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An Information-Processing Theory of Some Effects of Similarity, Familiarization, and Meaningfulness in Verbal Learning[1]

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Among the most commonly used paradigms in the study of verbal learning is the learning of nonsense syllables by the paired-associate or serial anticipation methods. The variables that have been shown to have important effects on the rate of learning include 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.

In previous papers (Feigenbaum, 1959, 1961; Feigenbaum and Simon, 1962b), a theory has been set forth that undertakes to explain the performance and learning processes underlying the behaviour of *S*s in verbal learning experiments. The theory, in its original version, makes correct quantitative predictions of the shape of the serial position curve (Feigenbaum and Simon, 1962a) and the effect of rate of presentation on learning (Feigenbaum, 1959; Feigenbaum and Simon, 1962a) as well as predictions of certain qualitative phenomena (for example, oscillation) (Feigenbaum and Simon, 1961).

In this paper, a simplified and improved version of the theory is reported that retains these properties of the earlier theory while providing correct quantitative predictions of the effects of the other important variables: familiarization, meaningfulness, and similarity. The tests of the theory discussed here are based on comparisons of the performance of human *S*s, as reported in published experiments on paired-associate learning (Bruce, 1933; Chenzoff, 1962; Underwood, 1953; Underwood and Schulz, 1960), 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 the 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 latter being 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 which allow the program to produce

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responses that have previously been associated with stimuli, subroutines for learning to discriminate among different stimuli, and subroutines for acquiring familiarity with stimuli. Top-level executive routines, which organize these subroutines into a program, represent hypotheses about the *S*'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.

In the first part of the paper a brief description of EPAM-III is provided. Since other descriptions of the program are available in the literature (Feigenbaum, 1959, 1961; Feigenbaum and Simon, 1962b), only so much of the detail will be presented as is essential to an understanding of the experiments and the interpretation of their results. In the second part of the paper, the results will be reported of comparisons of the behavior of EPAM-III with the behavior of human *S*s in paired-associate learning where similarity is the independent variable. In the third part of the paper, the results will be reported of comparisons in which familiarization and meaningfulness are the independent variables.

A Brief Description of EPAM-III

The computer language in which EPAM-III is written is known as IPL-V (Newell, Tonge, Feigenbaum, Green, and Mealy, 1964). A companion program simulates an experimental setting, more specifically, a memory drum capable of exposing stimulus materials to EPAM, in either the serial or paired-associate paradigm. The simulated drum-rotation rate can be altered as desired, as can the stimulus materials. An interrupt system is provided so that the simulated experimental environment and the simulated *S* can behave simultaneously, to all effects and purposes, and can interact, the *S* 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 (Feigenbaum, 1959, 1961; Feigenbaum and Simon, 1962b). 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 comparisons, the stimulus has been successfully recognized. We call such a stimulus *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 and which 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 responses. We may designate this compound symbol by S- ——, for 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 terminal 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 response 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 symbols 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, i.e., to print it. This information, which we may call the efferent image, is used to produce the response. Thus, the final step in the sequence is for the program to respond, say, XYZ.

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 effector 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 (*image building*),[2] and 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 image-building 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 discrimina-

[2] We use the term "image building" rather than the less clumsy and more descriptive term "familiarization" to resolve a dilemma of nomenclature that will become obvious in a later section.

tion 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 image building, 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. It is not easy to conjure up alternative schemes that will permit learning to proceed when the members of a pair of stimuli to be discriminated are not present simultaneously.

The stimuli that EPAM-III can make familiar and learn to discriminate are symbols of any kind, elementary or compound. Thus, the letters of the alphabet can be first made familiar, and the net elaborated to discriminate among them. Then EPAM can make familiar 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 making familiar 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 image-building and discrimination-learning processes will be activated. The executive routine makes use of a kind of knowledge of results. When the simulated *S* 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, 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 image-building and discrimination-learning processes are initiated.

There are many details of the EPAM-III program we have not described here, but this general sketch will give us a sufficient basis for discussing the behavior of the program in standard paired-associate learning situations.

Effects of Intralist and Interlist Similarity

The adequacy of EPAM-III as a theory of human rote verbal learning has been tested initially by replicating, with the program, experiments of Underwood (1953) on intralist similarity; of Bruce (1933) on interlist similarity; and a number of authors (Underwood and Schulz, 1960) on stimulus and response familiarization and meaningfulness. In this section the experiments employing similarity as the independent variable will be discussed; in the next section the experi-

TABLE 1
COMPARISON OF EPAM WITH UNDERWOOD'S (1953) DATA ON INTRALIST SIMILARITY
(RELATIVE NUMBER OF TRIALS TO CRITERION, LL = 100)

Data	Condition of stimulus and response similarity				
	L-L	L-M	M-L	L-H	H-L
Underwood	100	96	109	104	131
EPAM-III ("visual only")	100	88	141	91	146
EPAM-III ("aural only")	100	100	100	100	114
EPAM-III ("visual" and "aural" mixed, 1:1)	100	94	121	96	130
EPAM-III ("visual" and "aural" mixed, 1:2)	100	96	114	97	125

ments on familiarization and meaningfulness will be considered.

Underwood (1953) studied paired-associate learning of nonsense syllables under various conditions of intralist similarity of stimulus syllables and response syllables. If we use L. M, and H to designate low, medium, and high intralist similarity, respectively; and let, e.g., L-M stand for "low intralist similarity of stimuli, medium intralist similarity of responses," then Underwood's five experimental conditions are L-L, M-L, H-L, L-M, and 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 intralist similarity of *responses* had virtually no effect on ease or difficulty of learning;[3] (b) that trials required for learning increased with degree of intralist similarity of *stimuli,* the difference being about 30% between the LL and HL conditions. The first row in Table 1 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 LL condition taken as 100.

The syllables employed in the EPAM simulation were the same as those used by Underwood.[4] Row 2 in Table 1 summarizes the data from the EPAM tests. Response similarity facilitated learning very slightly, while stimulus similarity impeded learning by as much as 40%. Since relative learning times are reported in both cases, there is one free parameter available for matching the two series. (In the normal course of events, the compound images, S′-R′, are discriminated from each other on the basis of stimulus information, not response information. High intralist stimulus similarity makes difficulties for EPAM in discriminating and retrieving these images, and hence impedes learning. Response similarity, of course, has no such effect.)

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, we sought a much bettter quantitative prediction. This search led us into the following considerations. The prediction that is seri-

[3] In the Underwood experiment the effect of response similarity is inconsequential. In general, the evidence on the impeding or facilitating effects of response similarity is mixed. What does stand out, however, is this: The effects of response similarity, if any, are quantitatively small and insignificant when compared with the large effects of stimulus similarity.

[4] We are indebted to Professor Underwood for making these sets of syllables available to us.

ously out of line in Table 1 is the prediction for the M-L condition. The more carefully one scrutinizes the Underwood experiment and the Underwood materials, the more puzzling the experimental results become. Why do *S*s, as the results indicate, respond in the M-L condition so similarly to the way they respond in the L-L condition, while their responses in the H-L condition are so different from responses in either the M-L or L-L conditions? The answer is not to be found in the Underwood materials. We have analyzed the Underwood definition of "medium similarity" in terms of the information necessary to discriminate the items on a list of a given length (in EPAM-like fashion) and have 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 *S*s, which would make the "medium similarity" stimulus list formally identical with the "low similarity" stimulus list under Underwood's definition. Suppose that many *S*s were pronouncing the Underwood CVC's, 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 Underwood's "medium similarity" lists, none of 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, we reran the EPAM (simulated) experiments using "aural" recodings of the original syllables. The modified predictions are given in Row 3 of Table 1. 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 *S*s are processing in the visual-literal mode and some in the "aural" mode, we have computed the average (1:1) of the two sets of EPAM predictions. This is given in Row 4 of Table 1. If we weight the average 2:1 in favor of *S*s doing "aural" recoding, the result is as given in Row 5 of Table 1. Each of these averaging procedures gives a prediction which is much better than that for the Underwood lists non-recoded.

It is clear that we still have much to learn about this low-vs.-medium similiarity problem. In this regard, we are currently attempting a direct experimental test of the "aural" recoding hypothesis.

Bruce's *S*s (1933) learned two successive lists of paired-associate nonsense syllables. On the second list, response syllables, or stimulus syllables, or neither, could be the same as the corresponding syllables on the first list. Thus, using current designations, Bruce's three conditions were (A-B,C-D), (A-B,A-C), and (A-B,C-B), respectively. In summary, he found that learning of the second list was somewhat easier than learning of the first when all syllables were different (A-B, C-D), much easier when the response syllables were the same (A-B, C-B), and a little harder when the stimulus syllables were the same (A-B, A-C) (see Table 2). The relative difficulties are compared using the A-B,C-D group as the norm.

Nonsense-syllable lists of low Glaze value and low intralist similarity were used when the experiment was replicated with EPAM. The normalized results are shown in the second line of Table 2. The effects in the simulated experiment were qualitatively the same as in the actual data. If we compare the conditions A-B,A-C and A-B,C-B with A-B,C-D, we find that identity of stimulus

TABLE 2
COMPARISON OF EPAM WITH BRUCE'S DATA ON INTERLIST SIMILARITY
(RELATIVE NUMBER OF TRIALS TO CRITERION)

	Condition of stimulus and response similarity		
	A-B, A-C	A-B, C-B	A-B, C-D
A-B, C-D condition = 100	130	75	100
EPAM-III A-B, C-D condition = 100	112	75	100

syllables impeded learning less, and identity of response syllables facilitated learning to the same degree in the simulation as for the human *S*s. The ratio of difficulty for the A-B,A-C compared with the A-B,C-B conditions, where total number of different syllables discriminated and learned was the same, was 1.73 for the human *S*s and 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 intralist and interlist stimulus and response similarity upon the learning of paired-associate nonsense syllables. 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.

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 (1960).

The degree of familiarity of a syllable is usually not measured directly; instead, it is measured by the amount of ***Familiarization training*** to which *S* has been exposed with that syllable. In the following discussion, they are not synonymous. "Familiarization" will be used when reference is made to specific experimental conditions and operations. "Familiarity," on the other hand, will refer to a condition internal to an *S*: the state of information about a syllable in the memory of an *S* who has gone through some kind of familiarization training. Thus, familiarity is an intervening variable not directly observable. The use of an intervening variable hardly needs to be defended, since it is the rule rather than the exception in theory-building in the natural sciences as well as the behavioral sciences.

Familiarization training is accomplished by causing *S* 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 familiar a syllable may be for an *S* due to his 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 *S*s 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 familiarity 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 and 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 (1960) adduce a large body of evidence to show that there is a strong relation running the other way i.e., 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 pronunciability), or with their pronunciability.

The data are of course greatly complicated by the fact that *S*s may handle the material in either the visual or the aural mode, and that most *S*s 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 pronunciability is a better predictor than trigram frequency of ease of learning 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.

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 idea that familiarity is the critical variable in learning rests on the idea, certainly not original with EPAM model, that there are two stages in paired-associate learning: (1) integration of responses, and (2) association of responses with stimuli. Underwood and Schulz (1960) have used this idea, and it plays an important role in their analysis. It also plays an important role in the structure of EPAM (Feigenbaum, 1959, 1960). 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: image building and discrimination learning.

If response intgration 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, i.e., 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 where the tests in the net were 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 (1960) 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 the significance of this 2.5/1 ratio is considered further, it is necessary to discuss one difficulty with the hypothesis that familiarization and meaningfulness (via familiarity) facilitate learning primarily by virtue of responses being integrated 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 familiarization. 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 Chenzoff (1962), 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 his *S*s to the point where the syllable integration achieved is comparable to the integration of syllables of high meaningfulness.

Chenzoff's experiment can be summed up as follows. First, in his experiment he manipulated both meaningfulness and familiarization of both stimuli and responses. Thus, he had 16 conditions: all possible combinations of H-H, L-H, H-L, and L-L for stimulus and response meaningfulness[5] with F-F, U-F, F-U, and U-U for familiarity. Second, he em-

[5] The two levels of the meaningfulness variable were constructed as follows (using CVC's):
H: 53–100 Glaze, 85–100 Krueger, 67–97 Archer, 2.89–3.66 Noble (m′), 3.08–3.87 Noble (a′).
L: 0–53 Glaze, 39–72 Krueger, 9–48 Archer, 0.92–1.83 Noble (m′), 1.38–1.94 Noble (a′).

TABLE 3
EFFECTS OF FAMILIARIZATION AND MEANINGFULNESS

Meaningfulness (or familiarity)	Chenzoff's (1962) data[a]				EPAM-III[b]	
	(1) High meaningfulness	(2) High familiarization	(3) Low meaningfulness	(4) No familiarization	(5) No previous familiarization	(6) Previous familiarization
H-H or F-F	1.0	1.0	1.0	1.0	1.0	1.0
L-H or U-F	1.0	1.1	1.2	1.2	1.3	1.0
H-L or F-U	1.0	1.2	1.6	1.2	1.8	1.5
L-L or U-U	1.0	1.2	1.8	2.2	2.5	1.7

[a] Reciprocal of number of correct responses; H-H or F-F = 1.0.
[b] Relative number of errors to criterion; H-H or F-F = 1.0.

ployed a more thorough familiarization training technique for the F condition than had any previous investigator. The syllables were presented one at a time to *S* at about a 2.5-sec rate. The *S* was required to pronounce each syllable. After five trials, *S* was asked to recall the syllables in any order. If an incorrect syllable was given, *S* was told that it was not a member of the list. If, within 30 sec, *S* could not perform completely correctly, five more familiarization trials were administered. This continued until *S* learned the list. The range of number of trials for the various *S*s was 10–30; the median and mode were 15 trials.

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 3, Column (1)].

(2) For the L-L (low meaningfulness) conditions, unfamiliarized syllables (U-U) took 1.8 times as long to learn[6] 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 3, Column (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 3, Column (2)].

(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 3, Column (4)].

Thus, except for the quantitative deficiency in the effect of familiarization, Chenzoff shows meaningfulness and familiarity 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 attain familiarity with stimulus syllables, response syllables, or both. Amount of familiarity can be manipulated by varying the number of familiarization trials. In particular, familiarity 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 3 shows, for the four conditions, and taking the L-L conditions as the norm, the relative rates of learning as predicted by EPAM-III [Column (5)], and as reported by Chenzoff's *S*s [Column (4)]. Except for the rather high value for the H-L condition for Chenzoff's *S*s, which is in disagreement

[6] 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 3).

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.

Degree of Familiarization

If the present interpretation of the mechanism of familiarity 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. (See, however, the findings of Underwood and Schulz on differential pronunciability of such syllables.)

To examine the effects of varying amounts of familiarization training upon the ease or difficulty of paired-associate learning, EPAM was tested with various combinations of zero to five trials of stimulus- and response-syllable familiarization. The results are shown in Table 4 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 latter two cases were 27 errors and 38 errors, respectively, and were reached with three trials and two trials, respectively, of familiarization.

Table 4

Effects of Stimulus and Response Familiarization (Number of Errors to Criterion in Paired-Associate Learning)

Response familiarization (trials)	Stimulus familiarization (trials) 0	1	2	3
0	52	44	38	38
1	48	35	32	32
2	39	24	24	24
3	27	21	21	21

The detail of Table 4 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 eight and four 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 three, while an additional trial of response familiarization reduced errors by 11, from a level of 35. Other similar results may be read from Table 4. Many of the numerous small anomalies in the literature on familiarization training may be atributable to the lack of control over the amount of prior familiarity that *Ss* had with the syllables used in the experiments.

In Table 3, Column (6), we show the predicted effect, estimated from the EPAM data of Table 4, of familiarization training with syllables that were already somewhat familiar before the experiment began (i.e., that had previously received one simulated trial each of stimulus and response familiarization). Under the F-F condition, we would have 21 errors to criterion; under the U-F condition (one stimulus familiarization trial, three response trials), 21; under the F-U condition (three and one stimulus and response familiarization trials, respectively), 32; and under the U-U condition (one S and one R familiarization trial), 35. The resulting indexes of relative difficulty for the four conditions are 1.0, 1.0, 1.5, and 1.7, respectively, as shown in Column (6). These may be compared with the values 1.0, 1.2, 1.6, 1.8, for the actual data in Column (3). In other words, the fact that the effects shown in Column (3), and even in Column (4), are somewhat smaller than the predictions in Column (5) may be due simply to the fact that the syllables were already slightly familiar to the *S*s at the beginning of the experiment.

Conclusion

In this paper we have compared the predictions of EPAM-III, a theory of human verbal learning, with data from the experiments of Bruce, Chenzoff, Underwood, and others, on the effects of intralist and interlist similarity, of familiarization, and of meaningfulness upon difficulty of learning. We find that there is good quantitative, as well as qualitative, agreement between the published data and the predictions of the theory. Finally, we have used our findings to discuss the relation between familiarity and meaningfulness, and have 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.

Summary

Results obtained by simulating various verbal learning experiments with the Elementary Perceiving and Memorizing Program (EPAM), an information-processing theory of verbal learning, are presented and discussed. Predictions were generated for experiments that manipulated intralist similarity (Underwood, 1953); interlist similarity (Bruce, 1933); and familiarity and meaningfulness. The stimulus materials were nonsense syllables learned as paired-associates.

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 hypothesizing a process of "aural recoding."

The fit of the EPAM predictions to data of Chenzoff (1962) lends support to the hypothesis that the mechanism by means of 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 are shown to be surprisingly complex.

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