Density and dimensionality in the attainment of conjunctive concepts¹

WILLIAM J. KROSSNER

HARVARD UNIVERSITY²

Twenty-eight Ss solved conjunctive concept attainment problems in which density, the information load carried per instance, was either very low or maximally high. A higher percentage of subjects attained the concept with the high density type of presentation; increasing the number of relevant dimensions per concept caused a monotonic decrement in performance for both densities but widened the relative advantage of high density over low.

Studies of human information-processing capabilities have often been focussed on the rate at which the observer can absorb information without loss, the so-called "channel capacity" being the highest such rate (Miller, 1956). An analogous issue arises in concept attainment tasks, in which the S is presented with (or selects from) multidimensional stimulus arrays, and asked to discover an experimenter-selected categorization rule by which the set of possible arrays can be divided into two classes—those exemplifying the concept (positive instances) and those which do not (negative instances). A positive instance is one in which some of the component dimensions of the stimulus possess requisite values, and the aggregate set of these dimensions with the correct values is said to be the concept in question. In a concept attainment task, the presentation of each positive or negative instance to the S conveys information as to the presence or absence of stimulus dimensions in the concept, and the amount of such information per instance is susceptible to control by the experimenter. Is there a maximal or optimal information rate that the S can tolerate? An analysis of the effect of information load on performance in concept attainment tasks was made by Glanzer, Huttenlocher, & Clark (1963), who presented problems consisting only of positive instances to Ss who knew that exactly four of the stimulus dimensions would be involved in the concept. In addition, Glanzer, Huttenlocher, & Clark also varied the perceptual difficulty of the array and the memory burden on the Ss. Their results were, efficiency of performance improved with increasing informational density in the case when the memory burden and the perceptual difficulty were low, and either remained constant or declined for the other cases.

It is the purpose of the present paper to examine the effect of informational density on concept attainment for the case when conjunctive concepts would be defined in general by both positive and negative instances, the number of dimensions involved in a concept would change from problem to problem, the Ss would not know in

advance the number of relevant dimensions, i.e., those dimensions forming the concept, and there would be no memory burden on the Ss to retain previously shown information.

Method

Twenty-eight students from the Harvard Summer School population served as paid Ss. Ss, run as a group, saw the concept instances projected by a Kodak Cavalcade slide projector on a standard viewing screen.

A concept instance was a row of seven geometric figures in constant serial position, with each figure colored either red or blue. The figures served as the concept dimensions and the colors as the dimension values. After each row there was a plus sign if the concept was embodied in the instance, or a minus sign if it was not. The first instance in any problem was always positive.

The high and low density sequences were constructed as follows (for details, see Krossner, 1963). In the high density series, the irrelevance of all the irrelevant dimensions was shown with a second positive instance; the relevance of each relevant dimension was determined one at a time in the negative instances. In the low density series, dimensions were shown to be irrelevant one at a time in positive instances; the relevant dimensions were shown to be relevant in negative instances first all n at a time, then $n-1$ at a time, and so forth until they were shown to be relevant one at a time. Table 1 shows the number of instances resulting from the foregoing construction procedure for both the high and low densities. As can be seen from it, the number of instances required to specify a concept with a low-density presentation increases rapidly as the number of relevant dimensions in the concept rises. The actual number of relevant dimensions in the problem series ranged from zero through four of the seven possible.

The high density problems utilized the smallest possible number of instances to define the concept, hence, the information load per instance was maximally high. The low density problems, requiring more in-

Table 1. Number of Instances Required to Define Concept

Number of Relevant Dimensions	High Density	Low Density
0	2	8
1	3	8
2	4	9
3	5	12
4	6	19

Fig. 1. Proportion correct as a function of density and dimensionality.

stances, had the lowest non-redundant information load per instance. To lower the information density beyond this, it would have been necessary to incorporate instances that conveyed no new information as to the relevance or irrelevance of a stimulus dimension.

After Ss had been instructed they received 20 problems, two from each of the 10 cells of Table 1, in an order that was random with respect to density and number of relevant dimensions save that there were equal numbers of high and low density problems in both halves of the 20-problem sequence. Within each problem, the instances were shown in a simultaneous-successive manner, i.e., each new instance appeared with all of the preceding instances in order above it. An instance was shown for 12 sec.; at the end of a problem, Ss had 30 sec. to note their answers on a prepared form.

Results and Discussion

The effects of information density and dimensionality on Ss performance are presented in Fig. 1. It was always the case that a larger mean number of Ss correctly solved the high density problems. A *t*-test for the difference between correlated means, based on the number of Ss responding correctly, shows the difference be-

tween the two densities to be significant beyond the .05 level ($t=3.22$). As the number of relevant dimensions increased for both high and low densities, performance declined monotonically, with high density performance suffering less—the gap between high and low densities widens with increasing number of relevant dimensions. A test for trend based on runs (Olmstead, 1946) shows this monotonic effect of dimensionality on performance to be significant beyond the .05 level.

The results of the present experiment indicate that in certain conditions, at least, humans are able to assimilate chunks of information considerably larger than the minimum, and, in fact, if Ss are required to perform at levels in which new information is provided only at the minimal rate, their performance may suffer. This suggests that in the construction of programmed learning sequences, it may be possible to incorporate more than a minimum amount of new information in each sequence, and yet improve the acquisition of the material, while retaining the low error rate such sequences are designed to achieve (Skinner, 1958; Carr, 1959).

References

- Carr, W. J. Self-instructional devices: a review of current concepts. *WADC Tech. Rep. 59-503*, 1959, Wright-Patterson Air Force Base.
- Glanzer, M., Huttenlocher, J., & Clark, W. H. Systematic operations in solving concept problems. *Psychol. Monogr.*, 1963, 77, No. 564.
- Krossner, W. J. A design procedure for constructing conjunctive concept problems. *Ctr. Cog. Studies Rep.*, 1963, 1-8.
- Miller, G. A. The magic number seven, plus or minus two: some limits on our capacity for processing information. *Psychol. Rev.*, 1956, 63, 81-97.
- Olmstead, P. S. Distribution of sample arrangements for runs up and down. *Ann. math. Statist.*, 1946, 17, 24-33.
- Skinner, B. F. Teaching machines. *Science*, 1958, 128, 969-977.

Notes

1. This research was supported by a contract from the National Science Foundation; contract No. GS-192 and GS-1153 to Harvard University Center for Cognitive Studies.
2. Now at Department of Psychology, Vassar College, Poughkeepsie, New York.