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STUDIES IN
INFORMATION PROCESSING THEORY:
SIMILARITY AND FAMILIARITY IN
VERBAL LEARNING

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The Elementary Perceiver and Memorizer (EPAM) is a computer program which models human associative memory and the processes of verbal learning. As a model of psychological rather than neurophysiological processes, it is concerned with behavior at an information processing level intermediate between neuronic behavior and observable human behavior. EPAM programs are statements of hypotheses at the information processing level about symbol manipulation and storage during learning.

EPAM is based on the hypothesis that the learning of a complex stimulus object by humans consists of: a) fragmentation of the object into subobjects that are recognizable and familiar; and b) construction of an internal image of the object in the association memory as a set of tokens which "cue" the evocation of the complex object. The current version of the program--EPAM-III, programmed in the list processing language IPL-V--is a precise statement of this hypothesis. Its validity as a model of learning is determined by comparing its behavior in simulated laboratory experiments with the behavior of human subjects in the same experiments.

EPAM was developed at Carnegie Institute of Technology, University of California, and The RAND Corporation. The authors are Consultants to The RAND Corporation; Dr. Simon is on the faculty of the Graduate School of Industrial Administration, Carnegie Institute of Technology, and Dr. Feigenbaum is on the faculty of the School of Business Administration at the University of California, Berkeley.
SUMMARY

This Memorandum presents results obtained by simulating various verbal learning experiments with the Elementary Perceiving and Memorizing Program (EPAM), an information processing theory of verbal learning.

Predictions were generated for experiments manipulating intra-list similarity (Underwood); inter-list similarity (Bruce); and, familiarity and meaningfulness. The stimulus materials were nonsense syllables, learned in paired-associate fashion.

A description of the EPAM-III model is given.

The predictions made by the model are generally in good agreement with the experimental data. It is shown that the quantitative fit to the Underwood data can be improved considerably by introducing a process of "aural recoding."

The fit of the EPAM predictions to the Chenzoff data is particularly significant since it lends support to the hypothesis that the mechanism by means of which a high degree of meaningfulness of items facilitates learning is the high familiarity of these items.

The effects of varying degrees of stimulus and response familiarization on ease of learning were studied, and were shown to be surprisingly complex.
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I. INTRODUCTION

The laboratory paradigm most commonly used for the study of verbal learning is the learning of nonsense syllables by the paired-associate or serial anticipation methods. Among the variables that have been shown to have important effects on the rate of learning are the levels of familiarity and meaningfulness of the syllables, the amount of similarity among them, and the rate of presentation. In addition, in the learning of lists, there are well-known serial position effects.

Previous papers (1-3) have set forth a theory that undertakes to explain the performance and learning processes underlying the behavior of subjects in verbal learning experiments. The theory, in its original version, makes correct quantitative predictions of the shape of the serial position curve (4) and the effect of rate of presentation on learning, (1,4) as well as predictions of certain qualitative phenomena—for example, oscillation. (5)

This Memorandum reports on a simplified and improved version of the theory that retains these properties of the earlier theory while providing correct quantitative predictions of the effects of the other important variables: familiarity, meaningfulness, and similarity. The tests of the theory discussed here are based on comparisons of the performance of human subjects, as reported in published experiments on paired-associate learning, (6-9) with the performance predicted by the theory in the same experimental situations with the same, or equivalent, stimulus material.
The theory to be described is a theory of the information processes underlying verbal learning. The precise statement of such a theory is most readily made in the information processing language of a digital computer; i.e., the language of computer programs.

The formal and rigorous statement of our theory is a program called the Elementary Perceiver and Memorizer (third version), or EPAM-III. This program is a closed model and is used as an "artificial subject" in standard verbal learning experiments (the experiments are also simulated within the computer by means of an Experimenter program). Imbedded in the theory are hypotheses about the several kinds of processes that are involved in the performance of verbal learning tasks. These hypotheses take the form of subroutines that are component parts of the total program. Thus, there are performance subroutines that allow the program to produce responses that have previously been associated with stimuli, subroutines for learning to discriminate among different stimuli, and subroutines for acquiring familiarity with particular stimuli. The top-level executive routines, which organize these subroutines into a program, represent hypotheses about the subject's understanding of the experimental instructions and the learning strategy he employs. The computer simulation of verbal learning behavior using the EPAM-III theory is, in essence, generation (by the computer) of the remote consequences of the information processing hypotheses of the theory in particular experimental situations.
A brief description of EPAM-III is presented in Sec. II. Since other descriptions of the program are available in the literature,\(^{(1-3)}\) only that much of the detail will be presented as is essential to an understanding of the experiments and the interpretation of their outcomes. Section III reports on the results of comparisons of the behavior of EPAM-III with the behavior of human subjects in paired-associate learning where similarity is the independent variable. In Secs. IV and V, the results will be reported of comparisons in which familiarity and meaningfulness are the independent variables.
II. A BRIEF DESCRIPTION OF EPAM-III

EPAM-III is a computer program written in the interpretive language, IPL-V. (10) A companion program simulates an experimental setting—more specifically, a memory drum capable of exposing stimulus materials in either the serial or paired-associate paradigm—to a simulated subject. The simulated drum rotation rate can be altered as desired, as can the stimulus materials. The latter can simulate visual stimuli—letters or shapes—aural stimuli, or stimuli in any other sensory mode. The present experiments are concerned only with simulated letters and letter strings—syllables.

EPAM-III is a simulation of a human subject. An interrupt system is provided so that the simulated experimental environment and the simulated subject can behave simultaneously, for all intents and purposes, and can interact, the subject having access to the stimulus material presented in the memory drum window.

THE PERFORMANCE SYSTEM

EPAM-III incorporates one major performance system and two learning processes. (1-3) When a stimulus (a symbol structure) is presented, EPAM seeks to recognize it by sorting it through a discrimination net. At each node of the net, some characteristic of the stimulus is noticed, and the branch corresponding to that characteristic is followed to the next node. With each terminal node of the net is associated an image that can be compared with any stimulus sorted to that node. If the two
are similar in the characteristics used for comparison, the stimulus has been successfully recognized. Such a stimulus is called familiar; i.e., it has a recognizable image in the discrimination net memory.

An image is the internal informational representation of an external stimulus configuration that the learner has stored in memory. An image, thus, is comprised of the information the learner knows about, and has associated with, a particular stimulus configuration. An image may be elementary or compound. A compound image has, as components, one or more elementary or compound images which may themselves be familiar—may possess their own terminal nodes in the discrimination net. For simplicity in the current representation, letters of the Roman alphabet are treated as elementary stimuli, whose characteristics may be noticed, but which are not decomposable into more elementary familiar stimuli. On the other hand, syllables are compound stimuli, their components being, of course, letters.

A compound stimulus image, viewed from the bottom up, may be regarded as an association among the component stimuli. Thus, the net may contain stimulus images that represent pairs of syllables—these compound images having as components other compound images, the individual syllables.

In performing the paired-associate task, the program uses the stimulus, present in the window of the memory drum, to construct a compound symbol representing the pair comprised of the stimulus and its associated response. We may designate this compound symbol by S-.
since the second response member is not then visible in
the drum window. The compound symbol, S-__, is sorted
through the net, and the image associated with the ter-
"minal is retrieved. We will designate this image by
S'-R', for if the previous learning has been successful,
it will be comprised of two components—an image of the
stimulus syllable and an image of the associated re-
sponse syllable. The response image, R', which has just
been retrieved as the second component of the compound
image, S'-R', identifies a net node where an image,
say R'', is stored. R'' will have as its components sym-
bols designating the constituent letters of the syllable,
say X'', Y'', and Z''. Each of these, in turn, identifies
a terminal node. Associated with the terminal for a
letter is not only an image of the usual kind (an afferent
image), but also the information required to produce the
letter in question—to print it out. This information,
which we may call the efferent image, is used to pro-
duce the response. Thus, the final step in the sequence
is for the program to respond XYZ, for example.

It is a fundamental characteristic of this program
that elementary symbols and compound symbols of all
levels are stored in the discrimination net in exactly
the same way. Thus, a syllable is simply a list of
letters, and an S-R is simply a list of syllables. A
single interpretive process suffices to sort a letter,
a syllable, an S-R pair, or any other symbol, elementary
or compound. Moreover, the symbols discriminated by the
net are not restricted to any specific sensory or ef-
fecter mode. All modes can be accommodated by a single
net and a single interpretive process. Afferent symbols belonging to different sensory modes will possess different attributes: phonemes will have attributes like "voicing," "tongue position," and so on; printed letters will have attributes like "possession of closed loop," "possession of diagonal line," and so on. Because they possess entirely different attributes, they will be sorted to different parts of the net. Finally, symbols may be of mixed mode. In a symbol, S-R, for example, S may be in the visual mode, R in the oral.

THE LEARNING SYSTEM

EPAM-III uses just two learning processes, one to construct and elaborate images at terminal nodes of the net (familiarization), the other to elaborate the net by adding new branches (discrimination learning). The first learning process also serves to guide the second.

When a stimulus, S, is in view and is sorted to a terminal, the stimulus can be compared with the image, S', stored at the terminal. If there is no image at the terminal, the familiarization process copies a part of S and stores the copy, S', as the initial image at the terminal. If there is already an image, S', at the terminal, one or more differences between S and S' are detected, and S' is corrected or augmented to agree more closely with S.

When a positive difference (not a mere lack of detail) is detected between a stimulus, S, and its image, S', the discrimination learning process can use this difference to construct a new test that will discriminate
between S and S'. The terminal node with which S' was associated is then changed to a branch node; the test associated with the node S' is associated with a new terminal on one of the branches; and a new image of S is associated with a new terminal on another branch. Thus, the discrimination learning process adds a new pair of branches to the discrimination net, and attaches initial images to the branches.

Note that a stimulus, S, can be sorted to a terminal, T, only if S satisfies all the tests that point to the branches leading to T. But the image, S', stored at T must also satisfy these tests. Hence, there can be a positive difference between S' and S only if S' contains more information than is necessary to sort S to T. For instance, let S be the syllable KAW, and suppose that all the tests leading to the terminal T happen to be tests on the first letter, K. Then the image, S', stored at T must have K as its first symbol, but may differ from KAW in other characteristics. It might be, for example, the incomplete syllable K-B. The discrimination learning process could detect the difference between the W and the B in the final letters of the respective syllables, construct a test for this difference, and append the test to a new net node. The redundancy of information in the image—in this case the letter B—permits the further elaboration of the net.

Thus, learning in EPAM-III involves cycles of the two learning processes. Through familiarization, the stimulus image is elaborated until it contains more information than the minimum required to sort to its terminal.
Through discrimination, this information is used to distinguish between new stimuli and the stimulus that generated this terminal and grew its image. On the basis of such distinctions, the net is elaborated. The interaction of these two processes is fundamental to the whole working of EPAM.*

The stimuli that EPAM-III can familiarize and learn to discriminate are symbols of any kind, elementary or compound. Thus, the letters of the alphabet can be familiarized first, and the net elaborated to discriminate among them. Then EPAM can familiarize and learn to discriminate among syllables, using the now-familiar letters as unitary building blocks. But now, paired-associate learning can take place without the introduction of any additional mechanisms. Instead of postulating a new associational process, we suppose that an S-R pair is associated simply by familiarizing and learning to discriminate the compound object SR.

The entire EPAM-III paired-associate learning scheme is completed by an executive routine that determines under what circumstances the several familiarization and discrimination learning processes will be activated. The executive routine makes use of a kind of knowledge of results. When the simulated subject detects that he has made an incorrect response to a stimulus syllable, he engages in a rudimentary diagnostic activity--distinguishing between no response and a wrong response,

*It is not easy to conjure up alternative schemes that will permit learning to proceed when a pair of stimuli to be discriminated are not present simultaneously.
and determining to what extent the response syllable, the stimulus syllable, and the S-R pair are familiar. Depending on the outcome of the diagnosis, various familiarization and discrimination learning processes are initiated.

Many details of the EPAM-III program have not been described here, but this general sketch provides a sufficient basis for discussing the behavior of the program in standard paired-associate learning situations.
III. EFFECTS OF INTRA-LIST AND INTER-LIST SIMILARITY

The adequacy of EPAM-III as a theory of human rote verbal learning has been tested initially by using the program to replicate experiments of Underwood\(^{(8)}\) on intra-list similarity, of Bruce\(^{(6)}\) on inter-list similarity, and of a number of authors\(^{(9)}\) on stimulus and response familiarization and meaningfulness. In this section, the experiments employing similarity as the independent variable are discussed; the experiments on familiarization and meaningfulness are considered in Sec. IV.

Underwood\(^{(8)}\) has studied paired-associate learning of nonsense syllables under various conditions of intra-list similarity of stimulus syllables and response syllables. If we use L, M, and H to designate low, medium, and high intra-list similarity, respectively; and let, for example, L-M stand for "low intra-list similarity of stimuli, medium intra-list similarity of responses," then Underwood's five experimental conditions are L-L, M-L, H-L, L-M, L-H. Underwood also studied three different conditions of distribution of practice, but since he found no significant differences in his data, we shall not consider this variable further.

In summary, Underwood found: a) that intra-list similarity of responses had virtually no effect on ease or difficulty of learning; and b) that the number of trials required for learning increased with the degree of intra-list similarity of stimuli—the difference being about 30 per cent between L-L and H-L conditions. The row in Table I labeled "Actual" summarizes Underwood's findings averaged over the three conditions of distribution.
of practice. The numbers are relative numbers of trials to criterion, with the number for the L-L condition taken as 100.

The syllables employed in the EPAM simulation were the same as those used by Underwood.*

Row 2 in Table I summarizes the data from the EPAM tests. Response similarity facilitated learning very slightly, while stimulus familiarity impeded learning by as much as 40 per cent. Since relative learning times are reported in both cases, there is one free parameter available for matching the two series.

The qualitative fit of the EPAM predictions to the Underwood data is better than the quantitative fit, although, considering the (a priori) plausible range of impact of the similarity variable on difficulty of learning, even the quantitative fit is not bad. Nevertheless, a much better quantitative prediction was sought. This search led to the following considerations.

The prediction that is seriously out of line in Table I is the prediction for the M-L condition. The more carefully one scrutinizes the Underwood experiment and the Underwood materials, the more puzzling do the experimental results become. Why do subjects, as the results indicate, see the M-L condition as being so much like the L-L condition, whereas the H-L condition appears to be so different from either the M-L or L-L conditions? The answer is not to be found in the Underwood materials.

*We are indebted to Professor Underwood for making these sets of syllables available.
Table I

COMPARISON OF EPAM WITH UNDERWOOD'S DATA ON INTRA-LIST SIMILARITY
(Relative number of trials to criterion, L-L=100)

<table>
<thead>
<tr>
<th>Condition of Stimulus and Response Similarity</th>
<th>L-L</th>
<th>L-M</th>
<th>M-L</th>
<th>L-H</th>
<th>H-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underwood</td>
<td>100</td>
<td>96</td>
<td>109</td>
<td>104</td>
<td>131</td>
</tr>
<tr>
<td>EPAM-III (&quot;visual&quot; only)</td>
<td>100</td>
<td>88</td>
<td>141</td>
<td>91</td>
<td>146</td>
</tr>
<tr>
<td>EPAM-III (&quot;aural&quot; only)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>114</td>
</tr>
<tr>
<td>EPAM-III (&quot;visual&quot; and &quot;aural&quot; mixed, 1:1)</td>
<td>100</td>
<td>94</td>
<td>121</td>
<td>96</td>
<td>130</td>
</tr>
<tr>
<td>EPAM-III (&quot;visual&quot; and &quot;aural&quot; mixed, 1:2)</td>
<td>100</td>
<td>96</td>
<td>114</td>
<td>97</td>
<td>125</td>
</tr>
</tbody>
</table>
The Underwood definition of "medium similarity" has been analyzed in terms of the information necessary to discriminate the items on a list of a given length (in EPAM-like fashion), and it has been found that Underwood's definition is quite careful and correct. By his definition, one should expect "medium similarity" lists to be midway in effect between his "low similarity" and his "high similarity" lists.

The answer, we believe, lies in the recoding, or "chunking," behavior of subjects, which would make the "medium similarity" stimulus list formally identical with the "low similarity" stimulus list under Underwood's definition. Suppose that many subjects were pronouncing the Underwood CVCs--i.e., recoding the items into the aural mode--instead of dealing with them directly in the visual-literal (presentation) mode. The recoded ("aural") syllables will be "chunked" into two parts: a consonant-vowel pair, and a consonant. In other words, the visual-literal stimulus objects of three parts (CVC) quite naturally recode into "aural" stimulus objects of two parts (C'C or CC'). In the Underwood "medium similarity" lists, none of the C' chunks are duplicated, nor are any of the C" chunks. The recoding, therefore, has transformed the "medium similarity" list into a "low similarity" list, by Underwood's definition.

To test this hypothesis for sufficiency from the point of view of the theory, the EPAM (simulated) experiments were rerun using "aural" recodings of the original syllables. The modified predictions are given in row 3 of Table I. As the analysis above indicates, the M-L
condition is now no different from the L-L condition, but the prediction of difficulty for the H-L condition is too low. Assuming that some subjects are processing in the visual-literal mode and some in the "aural" mode, the average (1:1) of the two sets of EPAM predictions has been computed; this is given in row 4 of Table I. If the average is weighted 2:1 in favor of subjects doing "aural" recoding, the result is as given in row 5 of Table I. Each of these averaging procedures gives a prediction which is much better than that for the Underwood lists non-recoded.

It is clear that there is still much to learn about this low vs. medium similarity problem, and, in this regard, a direct experimental test of the "aural" recoding hypothesis is being currently attempted.

Bruce's subjects\(^6\) learned two successive lists of paired-associate syllables. On the second list either response syllables, or stimulus syllables, or neither, could be the same as the corresponding syllables on the first list. Thus, if we let S stand for "same," and D for "different," his three conditions were D-D, S-D, and D-S, respectively. In summary, he found that learning of the second list was somewhat easier than learning of the first when all syllables were different (D-D); was much easier when the response syllables were the same (D-S); and was a little harder when the stimulus syllables were the same (S-D). (See Table II.) The relative difficulties can be compared on either of two bases: taking the difficulty of learning the first list as the norm (line 1 of Table II), or taking the difficulty of
Table II

COMPARISON OF EPAM WITH BRUCE'S DATA ON
INTER-LIST SIMILARITY
(Relative number of trials to criterion)

<table>
<thead>
<tr>
<th>Condition of Stimulus and Response Similarity</th>
<th>S-D</th>
<th>D-S</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary List ( = 100)</td>
<td>109</td>
<td>63</td>
<td>84</td>
</tr>
<tr>
<td>D-D Condition ( = 100)</td>
<td>130</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>EPAM-III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-D Condition ( = 100)</td>
<td>112</td>
<td>75</td>
<td>100</td>
</tr>
</tbody>
</table>

the D-D list as the norm (line 2 of Table II). Since Bruce's subjects were evidently "learning to learn" from the first list to the second (as shown by the 16 per cent gain for the D-D group in the first line), using the D-D group as the norm is perhaps the more defensible procedure.

The experiment was replicated with EPAM, using lists of low Glaze value and low intra-list similarity. The results, translated to the second norm, are shown in the third line of Table II. Regardless of which norm is considered, the effects in the replication were qualitatively the same as in the actual data. If the conditions S-D and D-S are compared with D-D, it is shown that identity of stimulus syllables impeded learning less, and identity of response syllables facilitated learning somewhat more
in the simulation than was the case for the human subjects. In the D-D case, twice as many new discriminations must be learned than in the S-D and D-S cases. This difference had a larger effect on the performance of EPAM than on the human subjects' average performance. The ratio of difficulty for the S-D compared with the D-S conditions, where total number of syllables discriminated was the same, was 1.73 for the human subjects, 1.49 for EPAM.

From our analysis of the data of the Underwood and Bruce experiments, we conclude that EPAM provides satisfactory explanations for the main observed effects of intra-list and inter-list stimulus and response similarity upon the learning of paired associates. The effects predicted by EPAM-III are in the right direction and are of the right order of magnitude, although there is room for improvement in the quantitative agreement.
IV. FAMILIARITY AND MEANINGFULNESS

Among the other independent variables that have been shown to have major significance for the ease or difficulty of learning nonsense syllables are familiarity and meaningfulness. A thorough discussion of the definition of these two variables can be found in Underwood and Schulz. (9)

The degree of familiarity of a syllable is usually not measured directly. Instead, it is measured by the amount of familiarization training to which the subject has been exposed with that syllable. Familiarization training is accomplished by causing the subject to attend to the syllable in question in the context of some task other than the paired-associate learning task to be given him subsequently. It should be noted that there is no way of discovering, with this definition, how much familiarization the syllable may have had from the subject's experience prior to coming into the laboratory. Although the syllables are not meaningful words, the consonant-vowel combinations contained in them occur with varying frequency in English.

The meaningfulness of a syllable, on the other hand, is generally determined by measuring the number of associations that subjects make to it in a specified period of time. Nonsense syllables for learning experiments are generally selected from available lists that have been graded, in this way, for meaningfulness.

Since high familiarization and high meaningfulness both facilitate nonsense syllable learning, there has been
much speculation that the two phenomena might be the "same thing." This, in fact, is the central hypothesis examined in the Underwood-Schulz monograph. In one sense, meaningfulness and familiarity are demonstrably not the same, for a substantial amount of familiarization training can be given with low meaningful syllables without significantly increasing their meaningfulness. However, Underwood and Schulz adduce a large body of evidence to show that there is a strong relation running the other way—that meaningfulness of words is correlated with their frequency of occurrence in English, and that ease of learning nonsense syllables is correlated with the frequency, in English, of the letters that compose them (for syllables of low pronounceability), or with their pronounceability.

We conclude that high meaningfulness implies high familiarity, although not the converse. If this is so, then the correlation of meaningfulness with ease of learning may be spurious. Familiarity may be the variable that determines ease of learning, and meaningful syllables may be easy to learn only because they are highly familiar.

*The data are, of course, greatly complicated by the fact that subjects may handle the material in either the visual or the aural mode—and that most subjects probably encode into the latter, at least part of the time. Hence, for relatively easily pronounceable syllables, frequency of phoneme pairs in the aural encoding is a more relevant measure of frequency than frequency of the printed bigrams or trigrams. Thus, the finding by Underwood and Schulz that pronounceability is a better predictor of ease of learning than trigram frequency does not damage the hypothesis that familiarity of the component units is the critical variable, and that familiarity, in turn, is a function of previous exposure.
The idea that familiarity is the critical variable in learning is not gratuitous. It rests on a classical idea, going back to Woodworth if not to Ebbinghaus, that there are two stages in paired-associate learning: 1) integration of responses; and 2) association of responses with stimuli. Underwood and Schulz have revived this idea and it plays an important role in their analysis. It also plays an important role in the structure of EPAM.\(^{(1,2)}\)

From our earlier description, it can be seen that these two stages of learning are also present in EPAM-III, but that both stages make use of the same pair of learning processes—familiarization and discrimination learning.

If response integration is the mechanism accounting for the relation between meaningfulness and familiarity, on the one hand, and ease of learning, on the other, then there should be a point of saturation, beyond which additional familiarization will not further facilitate learning—the point at which the syllables are so familiar that they are completely integrated. In the EPAM-III mechanism this would be the point where the syllable images were complete, and the tests in the net fully adequate to discriminate among them.

There is strong empirical support for the hypothesis of saturation. At the high end of the meaningfulness scale, further increases in meaningfulness of syllables have relatively little effect on ease of learning, but the effects are large over the lower range of the scale. In fact—and this is the most striking evidence relevant to the issue—the experiments on meaningfulness in the literature reveal a remarkably consistent upper bound on the
effect of that variable. Underwood and Schulz survey a large number of the experiments reported in the literature, of both paired-associate and serial learning of CVC syllables, and find rather consistently that the ratio of trials to criterion for the least and most meaningful conditions, respectively, lies in the neighborhood of 2.5. That is to say, syllables of very low meaningfulness take about two and one-half times as long to learn as syllables of very high meaningfulness (and about two and one-half times as many errors are made during learning).

Before considering further the significance of this 2.5:1 ratio, some comment should be made on one difficulty with the hypothesis that familiarization and meaningfulness (via familiarity) facilitate learning primarily by integrating the responses prior to the associational trials. The effects reported in the literature with meaningfulness as the independent variable are generally much larger than the effects reported for familiarity. No one has produced anything like a 2.5:1 gain in learning speed by familiarization training.

There is now some evidence, primarily in a doctoral dissertation by A. Chenzoff,\(^7\) that the main reason for this discrepancy is that the familiarization training in experiments has been too weak, has stopped too soon. It appears that no one has carried out familiarization training with subjects to the point where the syllable integration achieved is comparable to the integration of syllables of high meaningfulness.

Chenzoff's evidence can be summed up as follows. First, in his experiment he manipulated both meaningfulness
and familiarization of both stimuli and responses. Thus, he had sixteen conditions: all possible combinations of H-H, L-H, H-L, L-L, for stimulus and response meaningfulness, with F-F, U-F, F-U, U-U, for familiarity. Second, he employed a more thorough familiarization training technique for the F condition than had any previous investigator. Familiarization was continued until the subject could reproduce all the items on the familiarization training list. With this training, the effects of familiarization were qualitatively similar to, and more than half as large in magnitude as, the effects of meaningfulness. Specifically:

1) For the H-H (high meaningfulness) conditions, amount of familiarization of stimuli, responses, or both, had no effect on ease of learning--the saturation was complete (Table III, col. 1).

2) For the L-L (low meaningfulness) conditions, unfamiliarized syllables (U-U) took 1.8 times as long to learn* as familiarized syllables (F-F). Response familiarization (U-F) had a greater effect than stimulus familiarization (F-U)--the ratios were 1.2 and 1.6, respectively (Table III, col. 3).

3) When familiarization training was provided, the effects of meaningfulness upon ease of learning were reduced by about two-thirds. In the F-F conditions, the L-L pairs took only 1.2 times as long to learn as the H-H pairs--the L-H and H-L pairs falling between the two extremes. Saturation was not quite complete, but was clearly visible (Table III, col. 2).

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*Because of the form in which Chenzoff presented his data, the actual measure of speed of learning used here is the reciprocal of the number of correct responses between particular (fixed) trial boundaries relative to the (H-H, F-F) condition taken as a norm of 1.0 (see Table III).
Table III

EFFECTS OF FAMILIARIZATION AND MEANINGFULNESS

<table>
<thead>
<tr>
<th>Meaningfulness (or familiarity)</th>
<th>Chenzoff's Data</th>
<th>EPAM-III</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(1) High meaningfulness</td>
<td>(2) High familiarization</td>
</tr>
<tr>
<td>H-H or F-F</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>L-H or U-F</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>H-L or F-U</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>L-L or U-U</td>
<td>1.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Reciprocal of number of correct responses, H-H or F-F equals 1.0.

\textsuperscript{b}Relative number of errors to criterion, H-H or F-F equals 1.0.
4) In the absence of familiarization training, the usual large effects of meaningfulness were visible. In the U-U conditions, the L-L pairs took 2.2 times as long to learn as the H-H pairs (Table III, col. 4).

Thus, except for the quantitative deficiency in the effect of familiarization, Chenzoff shows meaningfulness and familiarization to be equivalent. But they are not additive, because of the saturation effect.

Further, and very strong, evidence, for the syllable integration hypothesis is obtainable from the predictions of EPAM-III. By presenting syllables with appropriate instructions, EPAM can be familiarized with stimulus syllables, response syllables, or both. Amount of familiarization can be manipulated by varying the number of familiarization trials. In particular, familiarization can be carried to saturation--to the point where complete syllable images are stored in the discrimination net. The maximum effects predicted by EPAM-III for familiarization are of the same magnitude as the maximum effects of meaningfulness observed in the empirical studies. Table III shows, for the four conditions, and taking the L-L conditions as the norm, the relative rates of learning as predicted by EPAM-III (col. 5) and as reported by Chenzoff's subjects (col. 4). Except for the rather high value for the H-L condition for Chenzoff's subjects--which is in disagreement with the other experiments in the literature on this point--the quantitative agreement with the EPAM-III predictions is remarkably close. In particular, EPAM predicts the 2.5 maximum ratio that has been so often observed. Since syllable integration is the mechanism that EPAM employs to achieve this
result, this implication of the theory provides support for the hypothesis that syllable integration is the mediating mechanism in producing the effect of meaningfulness (and familiarization) upon ease of learning.
V. DEGREES OF FAMILIARIZATION

If our interpretation of the mechanism of familiarization is correct, then the effects of a given amount of familiarization training will depend, in a sensitive way, upon how familiar the syllables were at the beginning of training. There is no way of knowing this exactly, although it is reasonable to assume that nonsense syllables of low association value are close to the zero level of familiarity. *

To examine the effects of varying amounts of familiarization training upon the ease or difficulty of paired-associate learning, EPAM-III has been run with various combinations of zero to five trials of stimulus and response syllable familiarization. The results are shown in Table IV, in terms of number of errors to criterion.

Under the conditions employed in these experiments, the maximum possible effects of familiarization were obtained with a combination of three trials of response familiarization and one trial of stimulus familiarization--additional familiarization did not facilitate learning. The asymptote--21 errors--for this amount of familiarization was not attainable with any amount of response familiarization in the absence of stimulus familiarization, or with any amount of stimulus familiarization without response familiarization. The asymptotes in the

*See, however, the findings of Underwood and Schulz on differential pronounceability of such syllables.
latter two cases were 27 errors and 38 errors, respectively, reached with three trials and two trials, respectively, of familiarization.

The detail of Table IV shows some exceedingly complicated relations. For example, if syllables have received no prior familiarization, one trial of stimulus familiarization reduces errors more than one trial of response familiarization—reductions of 8 and 4 errors, respectively, from 52 in the no-familiarization case. On the other hand, for syllables that had already received one trial of stimulus and response familiarization, an additional trial of stimulus familiarization reduced errors only by 3, while an additional trial of response familiarization reduced errors by 11, from a level of 35. Other similar results may be read from Table IV. Many
of the numerous small anomalies in the literature on familiarization training may be attributable to the lack of control over the amount of prior familiarity that subjects had with the syllables used in the experiments.

In col. 6 of Table III is shown the predicted effect, estimated from the EPAM data of Table IV, of familiarization training with syllables that are already somewhat familiarized before the experiment begins (i.e., that have previously received one simulated trial each of stimulus and response familiarization). Under the F-F condition, there would be 21 errors to criterion; under the U-F condition (1 stimulus familiarization trial, 3 response trials), 21; under the F-U condition (3 and 1 stimulus and response familiarization trials, respectively), 32; and under the U-U condition (one S and one R familiarization trial), 21. The resulting indexes of relative difficulty for the four conditions are 1.0, 1.0, 1.5, and 1.7, as shown in col. 6. These may be compared with the values 1.0, 1.2, 1.6, 1.8, for the actual data in col. 3. In other words, the fact that the effects shown in col. 3—and even in col. 4—are somewhat smaller than the predictions in col. 5, may be due simply to the fact that the syllables were already slightly familiar to the subjects at the beginning of the experiment.
VI. CONCLUSION

The predictions of EPAM-III, a theory of human verbal learning, have been compared with data from the experiments of Bruce, Chenzoff, Underwood, and others, on the effects of intra-list and inter-list similarity, the effects of familiarization, and the effects of meaningfulness upon difficulty of learning. There is good quantitative, as well as qualitative, agreement between the published data and the predictions of the theory. These findings have been used to discuss the relation between familiarization and meaningfulness, and it has been shown that most of the known facts can be explained by supposing that a symbolic structure necessarily becomes familiar in the process of becoming meaningful—but that the converse is not necessarily the case.
REFERENCES


