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BRIEF NOTES ON THE EPAM THEORY OF VERBAL LEARNING[1]

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We have been asked briefly to sketch the EPAM (Elementary Perceiver and Memorizer) model. If these notes are overly succinct, clarification will be found in the references.

Model and Method. EPAM is a theory of the information-processing activity underlying verbal learning behavior. The precise formulation of the model is given in an information-processing language for a computer. The computer is then used as a tool for generating the remote consequences of the information-processing postulates in particular experimental conditions. EPAM is a closed model in the sense that it can be treated as a subject in learning experiments. The experiments are not run "live" but are simulated using programs to simulate an experimenter, the apparatus, and the stimulus environment. Such simulated experiments yield a stream of verbal behavior from EPAM fully equivalent in nature to the "raw data" which an experimenter takes from his subject in a live experiment. Of course, the degree to which this behavior looks like human behavior in the same experiments is the fundamental question of model validation.

EPAM I. EPAM contains a set of "macroprocesses" which deal with the organization of the total learning task, and a set of "microprocesses" which learn the individual items. (The macroprocesses are referred to as EPAM I, the complete model as EPAM II.) That such a factorization of the learning activity is useful and valid is argued in another place (Feigenbaum and Simon, 1962).

The fundamental assumptions of EPAM I are as follows:

1. Any given stimulus item requires a definite amount of processing time before it is learned. For items of the same average difficulty, this time is relatively constant. Thus, the total time to learn *n* items is given approximately by $T_n = Kn$. (It is postulated that *time*, rather than *number of exposures* per se, is the critical variable.)

[1] These notes were contributed after the conference at the invitation of Professor Postman (Ed.).

2. There exists an immediate memory of extremely limited size, which provides "temporary storage" for stimulus items undergoing processing. (The effect of this is to postulate an "information bottleneck.")

3. In the face of immediate memory constraint, subjects not otherwise instructed adopt an anchor-point strategy for organizing the learning task. Items at perceptually unique anchor points are learned first. An item, once learned, becomes an anchor point for further learning. (This postulate determines the order in which items are attended to for learning. It is all-or-none attention in that a new pair of items will not be attended to until the previous pair is considered adequately learned.)

EPAM I yields predictions of macrophenomena of serial learning. In particular, we have shown that it predicts the McCrary and Hunter serial position curves better than any other existing theory (Feigenbaum and Simon, 1961c, 1962).

EPAM II. The function of the macroprocesses is to focus the attention of the microprocesses successively on the stimulus-response item pairs which comprise the learning task. For any pair, the primary learning process is as follows: Learn to discriminate the S item from all items in the set already learned; do the same for the R item; finally, construct an association between S and R.

The microprocesses perform four principal functions:[2]

a. Recognize an external stimulus as one about which some information has already been memorized

b. Add new stimulus items to the memory by building discriminations (tests) that allow the new item to be distinguished from the stimuli previously learned

c. Associate (internally) two stored items, say x and y, by storing with x some cue information about y

d. Respond to an external stimulus X with a response, Y, by retrieving the cue to the response, and then retrieving the response using the cue

Thus EPAM has two performance processes, enabling it to respond with material already learned: the discrimination process (a), which recognizes the stimulus, and the response process (d), which finds the appropriate response associated with the stimulus and produces it. EPAM also has two learning processes: the discrimination learning process (b), which elaborates the structure of discrimination tests it applies to stimuli, and the association learning process (c), which associates response cues with stimuli.

The central memory structure, which the performance processes use and the learning processes construct, is the *discrimination net.* It is a net of

[2] The following discussion is adapted from an earlier paper (Feigenbaum and Simon, 1961b).

associations at whose terminal nodes are stored *images* of encodings of external stimuli. At the nonterminal nodes of the net are stored *tests* which examine particular features of the encodings. The internal image of a stimulus is retrieved by sorting the encoding of the stimulus down through the tests of the net to the appropriate terminal. In learning a set of stimuli, the net is grown to a size that is just large enough (roughly) to discriminate among the different stimuli that have been presented to the system.

Association of a response, y, to a stimulus, x, is accomplished by storing a small amount of the information about y (an incomplete *cue image* of y) along with the image of x. The system determines by trial and error how much information must be stored as a cue to retrieve the response from the net when the association is made.

EPAM responds to a stimulus by sorting it in the discrimination net, finding the associated response cue, sorting that cue in the same net, finding its image, and using the response image to produce the response.

Results. Study of the behavior of EPAM in an initial set of about a hundred simulated experiments shows that a variety of "classical" verbal learning phenomena are present. Referring to traditional labels, these include serial position effect, stimulus and response generalization, effect of intra-list similarity, types of intra-list and interlist errors, oscillation, retroactive inhibition, proactive effect on learning rate (but unfortunately not proactive inhibition), and log-linear discriminative reaction time. Further experiments, especially those involving inhibition phenomena and transfer phenomena, are now in progress.

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