meaningful material. Actually, it might be more appropriate to think of mnemotechnics and learning strategies along a continuum. To the extent that information to be learned appears meaningless, mnemotechnics can be employed. As materials become more meaningful learning strategies which exploit the inherent structure of the to be learned material can be employed. This paper has focused on mnemotechnics because the research on mnemotechnics was substantive enough to warrant a report in its own right. Although the current body of research on learning strategies is not as voluminous as that on mnemotechnics (O'Neal, 1978), it is hoped that it will rapidly grow. Military trainers need to be aware that current development in experimental and educational psychology have direct training implications. It is hoped that the training community will not miss the benefits of this "cognitive revolution."

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Appendix

A Brief Annotated Bibliography of Some Popular Books on Memory

Cermak, Laird S. Improving Your Memory. New York: W. W. Norton and Company, Inc., 1975. Cermak is a research psychologist who has published extensively in the field of memory. He wrote Improving Your Memory for the laymen, however. For the most part, Cermak focuses upon simple means of improving memory rather than upon elaborate mnemotechnics. After providing a brief overview of memory, Cermak discusses the importance of focusing attention and organization to memory. Next he discusses how mediation can enhance memory and how imagery can be employed as a mediator. Cermak does devote one chapter to specific mnemonics and mnemotechnics. Here Cermak provides a discussion of the number-consonant alphabet. Cermak's book is useful either to someone not willing to devote the time required to developing a genuine proficiency in mnemotechnics or as a preliminary text to more advanced study in mnemonics.

Higbee, Kenneth L. Your Memory: How it works and how to improve it. Englewood Cliffs, N. J: Prentice-Hall, Inc., 1977. Like Cermak, Higbee is also a psychologist who has done research in the area of human learning and memory. Higbee intended this volume to be a compromise between an academic text and a popular book on memory. After providing the reader with an overview of the intent and content of the book, Higbee proceeds to review briefly contempory theory and research in human memory. Chapter three outlines some general principles (e.g., meaningfulness, organization) for memory improvement. Chapter four is concerned primarily with learning strategies useful for the retention of meaningful material (e.g., most prose). The remainder of the book is concerned with mnemonics and mnemotechnics. Chapter five provides an overview of mnemonics and mnemotechnics. Chapters six, seven, eight, and nine are concerned with the link, loci, pegword, and number-consonant mnemotechnics, respectively. Chapter ten discusses some ad hoc mnemotechnics. Two appendices are included. One provides practice words for visual associations and the other provides words for use in the number-consonant alphabet. The work is amply documented with footnotes. Higbee has provided one of the most extensive reviews on the existing literature in mnemonics and mnemotechnics.

Lorayne, Harry. How to develop a super-power memory. New York: Frederick Fell, Inc., 1957. Lorayne is a professional mnemonist and memory teacher. In spite of the hype in the title, this is an instructive book on many of the mnemotechnics discussed in this report. In fact, one of the mnemotechnics for Morse Code learning comes directly from this book. At the beginning of this book, Lorayne provides a series of memory tests. After having

read the book and practiced the techniques the reader can retake the memory exams to estimate the benefit derived from the book.

Lorayne, Harry. Remembering people: the key to success. New York: Stein and Day, 1975. Just as the title indicates, this book is concerned exclusively with mnemotechnics for remembering people, what their names, positions, etc. are. The topic is thoroughly developed and exercises are provided so that the reader can practice the techniques.

Lorayne, Harry, and Lucas, Jerry. The memory book. New York: Stein and Day, 1974 (published in paperback by Ballantine Books, 1975). This popular book on memory actually made the national best seller lists. Essentially, it contains most of the material from Lorayne's earlier book (How to Develop a Super-Power Memory). Each chapter begins with some banter between mnemonist Lorayne and basketball player and mnemonist Lucas. Again the presentations of specifici mnemotechnics are most instructive.

Weinland, James D. How to improve your memory. New York: Barnes and Noble, 1957. Weinland is a retired psychologist. Written in 1957, the book provides a brief review of research and theory in memory until that time. Like Higbee, Weinland footnotes liberally, providing a very useful review of the literature. Although the book does discuss specific mnemotechnics, it concentrates more on the development of general memory and study techniques.

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