Wickelgren, Wayne A., *A Simulation Program for Concept Attainment by Conservative Focusing* , 7:2 (1962:Apr.) p.245

The graduate course just described was offered in substantially the same form by Professor Julian Feldman in the spring of 1961. Regular attendance (students and auditors) was about twenty persons. In May, 1961, the course was made a regular offering by the faculty of the School of Business Administration and will be permanently incorporated in the Berkeley curriculum as the spring semester of B.A. 210, Applications of Digital Computers to Problems in the Social Sciences (the fall semester of which deals with simulation of economic and industrial behavior).

Five reports on research done by graduate students in the course follow which are of particular interest and significance. The first two papers, by students of psychology, concern studies in concept attainment, using as a point-of-departure Bruner, Goodnow, and Austin's book, *A Study of Thinking*. The third paper, by a student of biophysics, summarizes an attempt to explore the consequences of certain assumptions about neural processes and organization. The last two papers are oriented more toward artificial intelligence than simulation of human cognition. The fourth paper, by a student of mathematics, deals with an interesting facet of the problem of analytic integration by machine. The fifth paper, by a member of the staff of the Lawrence Radiation Laboratory, is a report of an important attempt to program pattern recognition heuristics for the problem of automatic identification of interesting nuclear events in 3-dimensional bubble chamber photographs. The inability to process these photographs fast enough is perhaps the most important data-processing problem faced by high-energy physics today.

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A Simulation Program for Concept Attainment by Conservative Focusing, *Wayne A. Wickelgren, University of California, Berkeley.*

This is a summary of an information-processing model for conservative focusing in a concept-attainment task (Bruner, Goodnow, & Austin, 1956). *S* is presented with an array of cards differing on *n* attributes with m_i possible values for each attribute. Some of these cards are exemplars of a concept that *E* has in mind, and the rest are not. *S*'s task is to discover the concept, that is, the basis of classification as exemplar or nonexemplar. The model is restricted to apply only to situations in which the permissible concepts are conjunctive combinations of one particular value for each of several relevant attributes (i.e., all cards with red circles). Disjunctive concepts (i.e., all cards with a red circle or a black square) and relational concepts (all cards with a greater number of figures than borders) are excluded, and *S* is aware of this restriction. *S* is first presented with a positive instance of the concept called the focus card, and is permitted to obtain further information about the concept by selecting cards from the array of all possible combinations of values for each attribute and being told whether the card is an example of the concept. The conservative focusing strategy selects cards differing on only one attribute from the focus card and systematically determines the relevance or irrelevance of every attribute.

Both cards and concepts are represented in the IPL 5 computer by lists of attributes, which in turn have description lists that contain both attributes and values. The simulation program is divided into a subject program and an experimenter program. The experimenter program has access to the list of relevant attributes, whose description list contains the correct values. The subject program has access to only the lists of possible values for each attribute and the focus card, whose description list contains the attributes and values of the initial positive instance of the concept.

The subject program has two major subdivisions: an intratask problem-solving program and an intertask learning program. The problem-solving program is concerned with the solution of a given concept-attainment task, and the learning program is concerned with the improvement of performance over a set of tasks.

The only learning feature built into the program so far is change of *AO*, the attribute order, which determines the order in which the subject tests the relevance of the possible attributes. The learning mechanism promotes by one the position (in the priority sequence) of the attributes that proved relevant in the preceding task. It should be noted that, given a conservative focusing strategy and the type of concept-attainment tasks that are being simulated at present, the learning mechanism does not improve performance if this is judged by the number of trials necessary to attain the concept. However, if performance is measured by accuracy of guessing the concept after a fixed number of trials, and certain reasonable assumptions are made about an individual's guessing habits under incomplete information, then this learning mechanism will exploit any persistent biases in the experimenter's selection of relevant attributes. The learning mechanism would be of greatest benefit to a focus gambling or successive scanning strategy, and its inclusion in this conservative focusing model is a consequence of the assumption that the most frequently relevant attributes will gradually assume increased saliency, no matter what the initial saliency ordering is.

The problem-solving program has three logical subdivisions: card selection, information storage, and information evaluation relative to the concept-attainment task. The basic flow of the simulation is: card selection, confirmation or infirmation by the experimenter, information storage, and testing to determine if sufficient information has been obtained to discover the concept. When the answer to this evaluation is yes, the subject generates the concept and exits from the cycle.

The heart of any simulation program for this type of concept-attainment task is the type of memory structure it posits. In the development of the information-storage routine the following assumptions were made about human memory, borrowing extensively from Miller (1956):

1. Immediate memory can contain without loss only a highly limited number of chunks of information.
2. The maximum number of chunks that can be stored in immediate memory is a parameter varying over individuals, but in the vicinity of seven.
3. The amount of information contained in a chunk does not affect the immediate memory capacity for chunks.
4. Humans solve problems requiring extensive storage of information by the construction of chunks richer in information than the "atomic" chunks in which the problem is presented.
5. These richer chunks are names of lists of poorer chunks.
6. There are limits to this abstraction process.
7. There is a semipermanent memory structure which is the subject program itself and is conceived to be a part of the structure of the individual.
8. Task instructions and the initial focus card temporarily become part of this semipermanent memory structure and do not need to be channeled through immediate memory to be recalled.

The primary memory structure combines an attribute with a symbol *IO* or *LO* for irrelevant or relevant, and this *pair* of symbols is the basic chunk which is stored in immediate memory, *MO*. The attribute is in *MO*, and the list of pairs is the description list of *MO*. If the number of attributes tested ex-

ceeds the primary capacity of *MO*, then the subject program restructures immediate memory by constructing richer chunks of information. These chunks are new symbols naming lists containing two attributes each, and the attributes on these new lists are considered to be chunks representing both the attribute and its relevance or irrelevance to the concept. Depending upon the immediate memory capacity and the complexity of the problem, the subject program may operate entirely at the first level of abstraction or initially at the first and later at the second level of abstraction. If the number of attributes exceeds both primary and secondary memory capacity, then the model assumes the subject is unable to solve the problem. This is an acknowledged oversimplification. Another oversimplification is that loss of exactly one chunk occurs at exactly one point, when the subject program exceeds initial memory capacity. The model assumes that the subject does not restructure memory until he has exceeded capacity and forgotten one chunk. The intuitive notion is of a box with a capacity for *n* blocks such that, when the $n+$ 1st block is forced in, one block has to pop out somewhere. Realizing the information loss, the subject restructures memory in order to proceed with the task.

The card selection mechanism is really a card generator, in that it constructs a card out of attributes and values rather than selecting from an array of cards read into the computer as input. The card selector first chooses a new attribute to be tested from *UO*, the list of untested attributes. *UO* is ordered at the beginning of the task by *AO*. Both *AO* and *UO* are presumed to be part of the temporary hardware of the organism and are not channeled through *MO*. A value for the currently tested attribute is selected randomly from the list of possible values, excluding the value on the focus card. Then the rest of the untested attributes and the relevant attributes are added with their focus values, and the irrelevant attributes are added with any admissible values. A card is selected on the basis of information contained in the immediate memory structure, the list of untested attributes, and the focus card.

The evaluation program is quite simple. After each trial it merely tests to see if all the attributes have been tested and remembered, recycles if they have not, and produces the concept from immediate memory and the focus card if they have.

The simulation program has been debugged for operation under both primary and secondary memory structures, and the results are qualitatively very similar to those obtained with human conservative focusers. Nevertheless it is possible to point up a number of features that need modification. First, the model probably forgets less often than normal human subjects. Second, the model never codes an attribute incorrectly or remembers it incorrectly. The program either remembers correctly whether an attribute was determined to be relevant, or it does not remember at all. Third, the model never offers an incorrect hypothesis before it possesses complete information, and human subjects sometimes do this.

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A Concept Attainment Program that Simulates a Simultaneous-Scanning Strategy, *Max Allen, University of California, Berkeley.*

INTRODUCTION

Bruner, Goodnow, and Austin (1956) have suggested that humans employ four basic strategies in concept attainment: (1) simultaneous scanning, (2) successive scanning, (3) conservative focusing, and (4) focus gambling. The programs described below are simulations of the simultaneous scanning strategy demonstrated in one of their experimental situations. The situation consists of an experimenter *E*, a subject *S*, and a finite array of instances known to both *E* and *S*. The instances in this case are 27 cards, each of which may vary in three dimensions: (1) shape of the figures, (2) color of figures, and (3) number of figures. Each of the three di-