A brief statement of schema theory[1]

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Schema theory has recently been extended, coupled with suitable stimulus generating procedures, and shown to have some predictive utility. A concise summary of extended schema theory is here presented, with provisional definitions of key terms and a statement of the basic suppositions. A distinction is made between the single schema condition and the mixed schema conditions; suppositions about schema learning are offered for both cases.

Schema theory is not a fully developed and rigorous system. An integrated statement of its concepts and suppositions is nevertheless needed to provide a context for related research. The following statement is presented for that purpose; the statement should be regarded as tentative.

The single schema case

Definitions. A *schema* is a characteristic of some population of objects. It is a set of rules which would serve as instructions for producing (in essential aspects) a population prototype and object typical of the population. *Schematic (or constraint) redundancy* (Evans, 1967a) is a measure of the extent to which individual members of the population adhere to the schema rules. A *schema family* is a population of objects, all of which can be efficiently described by the same schema rules. In the context of research with the rule-generated patterns (Evans & Mueller, 1966; Evans, 1967b), a schema family is a population of patterns generated under the same rules. In the context of the natural environment, a schema family is a population of objects which may be judged as conforming to the same schema rules. Members of a single species (in some cases, a variety, a genus, or other taxonomic classification) would often constitute a schema family; in this case, adherence to the schema rule is enforced by genetics. *Object* is here used in the most general sense possible, denoting anything which might be regarded as a single entity, including solid articles, forms, patterns, sequences of sounds or events, etc.

Suppositions. Schema theory proposes that humans abstract and use the redundant aspects of the environment to reduce information processing and storage requirements. Earlier work (Oldfield, 1954; Attneave, 1957) emphasized the reduction in memory storage requirements which could be gained by encoding stimuli having a common schema in the form of schema plus correction. The schema would be stored only once and each stimulus or instance would be stored by noting only those aspects which deviated from the schema. In the case of quantitative stimulus variables, additional efficiency might be obtained by encoding each correction as a deviation measured from the schematic or mean value; if the deviations were compactly distributed about the mean, smaller (and more frequent) deviations could be efficiently represented by shorter codes.

A schema must be learned, or given by heredity, before it can be used. Some supposition about the manner of schema learning is thus needed. I offer the following: In the natural environment, a schema family usually consists of more or less different instances with no single instance identifiable as a prototype. If a schema rule is to be found, it must be abstracted as a set of commonly occurring characteristics in a collection of otherwise different instances. Furthermore, the schema rule must be regarded as probabilistic; no single instance will necessarily follow the rule in all respects and no single aspect of the schema rule will necessarily apply to all instances. The schema does, however, include a large number of attributes; and schematic redundancy, if it could be calculated, would be quite high. Schema learning occurs spontaneously when Ss have an opportunity to inspect several instances of the same schema family and when other, as yet unknown, conditions are met. These conditions probably include the magnitude of schematic redundancy, the amount of attention given to the instances, and instructional set. The conditions do not include knowledge of results or externally provided reinforcement.

For the demonstration and study of schema learning, nonsense forms (Attneave & Arnoult, 1956; Evans & Mueller, 1966; Evans, 1967b) offer an excellent methodology because they can be constructed to have schemata which have been provided neither by heredity nor by experience. Such forms have been used (Attneave, 1957) to demonstrate schema learning and to confirm that it occurs without a prototype, without knowledge of results, and with no external reinforcement (Edmonds & Evans, 1966; Edmonds, Evans, & Mueller, 1966).

To the extent that a schema has been learned, higher levels of schematic redundancy should be associated with better performance in a reproduction task and in all other tasks which have memory of the whole stimulus as a prominent requirement. On the other hand, increases in schematic redundancy make the stimuli more similar to each other (Evans, 1967a) and lead to decrements in performance when a task depends strongly on discrimination. Even in such tasks, knowledge of the schema might reduce the detrimental effect of schematic redundancy indirectly by helping to identify attributes which deviate from the schema and are thus most likely to contribute to an accurate discrimination.

Extension to the mixed schema case

Schema theory, as described above, is clearly inadequate to deal with ordinary human perception. The environment does not, in general, provide a collection of stimuli belonging to the same schema family. Instead, instances of various schema families are normally mixed together. Thus a schema recognition process is needed; reference to the definition of a schema family indicates that this process is equivalent to concept recognition. The mixed schema condition also poses new problems for schema learning. If examples of several schemata are mixed together, an unguided abstraction process would seek in vain for a single schema rule appropriate to all objects. The rule for a particular schema family can be found only if objects belonging to that family can be identified and distinguished from objects belonging to other schema families. The following definitions extend schema theory to the mixed schema case.

Definitions. A *statistical concept* is an equivalence class with an associated set of statistical rules for determining whether an object is or is not a member of the class. No single attribute need be a perfectly reliable contributor to the assignment process. Instead, assignment is based on a large number of attributes which have some statistical association with the class. Individually, these attributes may be unreliable, but collectively they may be sufficient for assignment with a very small probability of error. By way of conceptualization, suppose each object is regarded as reduced to a list or vector of quantitative attributes. Let the attribute vectors be used to map the objects into points in a multidimensional attribute space; then a statistical concept corresponds to a cluster or cloud of points. If several statistical concepts are mapped into the same attribute space, there will be a corresponding cluster for each. In turn, if most of the objects to be classified fall into one of these clusters, classification is a straightforward matter of determining the nearest cluster. Pattern recognizers, such as those which recognize hand-printed letters, do so by means of statistical concepts (Marril & Green, 1960). An *overdetermined* statistical concept is one which has more attributes associated with it than are needed for near-perfect classification.

Schema recognition is the assignment of objects to categories corresponding to the schema families to which the objects belong. A schema family may be regarded as an overdetermined statistical concept; in the appropriate attribute space, the prototype would be located at the center of a cloud of points corresponding to variants.

Schematic concept formation (SCF) is the development of the ability to assign objects to their corresponding schema families on the basis of the information derived from perceiving the objects, without any other source of information as the appropriate categorization, and without prior familiarization with the relevant schema. This process is to be contrasted with the traditional process of concept learning and with other procedures in which a more knowledgeable teacher conveys his previously determined categorization to S. These latter cases may be termed *didactic concepts;* such concepts need not be associated with a schema, and they may be entirely arbitrary. Schematic concepts, on the other hand, are defined by the objects in the environment, and they are by no means arbitrary.

At first glance, SCF may seem rather like producing something out of nothing. If objects could be assigned to the appropriate schema family, the schema could be abstracted from them. If the schema were known, objects could be assigned to the appropriate schema family through the schema recognition process. But SCF requires that both the assignment capability and the abstraction develop at the same time. SCF, however, is merely a process of finding clusters of points in a multidimensional attribute space. Such cluster finding is certainly possible; if clusters exist in a two dimensional space, they can be found with a scatter plot. The problem is greater in multidimensional space, but there are a number of proposed solutions, of which one, numerical taxonomy (Sokal & Sneath, 1963), is conceptually very similar to SCF. SCF has been demonstrated in human categorizing performance under the term "perceptual category formation" (Evans, 1964) and "schema discrimination" (Edmonds, Mueller, & Evans, 1966). The former study also presented a computer simulation of the process. A more extensive discussion of SCF will be presented in a subsequent paper.

From the above definitions, and their implicit suppositions, it is clear that extended schema theory bears not merely on how people remember patterns, but also on concept formation and concept utilization. This circumstance arises inevitably from considerations of the mixed schema case. The particular suppositions offered above, however, are certainly open to challenge; whether these or other suppositions are appropriate is a matter for future empirical determination.

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Note

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