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ABSTRACT

The impact of cybernetics on information science occurs chiefly through the concepts of variety, the law of requisite variety, and theory of transformations. Through these it pervades every aspect of information science. However, other basic sciences such as physics, biology, psychology are in their spheres equally pervasive, and information science is seen as a special discipline containing a high admixture of interdependent sciences, with applications that subserve every science and itself. As the title suggests, this paper presents a broad viewpoint in a very small space, and relies heavily upon an earlier work entitled "On Access to Knowledge and Information in the Social Sciences and Humanities from the Viewpoint of Cybernetics and Information Science" which is available as LI 004 282. (Author/SJ)

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IMPACT OF CYBERNETICS ON INFORMATION SCIENCE, AND VICE VERSA

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Abstract: The impact of cybernetics on information science occurs chiefly through the concepts of variety, the law of requisite variety, and theory of transformations. Through these it pervades every aspect of information science. However, other basic sciences such as physics, biology, psychology are in their spheres equally pervasive, and information science is seen as a special discipline containing a high admixture of interdependent sciences, with applications that subserve every science and itself. Reference to a prior paper is necessary in order to understand the present one.

1. As the title suggests, this paper presents a broad viewpoint in a very small space. Fortunately this can be attained by brief comments on a recent longer paper, "On Access to Knowledge and Information in the Social Sciences and Humanities from the Viewpoint of Cybernetics and Information Science."[1] This paper (Abbreviated OA) suggested that the cybernetic concepts 'variety' and the 'law of requisite variety' underlie much of information science. It showed that other basic sciences such as psychology and physics also contribute, and that an outstanding characteristic of information science is interdependence with other disciplines.

Pending publication of OA, a copy has been supplied your chairman for this meeting. Access to OA is assumed below.

2. OA presents a number of models. Among the most important is a psychological model of the mental levels of abstraction and their many roles. All of these increase the versatility of the human regarded as a goal-seeking system with internally - constructed self-regulatory devices. The mental levels are not hereditary but built up as new structures, by the body. They are constructed from traces of direct sense impressions (DSI's). Stored DSI's were called SSI's, and sets of naturally associated SSI's were named I-sets. Abstractions from I-sets were called A-sets. That is, an abstraction was presented as a single mental structure based on association of a finite number of SSI's. Two main kinds of association were recognized: natural association and conditioned or Pavlovian association. The former gives rise to our concepts of real objects, and through external and internal (body) constraints preserves the original order in space and time of the sampled stimuli. The latter are associations of arbitrary partial patterns -- simpler than the patterns in natural DSI's, yet, because sensed, yielding DSI's. They are symbols, and their role is to be arbitrarily associated with ("attached to") the naturally associated A-sets or concepts.

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Physically associated with the concept, the symbol DSI when received acts as a trigger, handle, or switch evoking the abstract concept to which it is conditionally associated out of latent memory into active awareness. Thus in "conversation" a speaker "plays upon the keyboard" of the recipient's A-sets by means of the attached symbol, i.e. DSI's. For only a stimulus leading to a DSI can cross the inter-individual separation ("segment bc").

3. OA speculates as to how the abstraction or A-set is formed. It is conjectured that the neural-brain system acts like a prism or diffraction grating on light, and decomposes any DSI into a spectrum of "partial patterns" or "qualities" or "characteristics". Once such a spectrum has been constructed (induction) the rapid "understanding" of any new DSI (its "meaning") is attained by an instantaneous spectrum analysis (deduction) of the DSI into its characteristics. The characteristics of DSI's are analogous to and in many cases the same as the "descriptors" and "terms" used in information search. No mechanism is suggested. This may be discovered by the neurologist, psychologist, biochemist, physicist, or others. However, the two forms of association, natural and conditioned, give a functional hint. The "sender" of a message is thereby enabled to force into the "recipient's" awareness any sequence of concepts which both have formed, and to which both have attached the same symbols to the same concepts. This powerful means of regulating the recipient's behaviour is a cybernetic device.

4. Another aspect of this model is that communication takes place only by means of abstractions -- i.e., only when the level of abstraction exceeds some threshold of stability. Since any DSI is unique, and we cannot evoke in another individual any mental object which is unique to that individual, the levels of abstraction represent a system wherein the uniqueness of DSI's and SSI's is destroyed by suppression of parts of their pattern and retention of simpler "core patterns". This is cybernetically equivalent to increasing the versatility of the individual -- and we see the levels as direct applications of the law of requisite variety. An A-set above some threshold minimum number of naturally associated SSI's (called "n (c)" in OA) can be used for communication provided a symbol or partial pattern is conditionally associated with it. A-sets are abstractions of sufficient universality (over the "universe" of individuals) as to reflect mainly the constraints of the environment and of the "universal" human internal processing of stimuli. They omit the uniqueness of individual responses. The existence of some n(c) is not hypothetical, for we know we cannot communicate our DSI's; and that we can transmit our thoughts by symbols for abstractions. The only unknown in this bounded inequality is the level c at which the threshold occurs:

[redacted] $1 < \underset{\text{communicable}}{n(c)} < n(\text{A-set or concept})$

[redacted]

in which n is the minimum number (extension) of naturally associated SSI's at any level, and c is the critical level number. In other words, above n(c) the variety or intension of the A-set has been sufficiently reduced as to permit "similar" responses and therefore, communication. The components of DSI's, or characteristics into which the mind decomposes any DSI, are more nearly universal among individuals or <u>stable</u> in the sense of variation from one individual to another, than are the original patterns or DSI's, which are unstable because their patterns are unique. Thus the whole cognitive structure of concepts is suggested as a cybernetic device governed by the law of requisite variety. To produce sufficient stability for communication is to enormously increase the options of the human self-regulator and his versatility and power to survive through social interaction.

5. The model is also used to show that higher abstraction levels tend to further increase concept stability and versatility. Thus "additivity", a compatibility of a new kind, is obtained between two sets with different characteristics by using a higher generic level -- with less variety. The physicist calls this achieving dimensional homogeniety. Quantitative concepts are essentially <u>classes</u> or categories. Some of the most useful are those special categories related by class inclusion or implication. From these come the partially and completely ordered sets of logic, Boolean lattices, and similar mental constructs. Here again it is suggested that the achievement of quantitativeness, additivity, and logical relations are increases in the variety of the self-regulator -- man. Thus from the simple sensory DSI, by means of natural association the ladders of abstraction are constructed which lead to <u>lower</u> variety in concept, and <u>higher</u> versatility or variety in behavioural options.

6. Another connection between cybernetics and information science appears through recognition of the physical process in communication. There are two basic modes of physical propagation of the strain in the medium which constitutes the pattern of the message. These are SD and LD. Records and memories (static strain propagation) require LD; while all dynamic propagation requires SD. The law of requisite variety affects the transformation point at which the variety of two adjacent stages of propagation differs. An example is the use of many symbols for the same or similar concept. This wide variety blocks communication among users or searchers for messages. It can be reduced by a thesaurus -- essentially a means of setting up equivalence classes for symbols. The many-one homomorphic transformation of mathematics is generalized to a suppression of variety, with preservation of an isomorphic core of relations in the simplified structure. The invariant core is the generic meaning, and the resulting class has much larger extension. This enables many users to "find" the same response (set of objects or documents sought) with a wide variety of symbols. It is a typical cybernetic increase in versatility of the user, to be able to find the same conceptual material independently of his vocabulary differences from those of other searchers. The underlying principle is always the same: one stage must be reduced in variety if the process of propagation of messages is to be effective. This underlies all "standardization" of symbols, and leads to eventual

standardization of concepts. It is thus also an educational device, since we may view education as a process whereby the variety of information of a set of learners is reduced (among the set) by conscious regulation on the part of the educator. That is, learners come to share the same ideas.

7. Another aspect of the law of requisite variety (not developed in OA) concerns the so-called "objective" concept, as distinguished from the "subjective". We all live in the subjective, and never leave it. (Figure 1) However, part of the subjective is not communicable, and therefore appears "highly subjective". Part of our subjectivity is abstracted and above threshold of communication, but still possesses much variety. This is the area of "ordinary discourse" or "natural language." There is sufficient suppression of variety so that conditionally associated symbols evoke reasonably "similar" mental structures in the recipient. But there is still lack of precision and the "same message" may subjectively "mean" (i.e., have as its spectrum of characteristics) different concepts, to different individuals. Within the area of natural discourse are enclaves of "special languages," each used by members of a social subgroup -- e.g., the disciplines. Here the level of abstraction is usually greater, and so is the precision (lack of variety as between the concepts of individuals). This lack of variety is achieved by means of special variety suppressing techniques such as "operational definitions." All are directed toward one goal -- reducing the subjective variety of the discipline-shared concept so that individuals respond to it with identical behavioural patterns (to within a "null" in observed behavioural differences). Thus the disciplines achieve uniqueness of concept by a method of communication feedbacks and checks which insures compatibility, or calls attention to differences. This state, in which a concept is maintained by a social subgroup through continual checks for variety is "objective." The objective state of any individual is simply a subset of his subjective states. And science is a process of attaining objective observation and theory by cybernetically reducing the variety among the data observed and the derived concepts of the individuals of its fields. This is equivalent to categorization with least possible observational and theoretical differences in data and in abstractions from data, between individual observers.

8. The librarian and information processor perform many professional tasks by reducing the variety among documents and other artifacts used in common by society. For example, they construct categories of inclusion or hierarchies (precoordinated); or they may set up the potentiality of such hierarchies, or of simple class conjunctions (postcoordinated). The use of precoordination ("classification") in information search was studied in OA by the model:

$$N = CKVT$$

This model demonstrates a number of properties of the level system of abstractions. In information search of a collection there is a reciprocal use of K and C, such that the total number of symbols sensed (VT) is kept small, and search takes place on the compressed and

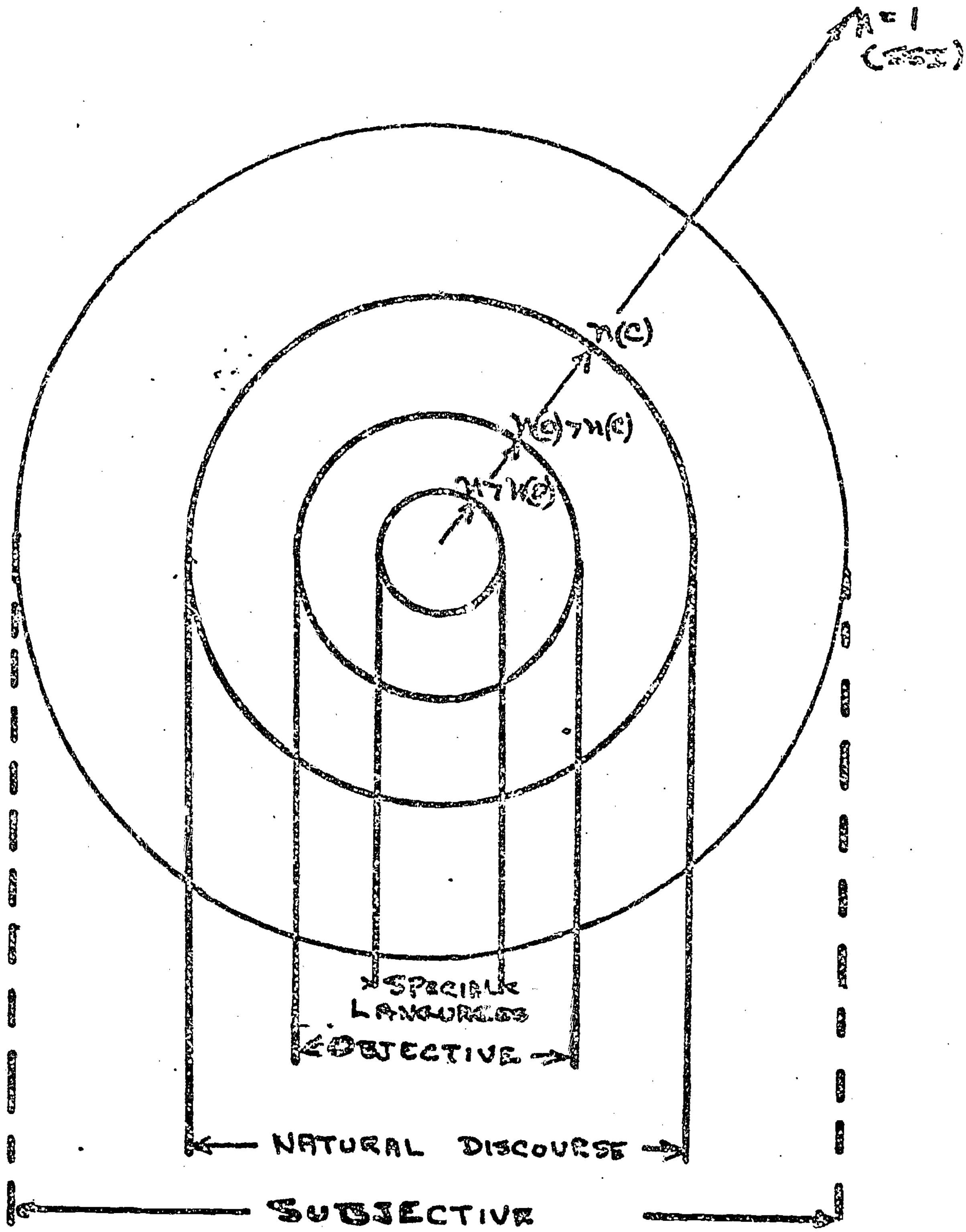

FIG. 1. SCHEMATIC ROLE OF ABSTRACTION IN REDUCING VARIETY (INTENSION) OF CONCEPTS AND INCREASING VARIETY OF OPTIONS (VERSATILITY).

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selected "surrogate" collection (N/CK). The model suggests some ways of organizing concepts for retrieval both from single collections and from networks of such collections.

9. In conclusion, the impact of cybernetics on information science is all-pervasive. The concept of variety combines the sensing of data (DSI's), the association of data (I-sets) and compression and selective filtering of associated data (A-sets). The concept of variety applies to all levels of abstraction, and thus has very wide applicability. The law of requisite variety is equivalent to abstract description of necessary and sufficient cognitive decision-making conditions for a regulator to maintain a system within a bounded "safe" region of "states" -- safe in that it survives and does not pass to a state from which it cannot return.

However, we should not forget that other sciences, e.g. physics, biology, and psychology are also all-pervasive in their application to information science. Perhaps "IS" can be defined by its unique admixture of other sciences. OA suggests it in the model of the domain of information science. In the light of this model IS is a partly independent science based on the propagation of meaningful messages. With enormous applications, it bids fair to become a discipline. Through these applications it already subserves all sciences. Reciprocal interactions of a more theoretical kind seem almost inevitable, and justify the prophetic rather than scientific words in the title, "and vice versa". Already the model of the IS path and of the set of IS paths used in the concept of the domain of information science are providing new insights. The concept of the domain is not well developed in OA, but it is hoped to show in a subsequent publication that an "operational definition" of considerable complexity is involved.

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1 Heilprin, L.B. "On Access to Knowledge in the Social Sciences and Humanities, from the Viewpoint of Cybernetics and Information Science." To be published (probably late 1972) by the Library Science Department, Queens College of the City University of New York, in proceedings of a Conference on Access to Knowledge and Information in the Social Sciences And Humanities: Problems and Implications, April 5-6, 1972, New York City.