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The Feasibility of a Computer-Based Library Reference Interview

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THE FEASIBILITY OF A COMPUTER-BASED
LIBRARY REFERENCE INTERVIEW

by

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Although early man was not the hardiest of organisms or the strongest of body among living creatures, mental advantages gave him the upper hand in an evolutionary development that was exceedingly rapid. In our own day, among all the creatures on earth, it is given to man alone to contemplate the panorama of nature with some appreciation for the magnificance of its detail and historical scope. From this pinnacle only man may question the steps and relationships that led from the beginning to his own time.

Parsegian (1973, p. 229)

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ABSTRACT

The Feasibility of a Computer-Based

Library Reference Interview

by

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Utah State University, 1977

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The feasibility of a computer-based library reference interview is forecasted through an analysis of the literature concerned with primary aspects of the library reference interview, concept formation, computer concept formation, computerization of reference service and the future of reference service. The state of the art is discussed in light of specific computer programs currently available for the automation of library reference service. Factors supporting and limiting the automation of library reference service are presented. Conclusions and recommendations are made for the realization of a computer-based library reference interview.

(130 pages)

CHAPTER I

INTRODUCTION

Origin and nature of the problem

The equipment required to automate reference work was available to libraries long before anyone tried to implement it. Schultz (1964) indicates that experimentation with library automation began in the 1940's, pointing out to some extent that a need for automated reference service was not apparent prior to World War II. The exponential growth of information occurring after World War II caused the reference librarian to become progressively more aware of the inadequacy of traditional tools for retrieving information (i.e., indexes, catalogs, bibliographies, and abstracts) and the increasing time factor involved in a literature search. Stevens (1965) suggests that a recognition of inadequacies within manual information retrieval systems has prompted consideration of the feasibility of using computers to assist in the information retrieval process.

Thus far the role of the computer has chiefly been that of an indexing instrument; whether or not it can fully assume the task of information retrieval in a traditional reference situation is still in doubt. A computer-based library reference system, like the manual system, involves a search strategy. A reference librarian knows how to separate the relevant from the irrelevant in the reference interview through a complex communication process involving "thinking." Schultz (1964) elaborates on this point by implying that in the human procedure, then, there are many uncertainties and many decisions to make in

answering even a simple reference question and that these all become important when the procedure is computerized.

Quite simply, the problem is whether or not a computer can conduct an adequate reference interview. The questions which arise in discussing this problem are:

1. Does a computer have the capacity to be programmed to simulate the dynamic cognitive processes involved in human concept formation and communication.

   a. Does a computer have the capability to find out what an inquirer wants to know when the inquirer cannot describe his need precisely?

   b. Does a computer have the capability to determine the objective or the motivation of the inquirer to qualify the subject of the inquiry?

   c. Does a computer have the capability to delimit the subject of the inquiry?

   d. Does a computer have the capability to determine the personal background of the inquirer to discover what questions should and may be asked during the reference interview process?

   e. Does a computer have the capability to determine the inquirer's acceptability of an answer?

   f. Will an information specialist be required as a communication interface between the inquirer and the computer?

2. To what extent will the biases and personality of the computer programmer affect the adequacy of a computer-based library reference interview?

3. To what extent will the capacity of a computer to store bibliographical information have influence on the capability of a computer to conduct an adequate reference interview, storage and retrieval requiring two or more separate but interdependent programs?

4. Does a computer have the capability to reprogram itself in a self-adaptive way to interpret and restructure the inquiry so it fits the files as they are organized in a particular library, to include not only catalogs, indexes, abstracts and other standard files but also a "who knows what" file?

5. Does a computer have the capability to educate the inquirer in the use of reference materials?

6. To what extent is it feasible to enter the contents of indexes, catalogs, bibliographies, abstracts and other traditional reference tools into a computer-based library reference service?

7. What are the cost factors involved in the implementation of a computer-based library reference interview system?

The future of information retrieval includes the elimination of manual library reference systems presently in use and the adoption of some form of automated reference system. Hallworth (1969) says the simulation of human cognitive processes by means of computer programs has a very brief history, but it seems certain that in the future there will be a close association between theories of human behavior and attempts to increase the intellectual capacity of machines. The significance of this study rests in its attempt to research the intellectual capacity of computers to determine their potential to make

information more efficiently attainable to the inquirer than the outmoded, traditional manual system presently in use.

CHAPTER II

LIBRARY REFERENCE SERVICE

Some historical notes

Shera (1972) introduces the idea that the founding fathers of the public library movement in the United States saw the library as an institution for enlightening the citizenry, and thereby giving them a greater capability of making wise decisions in the voting booth. No doubt the founding fathers of the public library movement in the United States saw the library as also a place to promote scholarship, invention and the Christian ethic.

The years from 1840 to 1860 were significant years for libraries in the United States. Society was experiencing an awakening of intellectual activity in the arts, literature, scholarship, and the sciences. Linderman (1967) feels this awakening stimulated reading, causing librarians to turn their attention to the invention of reference aids. Over the hundreds of years that separated the ancient library at Alexandria from the libraries of the 1840's librarians had been merely custodians, collectors, and catalogers. The function of use had now been added to their collections. Crowley (1971, p. 6) summarizes this viewpoint when he states:

> More than a custodian, the librarian of the late 1800's began to formulate a concept of the profession which emphasized the utility of the library collection, and the ability and duty of the librarian to facilitate that use.

Librarians have always assisted patrons in the location of information. Linderman (1967) points out that perhaps the first

important new type of reference tool was Charles Coffin Jewett's use of specific subject entries in the construction of a subject index to the catalog of the Brown University Library. Jewett's subject index was published in 1843.

Linderman (1967) cites 1884 as the year when the profession of reference librarian was born. During that year Dewey appointed two full-time reference assistants to the Columbia University Library Reference Room. Linderman (1967) names George Baker and William G. Baker as "the heroic pioneers of reference librianship." Crowley (1971, p. 7) summarizes Linderman's historical narrative of library reference service:

> Librarians began, during the 1880's, to provide an additional service which consisted of answering questions, locating facts, and directing patrons to books that could be consulted in answering inquiries. This service, which acquired the name of "reference work," was distinct from personal assistance to readers in that the former was concerned with the supplying of information and sources of information, and the latter with helping patrons locate and select books.

Schiller (1965) gives us a typical reaction to the concept of "reference service" in the 1880's. She tells us that the Examining Committee of the Boston Public Library upon suggesting in 1887 there should be in Bates Hall a "person whose sole duty it would be to answer questions of all sorts, and to direct inquirers in their search for information, received the stiff reply from the Trustees that it was hardly practicable in that it would require the transfer of personnel from other work." The information Schiller has provided allows us to conclude that reference service represents a relatively new dimension in librarianship. Its establishment is in fact the product of a more or

less deliberate decision. As a result of this decision to establish reference service as a regular part of the American library system, the library profession began to deal in knowledge beyond dealing with just volumes.

A characteristic of the American library system since the end of the nineteenth century has been personal reference service to the patron. Personal reference service to the patron has conventionally comprised two factors: information and instruction. The ALA Glossary in 1943 defined reference work as "that phase of library work which is directly concerned with assistance to readers in securing information and in using the resources of the library in study and research." Schiller (1965) points out that in 1961, the ALA Standards Committee developed a statement on the content of reference services offered to library patrons. Direct reference service, which "consists of personnal assistance provided to library patrons in pursuit of information" was categorized as instruction and information service. The central feature of instruction "is to provide guidance and direction in the pursuit of information, rather than providing the information itself." The central feature of information service "is to provide an end product in terms of information sought by the library's patron." Schiller (1965, p. 12) concludes that the definition of reference is in sum, "instruction in the use of books and libraries; guidance in the choice of books, and information service."

Reference service

Katz (1969, p. 35) views reference service as consisting of two distinct types of services which he calls "direct" and "indirect."

Direct reference service is a person-to-person relationship usually one in which the librarian answers a patron's question. The second consists of technical processing activities and will not be emphasized in this discussion. Katz (1969, p. 35) cites the American Library Association, Reference Services Division, "Reference Standards," as giving the clearest definition of direct reference service.

> Direct reference service consists of personal assistance provided to library patrons in pursuit of information. Direct reference service may take one of many forms, each of which may consist of a number of activities, of which only the most frequent and representative are cited below:
>
> a. Instruction in the use of the library and in the use of items in the library's collection. This service may range from demonstration of how to fill out a call slip to explanation of the use of catalogs, bibliographies, and reference works, to assistance in interpreting the contents of materials in the library's collections. The central feature of this instruction, irrespective of its level or its intensity, is to provide guidance and direction in the pursuit of information, rather than the information itself.
>
> b. Information service. This service may range from answering an apparently simple question through recourse to an obvious reference source to supplying information based on search in the collections of the library, combining competence in bibliothecal techniques with competence in the subject of inquiry. The character and extent of library information service will vary with the kind of library, with the patron the library is designed to serve, and with the skill, competence, and professional training of the reference librarian providing the information service. Characteristic functions of information service are finding specific data or facts, interpreting the material or information found, translating, abstracting, literature searching, and others. The central feature of information service, irrespective of its level or its intensity, is to provide an end product in terms of information sought by the library's patron.

The reference question

Katz (1969) points out that the reference question is the essence of reference service. He justifies this viewpoint by implying that

the success of reference work can be measured by the proper answer. Katz (1969, pp. 37-41) recognizes that questions may take as many forms as answers but can be divided as follows:

Directional

> This presupposes that the patron knows or thinks he knows precisely what he wants. He only requires directions to find the answer.
> The term "directional question" is often employed to refer to bibliographical queries, that is, those which do not answer the question directly but "direct" the reader to a source. For example, the question, "What do you have on Albert Einstein?" is a directional type in that the librarian may first look up references in a source such as a bibliography, a card catalog, or an index. The index or catalog then "directs" the user to the needed information.

Ready reference

> This presupposes that the patron wants to know an answer that will be short and readily available in one or two sources. Questions are termed ready reference that are readily answered without undue research or, often, without much reflection.
> ... The ready reference, or quick-fact question represents by far the most common type of question asked in libraries, particularly in public libraries. Estimates vary, but surveys indicate that this type of question makes up from 85 to 95 percent of all those asked. They are usually answered in one to eight minutes, and 75 percent of them can be normally answered from current reference materials.

Specific search

> This presupposes that the patron needs more than one or two simple facts to answer a question. He may be seeking a limited amount of information on a subject, probably for a paper, a talk, or a program; how-to-do-it material for putting up a fence or for filling out his income tax return: or so-called "supporting" evidence for a position he has taken about some issue.
> Unlike the ready-reference query, it may involve a considerable amount of judgement and a recognition of relationships between things, persons, or events. For example, consider this supporting-evidence type of question: "Was the failure of Napoleon's Russian campaign due to his bad luck or his shortcomings as a general?" The reference librarian might go to a standard life of Napoleon, a history of Russia, or possibly a discussion of various battles. Even then, the answer would simply be a cumulation of probabilities.

Research

This presupposes that the patron has the type of query that cannot be readily answered in one or two sources, but will require many specialized sources. The extent of the search may expand the "several" to all forms of materials from periodical articles to phonograph records, from books to manuscript material. It may also call into play not only the resources of the library, but the resources of other libraries, both national and international in scope of holdings.

The obvious problem is that while every request for information is, in some sense, either of a directional, ready-reference, search, or research type, it may develop into a combination of all four. The eternal variable is the patron who really is not sure what he wants or needs. The eternal difficulty is that the library that attempts to organize itself about the four major types of questions must face certain patron variables.

Most requests may fit into a general class, but, in a very real sense, every request is unique. Even if the librarian knew what type of questions he had been asked over the past thirty years, he still would have no assurance that the next one would not be an exception.

Answering the reference question

Answering a library reference question is rarely a neatly sequential process following an exact outline. Katz (1969, pp. 56-58) lists for us the following steps which could be used to solve a reference question, though he states: "The librarian may short-circuit them all because he has particular knowledge, or even a sixth sense about a given question, which leads him to a direct answer."

1. Specific reference sources

Here the question is asked, and sometimes, almost at the subconscious level, the librarian knows precisely which reference source will give the best answer. The important conditions for proper use of specific reference sources are:

a. A thorough knowledge of the reference collection, and the ability to remember the purpose of specific tools. Usually the mnemonic device is simply seeing it on the shelf, or recalling that it proved useful in a similar situation the day or week or month before.

b. Once the specific work is selected for consultation, the librarian must have the ability to find the answer quickly and efficiently. This presupposes knowledge of the reference

work, but more important the ability to scan a table of contents, an index, or, in the case of a complicated work, the introduction that explains its uses and limitations.

2. The general collection

In using total library sources, the librarian immediately considers the subject approach. Usually this is in terms of which source to use and the various avenues offered to that subject within the specific work.

a. Success here depends upon a thorough knowledge of library system classifications from cross references in catalogs and indexes to how the material is stored or shelved. The librarian may realize that the query, for example, has to do with the history of printing in Montana but be unable to make the association between the subject and the likely subject heading in the catalog, or where the material might be on the shelf--under Montana history, technology, graphic arts, etc.

b. The reference librarian must be able to move comfortably from the general subject to the specific subject. This presupposes a thorough knowledge of close subject classification.

c. The librarian must have the imagination to move about in related subject areas. For example, if he is unable to find anything about the history of printing in Montana under the subject Printing, he should then move without question to the broader area of Montana history or general works on printing history of the United States. He must also know, if the material is not available in his library, what bibliographies and union lists to consult in order to obtain it from another library, or, at best, be able to advise the user what bibliographic sources to consider in larger libraries.

d. A thorough knowledge of the general collection is presupposed here, primarily because the query may be answered not in the usual sources, but from a standard bibliography, history, or manual in the circulating collection.

3. Classification by type of material

Here the most obvious type of classification is usually in terms of a simple question: "Is the answer most likely to be found in a book, a pamphlet, a periodical or a government document?"

a. The decision here is usually based on the kind of information sought in terms of depth and timelessness and the sophistication of the user.

b. Another decision is based on knowledge of the collection, or how easy it is to obtain materials from another library. For example, a library may have a good pamphlet collection, but the librarian who has not often used the collection may fail to consider it when a particular question is asked. Also, the librarian who realizes that technical materials on

> a given subject are well covered in a library a mile or so away has the advantage of being able to simply go to the phone for an answer, or to refer the user to the other library.

We can conclude from the foregoing that the librarian involved in reference service must exercise a considerable degree of judgement, evaluation, and imaginative skill. She must be able to associate concepts and like ideas from an approach that could take any conceivable direction. It is a challenge that requires intellectual activity at numerous levels of thought.

Katz (1969) feels that librarians fail to answer reference questions for a number of reasons. One reason is a lack of communication. If the librarian or the patron fail to express themselves in understandable terms, it is impossible to determine the exact information the patron is seeking. If a librarian fails to give sufficient time to a query, a reference question can again remain unanswered. Often a librarian will not go beyond the immediate reference collection because she is too busy or simply because she is lazy. Katz (1969) points out that many failures to arrive at an adequate answer to a reference question are due to the reluctance or the inability of the patron to evaluate the service he receives. The librarian, consequently, has no check or feedback to encourage her to improve the quality of service. Katz (1969, p. 44) cites Gertrude Stein and William James as having summed up the two principal aspects of the reference interview:

> Gertrude Stein's final words were: "What is the answer?" She hesitated a moment, and then wisely countered with "What was the question?" In a word, the problem of communication between the reference librarian and the patron is not so much one of answers as of questions.

Katz (1969) divides the reference interview into two parts. The first part is concerned with communication between the patron and the librarian. The second part is the search strategy, or where a likely answer is to be found. This phase of the reference interview deals with individuals rather than information sources. Katz (1969) points out that there is one aspect of the personal interview which is not easily categorized. He refers to this aspect of the personal interview as an "imaginative guess that no more than 35 percent of the meaning in a face-to-face communication is carried by the verbal message." Katz goes on to explain that the physical gestures a patron makes could tell the perceptive reference librarian more about the needs of a patron than any spoken word. The utilization of such data has infinite value for the reference interview.

Kilgour (1972), a proponent of library automation, has formed the opinion that patrons obtain from libraries only about half the items they want. He also feels that finding information in research libraries has become so difficult that even library staff members are seriously handicapped in their attempt to locate entries in working files arranged in a traditional catalog order. Moreover, creative thinking is facilitated by rapid transfer of information from library sources to the internal memory, the mind often being distracted by delays in this transfer. The primary objective of librarians, therefore, is the development of reference search techniques for extremely rapid and accurate transfer of information from library sources to the patron when and where he needs that information. Linderman (1967, p. 131) suggests that "we desperately need more librarians who are willing to

learn programming (or better still devise their own library/reference/cataloging-oriented compiler language) and librarians who will assist publishers in creating the tools they need in a way which will permit more effective and efficient reference service." Linderman (1967, p. 64) concludes:

> A great need for research is apparent, and unless this is undertaken, little more knowledge concerning the reference process will exist in ten year's time than is available at present. It is depressing to consider that insight into the factors involved in providing reference service has remained relatively static for more than thirty years. It is becoming increasingly apparent that the behavioral sciences have much to offer to librarianship by way of insight and research methodology, and since many of the problems underlying reference work are psychological, some fruitful research might be undertaken.

Summary

Linderman (1967) tells us that the profession of reference librarian was born in the year 1884. Nearly a century passed, however, until a definition of reference service appeared in the ALA Glossary. In 1943 the ALA Glossary defined reference service as "that phase of library work which is directly concerned with assistance to readers in securing information and in using the resources of the library to study and research."

Katz (1969) feels that we can picture reference work as consisting of two distinct types of services which can be called "direct" service and "indirect" service. This study will be concerned with direct reference service rather than indirect reference service. Direct reference service is a person-to-person relationship with a patron in which the librarian answers a patron's question.

Answering a library reference question is rarely a neatly sequential process. The librarian involved in reference service must exercise a considerable degree of judgement, evaluation, and imaginative skill.

The reference interview arises from direct reference service. Katz (1969) divides the reference interview into two parts: (1) communication between the patron and the librarian, and (2) the search strategy.

Kilgour (1972) feels that finding information in research libraries has become so difficult even library staff members are seriously handicapped by working files arranged in a traditional catalog order. We can conclude that a primary objective of librarians should be the development of reference search techniques for extremely rapid and accurate transfer of information from library sources to the patron when and where he needs that information.

CHAPTER III

CONCEPT FORMATION

Definition of concept

A concept can be perceived as a category of things. In most instances these so-called things have a real existence in the environment of an organism. We refer to these things as stimuli or stimulus objects. Bourne (1966, p. 1) gives us a working definition of the term "concept":

> ... we may say that a concept exists whenever two or more distinguishable objects or events have been grouped or classified together and set apart from other objects on the basis of some common feature or property characteristic of each.

Concepts exist to simplify to some degree the environment of an organism. If an organism were to use its full capacity to distinguish between stimulus objects, it would soon be overwhelmed by the complexity and unpredictability of its environment. Categorizing or concept formation is a necessary way of approaching the tremendous diversity an organism encounters in everyday life.

Bourne (1966) points out that concepts are not generated spontaneously in an organism. Some learning process has to take place before the concept exists. Bourne (1966) concludes that concepts are in this sense acquired with effort and attention to specific stimulus objects.

Some stimuli illustrate a concept and others do not. Bourne (1966) refers to those stimuli which illustrate a concept as <u>postive instances</u> of the concept and those which do not as <u>negative instances</u>. Hunt (1962, p. 34) points out that "we can consider concept learning

as an example of decoding, in which positive and negative instances transmit information which can be used to reduce the number of hypotheses remaining in the memory bank."

Bourne (1966) agrees that a conceptual problem exists when there is a goal or a solution to be learned or discovered. He feels that the attainment of a solution to a conceptual problem is in most cases a process guided by clues the problem solver receives from its environment. He concludes that if these clues are correctly interpreted, they can keep the problem solver on a path toward the correct solution. Bourne (1966) refers to these clues as "information feedback."

All conceptual problems require an organism to discover and learn some type of scheme for grouping stimuli. Bourne (1966) perceives this grouping process as an inductive task based on the observation of a set of positive and negative stimulus presentations. He continues to explain that "perceptual learning" and "labeling" are two learning processes resulting from stimulus grouping. These two learning processes are important to the discriminations an organism makes among stimulus attributes.

We may conclude that perceptual learning involves learning to detect features of an object or class of objects which distinguish it from others. Labeling is a term employed to describe the process of associating particular names or responses with discriminable attributes or complex groupings. Bourne (1966, p. 14) states that "the fact we custimarily refer to objects of a certain color as "red" implies a prior association between the label "red" and those objects and/or similar ones. There is a fair amount of empirical evidence that these

distinctive labels add to the discriminability of stimulus objects and their attributes." He concludes that concept identification occurs when an individual discovers and identifies the relevant attributes among the many that may vary from stimulus to stimulus.

Learning and utilization

It would follow, then, that learning is involved both in enhancing the level of discriminability among stimuli and in the process of labeling attributes. Learning through a discrimination process occurs when a conceptual problem requires finer differentiation among attributes or the acquisition of new labels. Bourne (1966) points out, however, that some conceptual problems are better described as requiring the utilization of previously learned discriminations and labels rather than the learning of new ones.

Conceptual rules are rules for grouping. They specify how the relevant attributes are combined for use in classifying stimuli. Bourne (1966, p. 15) tells us "it is not clear that every concept embodies a rule. But even in the case of primitive concepts, wherein a single attribute provides the basis, there is a rule--either the attribute is present (positive instance) or absent (negative instance)--to implement the sorting of stimuli."

Rules for grouping attributes or stimuli once learned can provide an organism with powerful conceptual tools. Bourne (1966, p. 18) proceeds to explain that "a repertoire of rules permits rapid acquisition of unfamiliar stimulus classifications based on it, increases the range of concepts that can be formed with any particular stimulus population, and enhances the flexibility of the subject's conceptual

behavior, in general." The difference between learning and utilization is then quite arbitrary. Bourne (1966) views the term "learning" as applicable for those tasks wherein the emphasis lies in the acquisition of some complex behavior strategy which implements a formerly unfamiliar rule for grouping. When it is clear that learning has taken place and when the task demands some use of that prior learning, we use the term "utilization."

The categories of concept formation explained in the foregoing discussion should be recognized as not mutually exclusive of each other. Conceptual behavior to some extent involves perception wherein environmental stimulation is received, transformed, and in most cases, organized before we respond to it overtly. It is quite clear that basic learning processes are also put to use wherein discriminations are acquired, verbal and other labels are acquired, and learning sets are acquired. Bourne (1966, p. 21) takes this discussion to a higher dimension by pointing out that "conceptual behavior impinges on _thinking_ and _problem solving_, for certainly adequate performance in conceptual tasks depends on internally organized symbolic activities and complex behavioral outputs."

Mediational stimulus - response theory

Learning and complex behavior which go on inside an organism can be explained by the mediational stimulus - response theory. Bourne (1966) explains that the mediational S - R theory attempts to describe internal symbolic activities which intervene between external stimulus and overt response. He is convinced that the mediational process plays an important role in governing overt responses.

Concepts are learned through an associational process which links two or more stimuli with a common response. The common response in the mediational S - R theory is viewed as having an internal as well as an external representation. The mediational S - R theory does not assume there exists a direct linkage between physical stimuli and an overt act of behavior, but rather assumes there develops a complex or at least two-stage chain of connections involving internal and external stimulus and response events. Bourne (1966) views an external stimulation as initiating in an organism an event called a "pure stimulus act." He sees this as an internal response, functioning solely to produce additional stimulation which serves as a cue for further overt responding. Figure 1 (Bourne, 1966, p. 31) represents a simple behavioral process. Here r is an internal "pure stimulus act" brought forward by an external stimulus, S. The internal pure stimulus act, r, in turn generates an internal stimulus, s. We can see that the internal stimulus, s, then produces overt behavior, R. The cue-producing function of r may itself be learned. Bourne (1966) believes this theory allows for the entry of prior learning into any new associational process.

Bourne (1966, p. 31) describes concept learning as an "acquired equivalence for a set of perceptibly different stimulus patterns. Within this theory the process is pictured as the acquisition of a common mediating response to the various patterns. This process is described in Figure 2.

We can see from this diagram that conceptual behavior is a special mediated chain involving multiple converging linkages between external stimuli and an internal response.

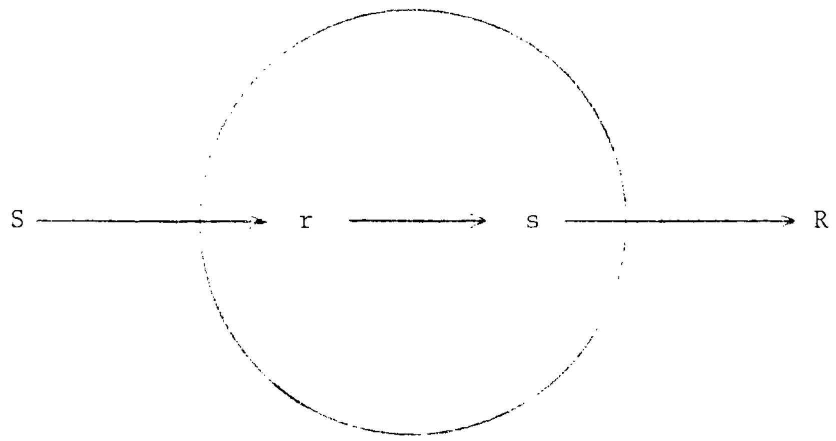

Figure 1. Simple behavioral process.

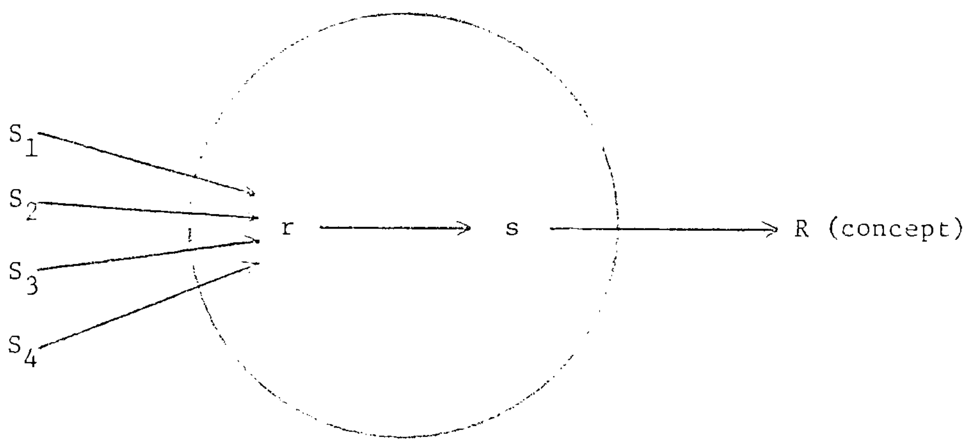

Figure 2. Different stimulus patterns.

Underwood (1952, p. 211) believes "thinking is a process in which the subject is motivated to solve a problem - reach a goal - and the solution depends upon his learning or recognizing certain relationships among symbols, objects, or among relationships themselves."

Mediators do play an important role in behavior. Bourne (1966, p. 32) is convinced "it is clear that the internal mechanisms of an organism are not 'silent'". He continues:

> There are internal response mechanisms (muscles, glands, nerves) which are continuously active. Further, there are internal sensing mechanisms (specialized receptor cells, nerves) which are continuously alert to the internal environment just as the exceptors (external receptors) are alert to the external environment. These activities are integrated complexly with the outward, ongoing behavior of an organism, which is probably reason enough to represent them in any theoretical account.

More specifically, mediators play an important role in a learner's orientation toward key aspects of the stimuli. Bourne (1966, p. 35) states that "prior associations of a given object carry its meaning and are represented internally as mediators." Here again he stresses the importance of verbal behavior in coding associates of a stimulus:

> ... Forming concepts often can be seen as a process wherein the common meaning of various stimuli (mediators) is linked with some (possibly new) overt naming or category response. As a concrete example, suppose a subject is given the task of learning to categorize a series of familiar objects (represented pictorially) such as a melon, a head of lettuce, a pork chop and so on, as positive instances and others, such as a house, an automobile, and a tree, as negative. This is quite obviously a case where mediated meaning, based on earlier learning, would play an important function. "Food" is a strong association (meaning) of all the positive items; the problem is solved once the new response - for example, "positive instance," "Category A," or some other label - is conditioned to this mediator.

Bourne (1966) has found that mediators act as building blocks from which abstract and/or hierarchically arranged concepts can be formed. The most basic concepts are those wherein simple stimulus attributes correspond to physical dimensions. Bourne (1966) believes that mediational representations of stimulus attribute groupings can be combined complexly so as to produce concepts with no physical referents. He views these groupings as concepts defined solely in the abstract with words. The mediator is in essence the means by which prior learning, or memory for previous events, enters into present behavior.

Associational theories and information processing models

Two other explanations exist regarding the internal learning behavior of an organism. Bourne (1966, p. 36) briefly outlines these explanations for us:

> Associational theories picture learning as a passive, somewhat automatic stamping-in of connections between stimulus events and responses. In contrast the type of theory we call hypothesis testing views the organism as an "active" learner. He is assumed to possess some selectivity. He operates in important ways on his environment. First, he may not respond to all available stimulus features, but rather select and attend to only certain aspects which, on the basis of a hypothesis, are considered relevant. Second, the subject decides upon and executes a response, in conformation with the hypothesis, which serves as a test of its adequacy. Typically, such a theory views any possible associational process, say, between critical stimulus features and the correct hypothesis (or the responses which implement that hypothesis) as trivial. While such associations may develop, they are merely a by-product of selection and test routines. Furthermore, because of the nature of these routines, associations are presumed to develop quickly, perhaps on a single trial, if the hypothesis can be proved all at once. The important learning does not involve S - R associations but rather the acquisition of knowledge, recognition, and "understanding" of a principle required by the task.

Bourne (1966, p. 42) continues:

> Associational theories visualize concept learning as a process wherein new linkages are gradually developed, either between distinguishable features of an external stimulus and an overt response or, somewhat more complexly, among a chain of stimulus and response events, some of which are internal to the organism. Hypothesis-testing theories assert that the linkages, if there are any, either already exist or are formed instantaneously and that the basic problem for the subject is discovering which linkages (hypothesis) works. The theories seem to be different and yet they are not entirely incompatible. It may be that an element of truth exists in both and that each "works" in certain problematic situations.

Bourne (1966) introduces information-processing models of conceptual behavior as those models which attribute to the concept learner certain primitive or basic procedures called information-processing units.

He concludes that these information-processing units receive, organize, and interpret stimulus and feedback inputs from the environment in such a way as to define a conceptual grouping. The objective of such information-processing models is to include within the framework of any particular model a minimal repertoire of procedures sufficient for the model to mimic the behavior of real subjects. Bourne (1966, p. 40) gives us a detailed description of an information-processing model:

> The model builds a description of the correct concept in the form of a tree of decisions. Each nodal point or decision point in the tree considers one relevant dimension of each successive instance, leading on to one branch if a certain attribute is present in the instance and to the other branch if it is missing. The complexity of the final tree, that is, the number of decision points it contains, depends both on the number of relevant dimensions and number of exceptions to the common attributes' description of a concept.
>
> ... We shall consider only a few additional points. First of all, the model can be realized as a computer program so that predictions and complex simulations of real data can be produced both efficiently and rigorously. Second, this theory is one of the few which makes any real attempt to account for the learning and utilization of concepts based on rules other than conjunction. This must be viewed as an important step, for real life concepts of disjunctive, relational, and other varieties are too common to be ignored.

Conjunctive, disjunctive and relational rules

Conjunctive, disjunctive and relational rules employed in the learning and utilization of concepts are explained by Hunt et al. (1966, p. 220).

> ... one can logically distinguish a number of different kinds of concepts, derived from the types of classifications of instances described by the logical operations "and" and "or." In the *conjunctive* type all of the instances have features in common, so the concept is one where each instance possesses characteristics A *and* B, *and* B *and* C, etc. In the case of *disjunctive* concepts, all instances have one or another feature (cf. Bruner, Goodnow, and Austin's (1956) example of the concept "strike" in baseball, where a strike is defined as either a pitched ball which crosses the plate between the batter's knees and his shoulders *or* is

alternatively any pitch struck at by the batter which fails to be sent into the field). The authors just mentioned found this type of concept exceedingly difficult to learn. The third type of concept, discussed most extensively by Smoke (1935), is relational, in which the common properties are sets of relationships rather than common specific stimulus elements. For example, the concept of isosceles triangle involves the common relationship of equality between two of the sides, and the positive instances may have widely differing size and shape.

Hunt et al. (1966, p. 224) have discovered that under their experimental conditions "both conjunctive and relational concepts are selected significantly more frequently than disjunctive ones." Accordingly, they plan to program their initial computer simulations so that "conjunctive possibilities are considered alternately with relational ones." They feel that "only when both have been explored without success will the program of the computer consider possible solutions involving disjunctive concepts." Wells (1963, p. 63) gives us one explanation for the difficulty of attaining disjunctive concepts. Of disjunctive concepts he says:

> ... each of the positive values of such a concept is found in some, but not all, of the positive instances. In the case of a conjunctive concept, on the other hand, both positive values appear in all of the positive instances. Thus the proportion of positive instances which contain each positive value is different for the two types of concepts.

Bourne (1966) believes that two sources of information are available to an organism who is learning a concept. These two sources of information are the stimulus and the informative feedback. He further believes that organisms must perceive correctly the information available in a stimulus or a feedback signal before they can learn or make valid inferences from it. It follows that the major factor controlling the perceptual activities of an organism is its attention to the stimulus field. Bourne (1966) concludes that behavioral events involved in

the learning of any conceptual problem can be viewed as a chain which begins with an orienting response initiated by some "ready" signal. That is to say, the stimulus, as perceived, initiates a mediational or symbolic response which serves as a cue to the overt act of categorizing. The mediational response, as explained earlier, is essentially an abstraction of certain stimulus attributes. Eventually, when the relevant attributes have been abstracted, mediational activities provide the internal stimulation to which correct category responses are associated.

It was explained earlier that any concept can be described in terms of a set of relevant attributes and a rule which combines or prescribes the function of or relationship among these attributes. Bourne (1966) feels that rule learning may be viewed as a process by which an organism acquires information on the assignment of all combinations of relevant stimulus attributes to response categories. To say, then, that an organism has learned a rule is to say that it understands how it uniquely assigns stimulus elements to response categories. Bourne (1966) points out that efficient concept formation presumes that an organism was able to achieve an encoding of known stimulus attributes into an effective truth table (Haygood and Bourne, 1965). They conclude that the distribution of these stimulus attributes into categories within the truth table then identifies the relevant rule.

Transfer of learning occurs when prior experience from one situation influences performance in another situation. Bourne (1966) tells us that original learning transfers from one situation to another with

a positive (facilitory), negative (inhibitory), or negligible effect depending on the characteristics of the circumstances creating the original learning. He believes that one way to evaluate the effectiveness of a learning experience is to determine the extent to which it transfers positively to other situations.

Sets or cognitive maps

Bourne (1966) tells us that an organism has preestablished tendencies and expectations called sets while attempting to solve new concept formation problems. He concludes that these sets occur as a result of past experiences in similar or related situations. It follows that because experiences differ among organisms, so do their sets. Bourne (1966) points out that sometimes a set is appropriate for solving a new concept formation problem, and sometimes it is inappropriate.

An organism acquires response patterns while attaining concepts. Response patterns occur as a result of regularities in information gathering decisions of an organism. Byers (1963) calls these regularities "strategies."

Tolman (1948, p. 193) believes that "learning consists not in stimulus-response connections but in the building up in the nervous system of sets which function like cognitive maps, and second, that such cognitive maps may be usefully characterized as varying from a narrow strip variety to a broader comprehensive variety." Harlow (1949. p. 51) emphasizes that:

> ... Our emotional, personal, and intellectual characteristics are not the mere algebraic summation of a near infinity of stimulus-response bonds. The learning of primary importance to the primates

> at least, is the formation of learning sets; it is learning how to learn efficiently in the situations the animal frequently encounters. This learning to learn transforms the organism from a creature that adapts to a changing environment by trial and error to one that adapts by seeming hypothesis and insight.

Harlow (1949) concludes that this learning to learn, or rather this transfer from problem to problem which we call the formation of a learning set, is a highly predictable and orderly process. He further contends that the acquisition of a learning set changes a concept formation problem from an intellectual difficulty into an intellectual triviality and leaves the organism free to comtemplate problems of another hierarchy of difficulty.

Bourne (1966) believes that an organism has a memory which produces responses even though the physical stimuli for those responses are not present. Furthermore, he believes that an organism brings past experiences to a situation which allows it to discard one or more stimuli as irrelevant. Underwood (1952, p. 212) is convinced that "because problem solvers are human does not necessarily mean that they would be superior to automation at solving problems, for they have biases and sets and prejudices which may retard as well as enhance solutions."

Haygood and Bourne (1965) conclude that an organism must have level II concepts available as components in order to correctly identify an instance of a level III concept. In like manner, to make use of level II concepts, an organism must be familiar with level I concepts. We can see from this that an organism must use and therefore have attained concepts at a lower level in order to have attained a complex concept. This interpretation of concept formation implies

that an organism does not learn level III concepts as such, but rather constructs or induces them from their component parts.

Neural physiology and concept formation

Simon and Barenfeld (1969) describe information-processing theories of human problem solving, especially those employing computer simulation of human concept formation, as a selective search through the "tree" of solution possibilities. The authors of these theories together with their critics agree that heuristic search is an important part of problem-solving behavior but is by no means the whole of it. Furthermore, we can postulate that the processes going on inside an organism involving sensory organs, neural tissues, and muscular movements controlled by neural signals are also symbol-manipulating processes; consequently, patterns in various encodings can be detected, recorded, transmitted, stored, copied, and so on, by the mechanisms of this system. Rosenblueth (1970, p. 47) categorizes sensory receptors as follows:

> ... the interceptors, which give us information pertaining to changes that take place inside our organism, e.g., the proprioceptors in muscles, tendons, and joints, and the chemoreceptors and baroreceptors in the carotid body; the surface receptors in the skin and mucosae, such as the tactile receptors and thermoreceptors; and finally, the telereceptors, which give us information about events that occur at a distance from our bodies. We have receptors for only a small number of forms of energy: light, in the retina; gravity and acceleration, in the labyrinth; vibratory, in the ear and in some skin and bone receptors; heat, in the receptors of the skin and some mucosae; and chemical, in the smell and taste receptors of the nose and tongue. With regard to light and sound waves, the corresponding receptors are sensitive to only limited ranges of wave lengths.

Rosenblueth (1970, p. 50) theorizes that "information about the material universe collected by the receptors is conveyed to the central

nervous system through nerve impulses that travel over the afferent axons connected to these receptors." He further theorized that "messages are thus in code and the number of independent parameters that can appear in the code is determined by the properties of the axons."

Arbib (1972, p. 33) gives us a description of the mammalian visual system:

> ... we see that rod and cone activity, after being preprocessed by two layers of cells within the retina, passes up the optic tract (the array of axons of the retinal ganglion cells) and branches into a number of pathways. Two of these lead to midbrain structures, the superior colliculus and the pretectum.
>
> ... A third destination for the optic tract - and the dominant one in man - lies in the thalamus and is called the lateral genticulate nucleus because it is the lateral part of two structures bent or angled like a knee (think of genuflection, bending of the knee), where signals are further preprocessed enroute to the region at the rear of the head. This visual cortex is somewhat striated (striped) in appearance and so is referred to as striate cortex. ... This visual cortex is also called area 17 because it was the seventeenth area that a man named Brodmann put a number on. The optic radiation - the axons from the lateral geniculate - also projects to the surrounding prestriate cortex in areas numbered 18 and 19. In addition to a two-way communication between visual cortex and superior colliculus, there are also pathways from visual cortex to other areas of cortex, of which the frontal eye field (involved in monitoring of eye movements) and infratemporal (i.e., on the underside of the temporal) cortex are actively involved.

Simon and Barenfeld (1969) have organized the "perceptual" process into a new chess-perception program, PERCEIVER, that can simulate the initial sequences of the eye movements of human subjects.

Summary

A concept is a category of things; these things are referred to as stimuli or stimulus objects. Bourne (1966, p. 1) concludes, "We may

say that a concept exists whenever two or more distinguishable objects or events have been grouped or classified together and set apart from other objects on the basis of some common feature or property characteristic of each."

Concepts exist to simplify to some degree the environment of an organism. Categorizing or concept formation is a necessary way of approaching the tremendous diversity an organism encounters in everyday life.

All conceptual problems require an organism to discover and learn some type of scheme for grouping stimuli. Bourne (1966) perceives this grouping process as an inductive task based on the observation of a set of positive and negative stimulus presentations. We may conclude that perceptual learning involves learning to detect features of an object or class of objects which distinguish it from others.

Conceptual rules are rules for grouping. They specify how the relevant attributes are combined for use in classifying stimuli. Bourne (1966), p. 18) explains that "a repertoire of rules permits rapid acquisition of unfamiliar stimulus classifications based on it, increases the range of concepts that can be formed with any particular stimulus population, and enhances the flexibility of the organism's conceptual behavior."

Bourne (1966) views the term "learning" as applicable for those tasks wherein the emphasis lies in the acquisition of some complex behavior strategy which implements a formerly unfamiliar rule for grouping. When it is clear that learning has taken place and when the task demands some use of that prior learning, we use the term "utilization."

Conceptual behavior is a special mediated chain involving multiple converging linkages between external stimuli and an internal response. Bourne (1966) has found that mediators act as building blocks from which abstract and/or hierarchically arranged concepts can be formed.

Any concept can be described in terms of a set of relevant attributes and a rule which combines or prescribes the function of, or relationship among these attributes. Bourne (1966) tells us that an organism has preestablished tendencies and expectations called sets while attempting to solve new concept formation problems. Harlow (1949) concludes that this learning to learn, or rather this transfer from problem to problem which we call the formation of a learning set, is a highly predictable and orderly process.

CHAPTER IV

COMPUTER CONCEPT FORMATION

Computer structure

Hunt (1962) tells us that a computer is useful in artificial intelligence research because it permits the testing of a wide range of designs for intelligent machines. He further contends that a computer can only add and compare numbers - in itself it is in no way intelligent. Garvin (1963) believes, however, that a computer can make certain types of elementary decisions. He feels that it cannot exercise judgement, but it can determine whether or not selected criteria apply in a given case and decide what to do next. In performing these elementary decisions, a computer chooses from several prespecified alternatives.

The concepts of computer hardware and computer software together comprise the computer system. Hardware includes the computer machine and peripheral equipment such as punching, sorting, listing, or duplicating machines. Software means the programs which communicate with the computer.

Henley (1970, pp. 3-4) describes a computer as a "collection of machinery or hardware" consisting of the following four elements:

> ... There is the store, or main memory, of the computer, which holds items of information for as long as they are needed. This information may take the form of instructions constituting a program to be executed, or data on which that program is to operate. Thus, in the case of a payroll program, the list of employees whose pay is to be recorded and the payroll program which carries out the actual operations would both be held in the computer's store. After the program has run to completion, the information

> may be erased from the computer memory as it is no longer needed.
>
> A second component is the control unit, which examines the instructions contained in the program, and sends out the electronic signals which instigate the required operations. Thirdly, there are the arithmetic and character-handling units, which perform the requested operations on items contained in the main store. Thus, an instruction to add two items together would reside in the main memory, be recognized by the control unit, and actually executed by the arithmetic unit. Fourthly, there are a number of input/output devices controlled by device control units, by means of which information is communicated to and from the main store. Instructions can be issued by the programmer to read from or write to those devices.

The main store, as has been described, contains items of information. Henley (1970) tells us that the programmer sees the store as being split into separate locations each holding one item of information. He describes these locations as being numbered consecutively from zero upwards. This number is called the address of the location to which it refers. He contends that the size of the store determines the amount of information that can be held at one time. A large store has over 1,000,000 locations.

Henley (1970, p. 4) explains how information appears in a computer:

> Within the individual store location, the information appears as a pattern consisting of 1's and 0's (binary digits or bits as they are called). Each item of information, such as a decimal digit or a letter of the alphabet or another significant character such as might appear on a typewriter keyboard, is represented by a unique pattern, and there are international standards for coding characters. Many modern computers use an 8-bit location or byte, which gives 256 different pattern combinations of 1's and 0's available to represent characters. Some patterns have a particular significance for the hardware, and represent instructions to be obeyed. Thus, if the control unit examines a location containing one of these patterns, the effect is to cause the instruction represented by that pattern to be obeyed.

Feigenbaum and Feldman (1963) consider the instruction to "compare and transfer control" very important because it enables the computer to make a simple two-choice decision - to take one of two specified

courses of action depending on the information found in some cell of the memory. By cascading these simple decisions, highly complex decisions could be fashioned. Feigenbaum and Feldman (1963, p. 2) further state:

> Information processes more complicated than those "wired into" the computer can be carried out by means of a sequence of the elementary instructions, called a _program_. The program is the precise statement of the information process that the user desires the machine to carry out. A computer program is stored in the memory along with all the other problem information and data. One part of a program can call in another part of the program from the memory to the working storage and alter it. The general-purpose digital computer can do any information processing task for which a program can be written. The same computer which one moment is computing a company's payroll may in the next moment be computing aircraft designs or insurance premiums. Any program for a general purpose computer effectively converts this general-purpose machine into a specific purpose machine for doing that task intended by the user who wrote the program.

Hunt (1962) explains that a list of computer instructions taken as a whole is called a program. Modern computers are programmed in a language which is more natural for humans. Hunt (1962) contends that modern computer languages such as ALGOL or FORTRAN are very similar to conventional algebraic notation. He explains that the user writes his program in FORTRAN, ALGOL, or some other human-oriented language which is then automatically converted into the sequence of digits that will actually control the computer. Languages such as this are called _source_ languages.

Garvin (1963, p. 234) concludes the following:

> ... Digital computers are advantageous only when one is going to perform the same task over and over again. Then the speed of the computer makes its application economical. As an example one might give the problem of finding the sum of a million numbers. One wouldn't say, as one might in hand calculations, _add the first number to the second number_, _add the third number to the sum_, _add the fourth number to the sum_, until one finally said _add the one-_

millionth number to the sum. Instead one would do something logically more complex and fantastically shorter. The instructions would be:

> Set the sum to equal 0.
> Set i to equal 1.
> Add the ith number to the sum.
> Does i = 1 million? If so, you are finished.
> If not, increase i by one and proceed through the third and fourth instructions.

J. R. F. Alonso and P. A. G. Alonso (1970, pp. 10-12) present a detailed explanation of machine language:

> What the computer really speaks, machine language, can be manipulated almost directly by the computer circuitry. A representative hypothetical machine language statement consists of a string of numbers preceded by a sign. This string may be divided into three parts: the instruction or operation code, the internal conventions according to which the instruction is to be executed, and the indication of where the datum to be acted upon is located. For example, consider the statement: '+100095247'. The sign and first two digits denote an operation code; '+01" stands for "store" or "locate in a given place." The following four digits (0009) denote certain internal computer conventions according to which the particular operation should be performed. In this case, 'according to the value stored in storage location 9.' The last four digits (5247) stand for the number of the storage location where the particular piece of information is to be stored, or in the case of other types of instructions, the particular storage location where or on which the computer is to operate on its numerical contents. Machine language is the logical choice for applications where computation speed is at a premium. It presents these disadvantages: programming in machine language is very difficult; the resulting program is strongly machine dependent, i.e., it may not be run in a computer other than for that for which it was written; and the resulting program is quite difficult to understand for a person other than the the original programmer.
>
> Assembly language statements look somewhat more like natural words than machine language statements. An assembler, (a special program that may be supplied with the computer) translates assembly language statements into machine language. Our hypothetical instruction '+100095247' when written in assembly language would become 'ST09A' which, when translated into natural language means 'store according to the contents of location 9 this information into the location corresponding to the variable A.' The programmer need no longer remember the location number '5247' because the computer automatically associates the name 'A' with whatever the contents of a location also 'chosen' by the computer may be. 'ST' is also far easier to remember than '+01'. 'Words' like 'ST' are called mnemonics and their value becomes evident when one realizes that

> there may be a hundred different instructions in a particular machine language. It would be sheer masochism to memorize these hundred different numbers instead of easy to understand mnemonics which closely resemble natural language. One lets the assembler translate these mnemonics into machine language. The same reasoning applies to trying to remember location numbers instead of letting the assembly program define and remember which location number corresponds to the variable or entity that the programmer chooses to call 'A'. Examples of commonly used assembly languages are FAP (Fortran Assembly Program) used by the IBM 7090 Series Computers and AUTOCODER used by the IBM 7070 Series Computers.
>
> User oriented languages do far more for the programmer, thereby simplifying the programming process significantly. User oriented languages may be mastered in a fortnight with a reasonable expenditure of effort by almost anybody with a secondary education. A compiler is the special program supplied with the computer that translates user oriented language statements into assembly or machine language. User oriented languages themselves are often called compilers, as follows: Mathematical compilers like FORTRAN (FORmula TRANslator) or ALGOL (ALGOrithmic Language) or MAD (Michigan Algorithm Decoder) are designed to operate on relatively few items of information, but to perform many complicated manipulations on them. Compilers are also particularly suited for the programming of algorithms, sequences of systematized operations or logical steps leading towards the execution of a particular computational task. Business compilers like COBOL (COmmon Business Oriented Language) are intended to operate on many items of information and to perform few simple operations on them. All purpose user oriented languages like PL/1 (Programming Language 1) can do both mathematical and business functions with equal ease, but they are still in the stage of development and are not as standardized and machine compatible as the most common languages, FORTRAN and COBOL. Logical Concatenation Languages operate on context-free strings of characters, and manipulate them to suit specific purposes like determining how many times the string 'and' was used by Shakespeare or reclassifying the card catalog of a large library according to a new classification scheme. Commonly used Logical Concatenation Languages are SNOBOL (StriNg Oriented symBOLic language), SNAP (Stylized NAtural Procedural language), and LISP (LISt Processing language).

Henley (1970) explains that a user program cannot issue any of its own input or output instructions. He states that it must branch into a supervisor program and pass across details of the information it needs and where in store the information is to be read; the supervisor program then issues the instruction on the behalf of the user.

It is worthwhile at this point to discuss the way in which large amounts of information required in information retrieval systems is organized. Each separate collection of information is known as a file. Henley (1970) explains that in a library context there would be an author file, a title file, and a master file with all the bibliographic information about each document.

Henley (1970, p. 7) states that within a file, each individual item is called a record.

> ... Thus a record in the above examples would comprise one author, one title, or the entry for one document. The file would be kept on a storage medium, and a program wishing to access one particular record in store, and it could then, for example, alter the entry required, and rewrite the new version of the file to storage again.

Henley (1970, p. 8) explains that a computer can process incredible amounts of information in what by human standards is impossible to achieve.

> ... In addition a machine does not get tired, can repeat operations again and again without any reduction in performance, and will not make mistakes. But it requires that the information it receives and the programs it executes be completely accurate. A system is only as good as the data and the programs used. This means that for example in a library situation, the work which might under a manual system go into writing out lists of books, or records cards, has to be channelled into preparing or checking the files to be read into the machine. And whereas a single mistake could safely have been ignored, it may now be the cause of a catastrophic failure of the system. This need for complete accuracy, and possible ways of surmounting it by programming, is one of the important concerns of this work.

Henley (1970, p. 41) describes a fully operational artificial intelligence information retrieval system as "a library with a set of terminals and display unit, some of which are used by library staff for accessions etc., and some of which are available to the general public.

> ... A number of keys would be available at the terminal, and the program would interrogate the user as to his requirements, and hand control to the appropriate routine. While the librarian was adding to the files from one console, the user could ask for information from another.

Henley (1970, p. 19) feels that the design of such consoles is important:

> ... Ideally they should comprise a keyboard with a selection of keys to initiate different processes, as well as a typewriter keyboard to enter the information. In conjunction with this is needed a video display unit, and a device such as a light pen enabling the user to point to and alter items displayed in the screen. Each keyboard is connected to the central processing unit. In connection with this a full suite of programs must be provided by the manufacturer which allow the operating system to monitor the various consoles and initiate any process or set of programs desired by any user. Sets of routines must be available which can be called in by the depression of the appropriate key.

Parsegian (1973, p. 15) compares a computer to the body and sensory system of man:

> A virtue of the electronic computer is its ability to receive and to hold in memory many signals that represent <u>information</u>, given to it through the language of the binary code or of other symbols. The computer operates on this "information" through preselected techniques and in response to new signals or results of computations. In this respect it is like the body and sensory system of man, which receives signals from sensory receptors and transforms these into meaningful information.

Salton (1970) believes the first comparison of conventional retrieval with automatic text processing systems was made by Swanson in the late 1950's using 100 documents and 50 queries. Salton (1970, p. 337) quotes Swanson's report:

> It is expected that the relative superiority of machine text searching to conventional retrieval will become greater with subsequent experimentation as retrieval aids for text searching are improved, whereas no clear procedure is in evidence which will guarantee improvement of the conventional systems. ... Thus even though machines may never enjoy more than a partial success in library indexing, a smaller suspicion might justifiably be entertained that people are even less promising.

Can a machine think? Selfridge and Neisser (1960, p. 50) gives us the answer to this old chestnut by saying:

> ... certainly yes: Computers have been made to play chess and checkers, to prove theorems, to solve intricate problems of strategy. Yet the intelligence implied by such activities has an elusive, unnatural quality. It is not based on any orderly development of cognitive skills. In particular, the machines are not well equipped to select from their environment the things, or the relations, they are going to think about.
>
> In this they are sharply distinguished from intelligent living organisms. Every child learns to analyze speech into meaningful patterns long before he can prove any propositions. Computers can find proofs, but they cannot understand the simplest spoken instructions. Even the earliest computers could do arithmetic superbly, but only very recently have they begun to read the written digits that a child recognizes before he learns to add them. Understanding speech and reading print are examples of a basic intellectual skill that can variously be called cognition, abstraction or perception; perhaps the best general term for it is pattern recognition.

Kucera (1969) describes a computer as much more than a machine for performing calculations. He believes that aside from their mathematical operations, computers can process, organize, compare, and manipulate data of a non-numerical nature including textual information. He concludes that it is this capacity of computers to deal with letters, words, sentences, or even whole texts that has made them of considerable importance in the study of language.

Machine learning

Hunt (1962) views mechanical concept learners in the same manner as biological concept learners which acquire categorizations based on an internal representation of an external object. Hunt believes that the transformation which creates this representation can be either a "parallel" one producing elements to which response strengths are associated, or in itself subject to learning during a particular

concept learning task. He concludes that categorization in concept learning involves the manipulation of coded symbols representing the objects to be categorized.

Parsegian (1973) views perception as "sensation plus past experiences." He feels that it is possible for identical stimuli to yield quite different understanding. He concludes that perception will differ depending on the state of the body generally, the emotional and mental set, purposeful selection, experiences from the past, memory, attention, ego-defense functions, and judgement that precede or accompany each stimulus.

Hunt et al. (1966) describe concept learning as a hierarchical process. In other words, they believe that an organism must have a concept in order to learn more concepts. It follows then that any value of an attribute is itself a concept, and when we speak of concept learning devices, we are talking about devices which discover rules for combining previously learned concepts to form a new decision rule. Hunt et al. (1966) view concept learning as a type of inductive reasoning.

Like perception, everyone agrees that memory is important in concept learning, but no one has a clear idea of how it is important. Shepard (1964) views the problem-solving ability of an organism as dependent in considerable measure upon the association structure of its memory and consequent efficiency with which it is able to retrieve from memory that which is most relevant to a given situation. He points out that such associative connections which are not yet built into the hardware of modern computers is implemented in programming

systems such as IPL and LISP. He states that these programs provide for the symbolic linking of each newly-stored item of information to any previously-stored items so as to form lists or "trees."

Hunt (1962) describes a computer as capable of storing all the information it ever received. He feels that it could use this bank of knowledge to evaluate proposed answers as they occurred. He further states that a computer could store all conceivable hypotheses with a current belief in each of them, and could thereby reason inductively without storing any specific information; each time the computer encountered a new piece of data, it could use it to readjust its belief in the plausibility of each of the hypotheses.

Continuing this discussion, Hunt (1969) concludes that a newly developed hypotheses is evaluated by an organism first on needed evidence and then on whether or not this evidence is available. He believes that the first step is not a memory task and that the second step does not require the organism to remember everything about a particular instance. He feels that the organism must instead search its memory to discover whether or not a particular subset of descriptive elements has or has not occurred jointly with a particular naming response.

Hunt (1962) describes a strategy as a plan for arriving at a predefined goal at minimum cost. He describes the goal in concept learning as the attainment of a definition of a concept which provides a satisfactory decision rule for assigning names to objects. He concludes that it can be imagined that learning progresses by a cumulative procedure in which an organism saves time by learning to

apply the current strategy, and to change strategy.

Arbib (1972) points out that an organism seeks enough cues to classify stimuli as pertaining to a known object, rather than trying to account for all the details of the visual input. Indeed a whole movement called Gestalt psychology has taken shape within the past half century to emphasize the idea that perceptions are not created from particles of sensations. Parsegian (1973) describes perception and mental activities in general as deriving significance from the relationship to each other of the parts that make up the total picture.

Hunt (1962) implies that problem-solving for an artificial intelligence system could consist of the application of Test-Operate-Test-Exist (TOTE) units. He describes a TOTE unit as a test to determine the difference between current knowledge and the desired state, operating to reduce these differences, and then testing again. He believes this type of cognitive psychology makes a strong appeal to the computer program as a model. A computer can be programmed to test data, to operate to reduce differences, and then to retest. The answer produced would be a combined product of the input data and the operators made available to the program.

Upon further examination, Hunt (1962) discovered that an artificial intelligence model must contain some provision for changing and improving its performance. He feels that this change could be handled by a TOTE unit that observed the performance of a subsidiary unit. He views this subsidary unit as the strategy. When the master unit tested it and found it wanting, it would be replaced. He believes that as experience was gained, stronger and stronger failure tests could be

made, so that faulty strategies would be detected earlier.

Hunt (1962, p. 184) tells us that a faulty strategy could be replaced with several other TOTE units if a failure were detected:

> ... On the particular problem under consideration it might not be a matter which unit was used. But on a second problem there might be a very great difference. One of the things that the subject might learn is what to do when the current strategy fails. Learning to select TOTES is similar to "learning to learn." ... In the TOTE analysis <u>any</u> transfer study is a study of inductive problem solving or, perhaps, concept learning. The objects are problems which can be described by their physical structure and by the feedback (e.g., success or failure of a particular operation) received when a strategy is applied to them. By observing this feedback, the concept learner could develop concepts to define the types of problems on which particular strategies will work. Often his experience will not be sufficient to permit him to learn an unequivocal concept about problems. Therefore he will have to guess about the "best" strategy to try; at some time this guess may lead him into an incorrect classification. This would be revealed by an incorrect choice of strategy.

Hunt (1962, p. 276) explains that "concept learning can be thought of as a technique for solving an inductive problem in symbolic logic through the use of information-processing routines. Such an analysis can and should be no less rigorous than any mathematical theory of learning."

Simon and Kavovsky (1963, p. 539) describe a list processing language as a system of processes for acting upon symbolic information represented in the form of lists and list structures (lists of lists). Among the fundamental processes in such a language are the process of writing or producing a symbol, the process of copying a symbol (i.e., writing a symbol that is the same as the given symbol), and the process of finding the symbol that is next to a given symbol on a list. In addition, there are processes for inserting symbols in

lists, deleting symbols from lists, and otherwise modifying lists and list structures."

Selfridge and Neisser (1960) view an organism as continuously exposed to great amounts of data from its senses. An organism abstracts patterns from this data relevant to its activity at the moment. They feel the ability of an organism to solve problems, prove theorems and run its life depends on this type of perception. They are convinced that until programs are developed to perceive patterns, achievements in mechanical problem-solving will remain isolated technical triumphs.

Gyr et al. (1966) conclude that the passive approach to perception, since it is not concerned with the contributions the organism itself makes to perception, assumes that rules on modes or organization of inputs are somehow given in the environment rather than partially affected by the nature of the organism's interaction with the environment. Gyr et al. (1966) further conclude that perception, or at least perceptual development, ought to be formulated as a sensorimotor or active process if perceptual development, perceptual organization, and perceptual attention and selection are to be studied. Gyr et al. (1966) suggest that any computer program which is based on a theory of perception as a passive process might code and organize its "precepts" in terms of units which are often quite irrelevant to the codes and organization employed by a living organism. If this is so, the program would have a limited usefulness as a tool in psychological research. Arbib (1972, p. 57) supports the conclusions of Gyr et al. for us to consider an organism interacting with its environment:

> ... The behavior of the organism will be influenced by aspects of the current activity of the environment - we speak of these aspects as constituting the input to the organism - whereas the activity of the environment will be responsive to aspects of the current activity of the organism - we speak of these aspects as constituting the output of the organism. Though our current models may not sufficiently stress this fact, our long-range theories must not fail to emphasize that we do not have isolated passive organisms upon which inputs just impinge from the outside, but rather organisms and environment in mutual interaction. The outputs of the organism may be construed as inputs to the environment, and vice versa.

The views on the relations between the material universe and the mental processes of an organism set some clearly defined limits to the knowledge that we can acquire of the events that occur in this universe. The chain of events that Rosenblueth (1970) accepted for human perception was the following: material processes → selective activation of some receptors → coded afferent messages → central neuronal and correlated mental events. He believes the knowledge an organism can acquire about the material events in its environment will depend on the properties of its receptors and nervous systems. From this he concludes that the material universe which an organism constructs, infers, or postulates will be determined and limited by those properties. Rosenblueth (1970) further concludes that the so-called secondary qualities of the material entities such as colors, pitch of sounds, etc., are mental and not material characteristics.

Rosenblueth (1970) states that an organism acquires new conditionings throughout its life as it learns and acquires a memory. He believes the neuronal reactions of the brain of an organism to a given stimulus are determined not only by whatever innate interneuronal connections the organism may possess but also by its previous

experiences and the traces which they leave on its nervous system. He feels that this is a dualistic philosophy in that we are asserting on the one hand the existence of our mental processes and on the other that of a material universe which determines the physical processes that develop in the brain of an organism. Rosenblueth (1970) concludes that an organism invents or postulates a material universe in order to rationalize its perceptions. Arbib (1972, p. 64) tells us that the "current output of the [neuronal] network need in no sense be a response to the current input regarded as stimulus. Rather, the firing of those neurons which feed the output can be influenced by activity within the network reflecting quite ancient history of the system."

Arbib (1972) believes that the "brain" interacts with "environment" on the basis of an internal model. He feels its interaction must be designed to update its internal model as well as to change its relationship with the external world in some desired way. He concludes that a brain needs a broad data base or internal model of the world in order to successfully interact with a complex environment. The result is that the utility of a relatively simple model of the world can be improved if an organism can adjust parameters in its brain to adapt to new and changing circumstances.

Continuing this discussion, Arbib (1972) explains that a normal mode of walking requires an extensive reliance upon our model of the immediate world to provide a feed-forward type of control of walking. He concludes that in the stepping or seeking mode of walking, each step is dependent on fed-back information about the spot on which the foot will land.

Arbib (1972) believes that as an organism matures, the "computer" in its head becomes so adjusted that its actions become better adapted to a whole range of properties of the world in addition to those that confront its senses at the very moment. The word "model" in the phrase "internal model of the world" is to be used in this abstract sense rather than some more pictorial sense. He calls the internal model of the world which an organism possesses "long term memory" - the collection of properties which reflect past experience in a way which will help an organism compute its present behavior and improve the model itself." He refers to short term memory as an internal model that represents the current surroundings of an organism. Arbib (1972, p. 91) explains:

> ... We do not perceive what we sense in front of our eyes. If we are in a room, we perceive our presence in that room with what is in it so that we may, for example, reach for an object previously seen behind us, without searching for it anew. Our perception does not involve independently processing a succession of "snapshots" of the room, but rather involves an initial comprehension of the room and the more salient of the contents, after which we need merely note discrepancies between our model and what we need to know of what is out there to "fill in gaps" and update this momentary model - as when we reach for that object behind us only to find that someone has moved it. We repeat that this modeling and updating is all encoded in terms of the properties and activities of neurons and has little resemblance to a photographic record.

Arbib (1972) stresses that he regards a perceiving system as representing its environment in terms of possible motor options, rather than creating a "little copy of the world" in any photographic sense.

Parsegian (1973) feels that cybernetics is not only concerned with neurological processes, but is also concerned with a search for comparable capacities for learning, memory, and recall in the electronic computer. Cybernetics involves the interactions of machines or organisms

with the environment. He believes that these interactions involve an element of purpose and make use of control principles addressed to those purposes. These interactions also involve feedback.

Parsegian (1973) views the results of any act as being fed back to modify the initial act, the feedback taking the form of information. He feels that each cybernetic system represents a dynamic situation in which energy is utilized to respond to changes and yet to maintain stability of sorts. He concludes that this utilization of control of energy constitutes a primary interest of cybernetics whether the energy is mechanical or human.

Continuing this discussion, Parsegian (1973) sees the human brain as being capable of receiving sensory signals and of processing these to become information that either immediately influences action or is stored for future use. He believes in the case of the neural system, information emerging as a product of neural processes becomes incorporated as awareness or memory. He concludes that in like manner, the computer may incorporate the answers to its calculations in its own memory system for use with future calculations.

Parsegian (1973) believes there is a mental set which determines whether or not an organism responds to a particular stimulus. He views this inner reaction of an organism to be as necessary as the external stimulus for the development of perceptual consciousness of what is going on. He states that even initial perceptual consciousness developes only with a coordinated activity of sensory receptors and the inner functions of the brain; this process occurs through the use of earlier experiences and memory as a base. He concludes that the

process of perception appears to be completed through judgment, comparison, selectivity of stimuli, modification of stimuli, and especially identification of a clearer causal relationship between object and stimulus.

Arbib (1972) contends that the "level" of an organism determines how much of its own activity is wired-in and how much is learned. In any case, he feels that the sensory system takes the physical input derived from the environment and converts this in the form of a vast number of sensations to the nervous system and the brain. He further believes that the brain in turn must accept, integrate, and ascribe meaning to the sensations according to immediate or earlier experiences. He views many of these integrative functions as taking place automatically, utilizing only the extensive neural interconnections within the neural system other than the cortex. He views the human nervous system, however, as capable of higher associative functions. He concludes that the ability of the human brain to interpret the significance of sensations, to think, to originate ideas, and to activate functions called for by various situations are examples of higher associative functions executed by the human nervous system.

Parsegian (1973) describes the flow of nerve impulses in the nervous system as producing a unidirectional control over flow. He likens this property of directional conduction through a synapse, or nerve connection, in the human brain to a diode rectifier, which is common in digital computer circuits. Both the computer and the nervous system depend on the flow of information being controlled through unidirectional units.

Parsegian (1973) points out that nearly three quarters of all neuronal cell bodies of the human nervous system are located in the cerebral cortex of the brain. He tells us that one of the principal functions of the cerebral cortex is to store information and memory of experiences. He contends that here in the cortex we find the most advanced forms of reasoning, integration of information, and planning of action taking place. Parsegian (1973) continues to point out that the most abstract processes of thought and the highest levels of association of information and of concepts take place in the prefrontal lobe in portions of the temporal and partietal lobes.

Hunt (1962) believes that a problem is solved when an adequate path is found from a possible problem (stimulus) to a possible solution (response). He views an artificial intelligence system as nothing more than a set of instructions for selecting a path. The system should always find the solution to a given problem. He explains that any computing system which has this characteristic is called an algorithm. An algorithm is a search method which will produce the correct response for any stimulus in the set of possible stimuli.

Hunt (1962) goes on to conclude that an intelligent machine must be able to do more than observe its own internal state. It must be able to observe where it is located in the entire problem-solving environment. Hunt (1962, pp. 202-204) presents the following explanation:

> ... It is not enough to know that the solution offered is not correct, we should know what are the differences between the solution offered and desired. The simplest such information is the relative distance between two offered solutions. Suppose an artificial intelligence produces two responses and keeps a record of how the responses are produced. If one solution is

better than the other, although neither were adequate, it could be a good heuristic to assume that the processes unique to the better response were desirable.

The way a predesigned artificial intelligence moves through its environment is to apply operators to its present solution to transform it into a new solution. ... Every system, including a random system, has operators that it can apply in a search for a solution. If the system is to satisfy Ashby's criteria for intelligence it must be answered: Can the operator be applied at all? Will the application of this operator (probably) result in a move toward solution? To do this, the artificial intelligence must have concepts. In progressing through the space of possible solutions the problem-solving mechanism must continually evaluate the difference between the desired results. Newell, Shaw, and Simon suggested that differences could be used to describe the overall situation. The problem solver could have a concept, based on differences, of situations in which the application of operator x, y, z, etc. usually reduced the differences.

Deciding whether or not an operator can be applied is often a straight forward question. For instance, we know that, now and for all time, we can find the logarithm of x only if x is a positive real number. We can specify rules for deciding whether or not a particular operator can be applied to a situation. It is much harder to specify when a machine should decide to apply a particular operator, although several other operators could be applied. Specifying a decision rule to answer this question is equivalent to stating how to decide on a good move in problem solving. If a machine is designed to attack problems that are at all complex (e.g., symbolic logic, chess, and even concept learning) we will not be able to specify all the situations in which the machine will have to make a choice. We may not even be able to partition the universe of possible choice points into useful classes of choice situations. The best approach we can take is to provide the machine with heuristic rules for selecting the operation that will probably move it closer to a solution. But "moving closer to a solution" is a slippery definition. A truly intelligent machine should have several ways of evaluating this phase and should be able to choose among them. Newell, Shaw, and Simon point out that a machine that could generate alternate descriptions of the choice situations it encountered and then choose among these descriptions would be an "intelligent learner." As it gained experience, it would become a better problem solver because it would discover better ways of looking at its environment.

Let us discuss artificial intelligence with reference to human problem solving. Hunt (1962) believes that if we define "concept" in symbolic terms, it is possible to build an automatic concept-learning symbol-manipulating device; it is difficult, however to build an

efficient one. He feels that when we try to devise an artificial concept learner, we may come away with more respect for human data-handling capabilities. He tells us that humans learn complex concepts under an amazing number of barriers such as imperfect memory.

Hunt (1962) explains that each "nerve" inside the digital computer is represented by a set of numbers specifying the current state of its parameters. He points out that all computations are carried out in a linear sequence when a stimulus is presented, as numerical operations, since the computer is a linear device. Hunt (1962, p. 215) cites Von Neumann:

> ... Von Neumann suggested that this may demonstrate the basic difference between a computer and a brain; in the biological organism the computation is a truly parallel operation (with the possibility of interaction between computations, as in Kohler's field theory of brain activity) using analog computational methods. In addition, the sheer number of units in biological systems - much greater than the number of neurons that can be represented within a modern digital computer - limits the realism of the simulation. Any behavior which, in the living brain, depends on the number of neurons cannot be represented in the simulation.

Feigenbaum and Feldman (1963), explain the goal of artifical intelligence as the construction of computer programs which exhibit behavior that we call "intelligent behavior" when we observe it in human beings. Feigenbaum and Feldman (1963, p. 4) go on to answer the question of whether or not a computer does exactly what it is told to do and nothing more:

> ... <u>This statement - that computers can do only what they are programmed to do - is intuitively obvious, indubitably true, and supports none of the implications that are commonly drawn from it. A human being can think, learn, and create because the program his biological endowment gives him, together with the changes in that program produced by interaction with his environment after birth enables him to think, learn, and create. If a computer thinks, learns, and creates, it will be by virtue of a program that endows it with these capacities. Clearly this will not be a</u>

> program - any more than the human's is - that calls for highly stereotyped and repetitive behavior independent of the stimuli coming from the environment and the task to be completed. It will be a program that makes the system's behavior highly conditional on the task environment - on the task goals and on the clues extracted from the environment that indicate whether progress is being made toward those goals. It will be a program that analyzes, by some means, its own performance, diagnoses its failures, and makes changes that enhance its future effectiveness.

Feigenbaum and Feldman (1963) elaborate on the foregoing by telling us that it is wrong to conclude that a computer can exhibit behavior no more intelligent than its human programmer. They feel that it is also wrong to conclude that a human programmer can accurately predict the behavior of his program. They believe that such conclusions presume that a human programmer can comprehend the remote consequences of a program which establishes general prescriptions for adaptive behavior in a computer. More importantly, they believe this presumes that a human programmer can perform the same complex information processing operations equally well with the device within his head.

Arbib (1972, p. 69) feels there is a deeper reason for the success of computing machines which has nothing to do with their circuitry, but rests on a basic logical property of algorithms ...

> ... namely, that an algorithm can be <u>specified</u> in far fewer steps than it takes to <u>execute</u> it (i.e., carry it out with particular data). At first this seems paradoxical, for one can imagine leaving out a few instructions on a given execution, but may be hard put to imagine where new ones come from! The resolution is simple - algorithms often contain sequences of instructions which may be paraphrased as "keep repeating the following steps until you've gone far enough." To make this quite literal, consider the following algorithm for telling a human how to find a door in a totally dark room. (For simplicity, we shall assume that all furniture is obligingly removed from our path, and that the door is closed). The verbal instructions we might give a human would be: "Walk to the wall, then walk along the wall until you find the door." This might then be broken down into the following sequence of "unit operations."

1. Extend left hand in front of you.
2. Does hand touch the wall or door?
   If answer is YES: Go to instruction 5.
   If answer is NO: Go to instruction 3.
3. Take one small pace, advancing the left and right feet equally.
4. Go to instruction 2.
5. With left hand still touching the wall or door, turn till it is to your left.
6. Does hand feel a door?
   If answer is YES: Go to instruction 9.
   If answer is NO: Go to instruction 7.
7. Take one small pace, advancing the left and right feet equally.
8. Go to instruction 6.
9. STOP (or: transfer to next program of action appropriate to having found doorway).

We doubt that a computer can really accomplish anything by trying out many programs and keeping a record in which each instruction is associated with the successes and failures of programs containing it. If this procedure could lead to some progress, the question may arise as to whether or not the simplest problem would require the trial of an astronomical number of programs. An experiment was begun to test a learning procedure of this type. A hypothetical computer was designed for this reason and called Herman. Friedberg (1958, p. 4) describes Herman:

> ... Herman has a very simple logic such that every number of 14 bits is a meaningful instruction and every sequence of 64 instructions is a performable program. An outside agent called the Teacher causes Herman's program to be performed many times and examines Herman's memory each time to see whether a desired task has been performed successfully in that trial. The Teacher's announcements of success and failure enable a third element, the Learner, to evaluate the different instructions which, on different occasions, appear in Herman's program. Basing its acts on this evaluation, the Learner tries to include "good" instructions in the program rather than "bad" ones. The experiment is run by simulation of these three elements on the IBM 704 Electronic Data Processing Machine.

Frieberg (1958, p. 6) continues his description of Herman:

... The routine changes enable the Learner to accumulate the data on the relative success of the two instructions on record for each location and gradually to favor the more successful instruction. The random changes are made in order that the Learner not be restricted to the 264 programs that can be made from the instructions on record at any one time.

Both the routine and the random changes are governed largely by a number associated with each instruction on record, called its "success number." The success number is supposed to indicate how well an instruction has served over many thousands of previous trials. Each time a success is reported, the success number of every active instruction is increased by 1. (If the program finished the successful trial before executing more than 32 instructions, the success numbers are increased by 2 instead of 1. This is done in order to encourage the development of programs that do not take long to finish, because it was anticipated that the success of the project might depend on the number of trials that could be simulated in the limited computer time available.)

...Thus the frequency with which each instruction on record is active depends partly on its long-term record, represented by its success number. When a certain set of instructions has been found to be successful in one problem and the Teacher now commences to pose another problem, it is intended that the frequent failures of the established program to perform the new problem will induce the Learner to alter the program and to use most frequently the instructions that are most often successful at the new problem. At the same time the instructions that were successful at the old problem ought not to be "forgotten," but should (at least for some time) retain their high success numbers, so that if the old problem is presented again the "memory" of these instructions will aid the Learner to arrive at a successful program. It should be emphasized that a change of problem is not signaled explicitly to the Learner but makes itself felt solely through the report of success or failure after each trial. The ability of the Learner to associate an instruction with a highly favorable long-term record, even while that instruction is currently inactive because it does not serve well in the problem at hand, is felt to be essential to the retention of things once learned.

Friedberg (1958, p. 7) concludes his description of Herman:

Herman, the Learner, and the Teacher are simulated together in the IBM 704. The program runs from 5,000 to 10,000 trials of Herman each minute, including the intervening acts of the Teacher and Learner. The actual execution of Herman's program is the most time consuming part of each trial. The part of the program that simulates the Teacher is rewritten or altered from day to day so as to present different problems or introduce modifications into the Learner. At the end of each day's run the IBM 704 punches out

> binary cards representing the state of Herman and the Learner. At the start of a later run, these cards can be read in so that the run will continue as though the 704 had not stopped, with the same active and inactive instructions, success numbers, and state numbers as at the end of the previous run.

Friedberg et al. (1959) tell us that a learning machine might learn to perform a task without being told how to perform it, but it would still have to be told exactly how to learn. They feel that for a machine like Herman to arrive at a program for solving problems simply from seeing whether trial runs succeed or fail depends in large part on having some efficient way of selecting one imperfect program over another. They believe the ability to partition problems and to deal with the parts on order of difficulty would seem helpful. They state that with this framework in mind, it is worthwhile to note the analogy between machine learning and the problem solving technique of directed machine search.

Hunt (1965, p. 214) mentions that "information processing theories of concept learning have also been proposed." He has developed a computer program for mimicking concept-learning behavior of humans.

> This program looks on concept learning as a decoding problem, and contains heuristics which enable it to "guess" an answer before one has been defined uniquely. This program responds solely to the information content of the stimulus sequence.

Feigenbaum and Feldman (1963, p. 300) describe a computer program which simulates verbal learning behavior. This program is called EPAM, Elementary Perceiver and Memorizer.

> Performance and Learning Conceptually, EPAM can be broken down into two subsystems, a performance system and a learning system. In the performance mode, EPAM produces responses to stimulus items. In the learning mode, EPAM learns to discriminate and associate items.
>
> The performance system is the simpler of the two. When a stimulus is noticed, a perceptual process encodes it, producing

an internal representation (an input code). A discriminator sorts the input code in a discrimination net (a tree of tests and branches) to find a stored image of the stimulus. A response cue associated with the image is found, and fed to the discriminator. The discriminator sorts the cue in the net and finds the response image, the stored form of the response. The response image is then decoded by a response generator letter by letter in another discrimination net into a form suitable for output. The response is then produced as output.

The processes of the learning system are more complex. The discrimination learning process builds discriminations by growing the net of tests and branches. The association process builds associations between images by storing response cues with stimulus images. The EPAM performance process for producing the response associated with a stimulus is as follows:

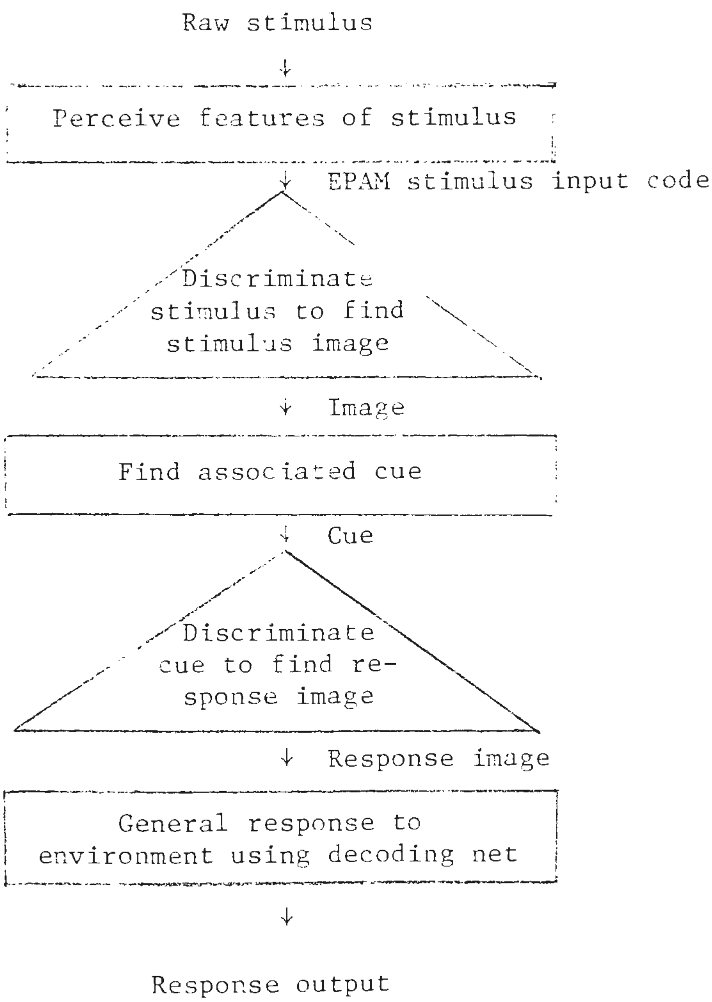

Figure 3. EPAM performance process.

Feigenbaum and Feldman (1963, p. 306) continue their description of EPAM as they explain the computer program employed:

> The EPAM model has been realized as a program in Information Processing Language V and is currently being run both on the Berkeley 7090 and the RAND 7090. Descriptive information on the computer realization, and also the complete IPL-V program and data structures for EPAM (as it stood in October, 1959) are given in an earlier work by the author (1959). IPL-V, a list processing language, was well suited as a language for the EPAM model for these reasons:
>
> a. The IPL-V basic processes deal explicitly and directly with list structures. The various information structures in EPAM (e.g., discrimination net, image list) are handled most easily as list structures. Indeed, discrimination is, virtually by definition, a list structure of a simple type.
> b. It is useful in some places, and necessary in others, to store with some symbols information descriptive of these symbols. IPL-V's description list and description list processes are a good answer to this need.
> c. The facility with which hierarchies of subroutine control can be written in IPL-V makes easy and uncomplicated the programming of the kind of complex control sequence which EPAM uses.

Newell and Simon (1961, p. 2014) describe a computer program called the General Problem Solver as a "program comprised of rather general processes for reasoning about ends (goals and means operators):"

> ... It is general in the sense that the program itself makes no reference to the precise nature of the objects, differences, and operators with which it is dealing. Hence, its problem-solving capabilities can be transferred from one kind of task to another if it is provided with information about the kinds of objects, differences, and operators that characterize and describe the particular task environment it is to handle. Thus, to solve logic problems, it must be provided with a format for representing logic expressions, tests for the differences that must be recognized between pairs of expressions, and a list of the allowable operators. The rules of the game it is to play must be described to it.
>
> ... At the grossest level, we may ask whether the program does, in fact, solve problems of some of the sorts that humans solve. This it demonstrably does. Hence we may say that its program constitutes a system of mechanism, constructed from

> elementary information processes, that is sufficient for solving some problems. It provides an unequivocal demonstration that a mechanism can solve problems by functional reasoning.

Linderman (1967) is convinced that the real problem is developing computer programs that not only organize information by subject but also are capable of logically reorganizing stored information in order to respond to the changing needs of library users. She feels the ultimate objective would be to extract underlying patterns of meaning from a complex information network. She believes the developments in programming suggest that a practical need will be felt more acutely in the future for a well-founded mathematical method of executing inductive inference, including hypotheses testing. She concludes that an artificial intelligence system would have to perform the entire inductive process, including the so-called "creative" work which is often considered a necessary ingredient of inductive inference. Watanabe (1960, p. 208) mentions ten important features of inductive inference:

1. Role of inductive inference. Inductive inference contains, as a necessary ingredient, a constant comparison of the deductive consequence from a hypothesis with the experiment. Accordingly, the model theory of inductive inference must permit deductive inference to play a corresponding role within its framework.
2. Logical refutation by counter-example. This is the most elementary step in inductive inference, in which a hypothesis is disqualified when the hypothesis excludes the occurrence of a certain event (observed datum) while actual experience shows that this forbidden event in fact occurs (is observed).
3. Continuous measure of preferential confidence on hypotheses. The essential theoretical difficulty concerning the process of inductive inference stems mainly from the fact that there usually exist a great number of, indeed often infinitely many, hypotheses which are not logically refuted by the available evidence, and which are not necessarily unanimous regarding the outcome of an observation which is not yet made known. For this reason, inductive inference is often declared to be "logically" ill-founded. It should be noted, however, that in actual inductive inference, we usually place preference on

one hypothesis to another even though both are not logically refuted.

4. <u>Successive approach</u>. The essence of scientific method resides not in discovering an absolute truth but in successive improvment of knowledge. This is true whether the term "improvement" means the applicability of a theory to a broader domain of experience, or the capability of a theory in yielding more precise agreement with the experimental measurement within a given domain of experience or a better fit of the predicted frequency distribution of various results with the experimental frequency. This basic nature of scientific method must be reflected in any theory of inductive inference.
5. <u>Effect of judgment from broader experience</u>. A test of hypotheses must be defined by some observational operation, and such a test must be instrumental in the above mentioned successive improvement of the evaluation of the credibilities. However, in this actual evaluation, enough flexibility must be left to accomodate the consideration originating from a broader field of experience, of which the test in question represents only a small part.
6. <u>Absolute certainty of validity of hypothesis denied</u>. No hypothesis should be declared to be a law (i.e., credibility unity) on the basis of a finite number of observed data. This is closely connected with the fact that it is impossible to derive a conclusion (or a hypothesis) for an infinite number of cases from the experience of a finite number of cases.
7. <u>Existence of law with objective validity</u>. Not withstanding the remark (6) above, we cannot deny the existence of a law (probabilistic or deterministic) governing a limited area of experience, for such denial would amount to renouncing scientific quest in general. Corresponding to this situation, it must be guaranteed that some hypothesis, whether or not already considered, reaches credibility unity in the limit where the size of the body of evidence becomes infinitely large. And this selection of hypothesis must be independent of any preconceived judgement, except in the case where there is more than one "equivalent" hypothesis.
8. <u>Distinction between credibility and confirmability</u>. As stated under (3), credibility is the degree of preferential confidence. In other words, it is a relative weight among the competitive hypothesis. As was seen in (6), the credibility is bound to be influenced by the experience at large, except in the limiting case discussed under (7). Distinct from credibility, there must be a certain measure of the degree to which a test (which is a series of the same type of observations) confirms a hypothesis individually taken, completely independent of the other hypothesis and of the experience outside the test in question. This degree of confirmation will be called confirmability and will be normalized so that it becomes unity when the confirmation becomes "perfect." Although credibility and confirmability are conceptually distinct, a high confirmability must tend to increase the credibility.

9. Room for new hypotheses. Usually we cannot from the outset think of all the possible hypotheses to cope with a certain series of experiments. On the contrary, a new hypothesis usually occurs to a scientist after he has accumulated a certain amount of experimental facts. Therefore, the model theory of induction must be such that we can add a new hypotheses at any stage of the process of induction and let it compete with the other hypotheses which have already been considered. In this case, of course, past experience must also be received in the light of the new hypotheses.
10. Anti-ergodicity and inverse H-theorem. Inductive inference is a process such that the distribution of weights (credibilities) become increasingly concentrated on a decreasing number of cases (hypotheses) no matter how widely one distributes the weights initially. Loosely speaking, this is contrary to the tendency of an ergodic stochastic chain in which, no matter on what case one might put the weight initially, the distribution of weights gradually spreads out to all of the cases, which are "connected" to the initially chosen case ... . As the H-theorem shows an increase (or nondecrease) of the entropy with time, in a certain sense of the average value, the inverse H-theorem can be expected to show a decrease (or non-increase) of the inductive entropy with the growth of experience, in a certain sense of the average.

Hunt (1962) describes self-organizing systems as systems which change their internal states in some random manner until they reach an integral stable state. He views artificial intelligence systems as cybernetic devices; they emit a response that causes a user to input a reward signal or fail to input a reward signal, thus completing a feedback loop. He believes that self-organizing systems improve with practice within a given problem area. He concludes that they reorganize their internal information processor based on the feedback being received so that it is more efficient in producing the kind of input-output mappings that are being required of it.

Niesser (1963, p. 193) believes that an artificial intelligence system will soon be fully developed:

> Popular opinion about "artificial intelligence" has passed through two phases. A generation ago, very few people believed

> that any machine could ever think as a man does. Now, however, it is widely held that this goal will be reached quite soon, perhaps in our lifetimes. It is my thesis that the second of these attitudes is nearly as unsophisticated as the first. Yesterday's skepticism was based on ignorance of the capabilities of machines; today's confidence reflects a misunderstanding of the nature of thought.
>
> ... Secondly, machines were once believed to be incapable of learning from experience. We now know that machine learning is not only possible but essential in the performance of many tasks that might once have been thought not to require it. Simple problems of pattern recognition, such as the identification of hand-printing capital letters, have been solved only by programs which discover the critical characteristics of the stimuli for themselves.
>
> Finally, it has often been asserted that machines can produce nothing novel, spontaneous, or creative - that they can "only do what they have been programmed to do."
>
> ... Existing programs have found original proofs for theorems, made unexpected moves in games, and the like.
> ... The sheer amount of processing which a computer does can lead to results to which the adjective novel may honestly be applied. Indeed, complexity is the basis for emergent qualities wherever they are found in nature.

Hormann (1962) believes that in order for an artificial intelligence system to be able to learn from a training sequence and use this experience toward creating its own trial sequence of tasks, it must be able to construct and modify a "cognitive map." He feels that the effective utilization of the cognitive map may be realized by a special higher-level program called a "master monitor" which takes a larger view of the tasks given in the past rather than focusing on one task at any given moment. It was shown earlier how perceptual processes employed in artificial intelligence systems can be organized to make initial analysis of problem structures. This is accomplished by using previous experience stored in memory to reorganize and consequently recode a complex stimulus into a smaller number of familiar units.

Induction is the process of generalizing on the particular. George (1970) believes that this process can be performed by a computer.

He concludes that if two or more events are associated all the time, then that relationship can be described by an inductive generalization.

Cherry (1961) implies that in order for an artificial intelligence system to be adaptive to its environment, it must exhibit a vast constantly changing matrix of conditional probabilities in all possible circumstances. He feels that this can be achieved by setting up a hierarchic structure of organizing sub-routines to determine these conditional probabilities. He views these conditional probabilities as being interlocked in such a way as to represent the structure of the environment with which the artificial intelligence system must interact. He concludes that we are in this sense filling out a world-map ready to be consulted according to current needs and goals.

Garvin (1963) states that the purpose of an artificial intelligence system is to provide relevant responses to an environment. He views the information stored in a memory bank file when combined with a suitable program of operations to be performed on that information as a set of responses to the environment of activity on the file. He describes this file as consisting of stored information concerning stored documents or humanly stored patterns of response. He feels that in each case this file should provide a response to a particular type of environment. He further believes that this environment could be represented by a set of changes, additions, deletions or interrogations concerning the stored items.

Hunt (1962, p. 207) explains the capabilities an artificial intelligence system ought to have:

> ... a digital computer should be recognized as a _list-processing_ device - a type of computing machine originally

developed by Newell and his associates. List processing can be done by the use of a special interpreter and requires no hardware modifications. Two such interpreters are in general use today, Information Processing Language (IPL-V) (Newell, 1961) and List Processing Language (LISP)(McCarthy, 1960b). These interpreters, in effect, create a machine in which the logic of data storage and computation is the interpreter's and not the computer's.

Hunt (1962, p. 211) continues this discussion:

> Set theory was central to the earlier discussion of concept learning. An artificial intelligence system ought to be able to manipulate sets, since these manipulations have such general applicability. Writing artificial intelligence programs in list-processing languages has the advantage that these languages can be thought of as being a special set-theoretic notation. A list may be equated with a set; the symbols on the list (not the cells on the list) become the elements of the set. The basic operations of union, intersection, inclusion, and identity may be made to refer to lists of common and unique symbols on specified lists or list structures.

Horman (1962, pp. 347-367) describes in detail the internal mechanisms of an artificial intelligence system:

> The system of programs proposed here contain three essential components: a community unit responsible for manipulation and generation of programs, execution of which leads to the system's action (either overt or covert); a planning mechanism which takes a larger view of a given task and guides the community unit by designating a rough sketch of a possible course of action; and an induction mechanism which takes a still larger view by considering the system's past experience with various problems and by attempting to apply that experience to related problems which have not previously been encountered. Higher level programs in the system which coordinate the functions of the three mechanisms initiate the task requests for activating each unit.
>
> The function of the community unit is to provide the higher-level programs (customers) with programs capable of performing requested tasks, or to perform a customer-stipulated task by executing a program. If the community unit does not have a ready-made program in stock to fill a particular request, it will have to construct a program and debug it, before outputting or executing it. The process of constructing a tentative program, testing, modifying, testing again, may have to be repeated many times.
>
> Within the community unit the members of a team of routines are identified as the task analyzer, the program provider, and the executor-monitor. ... the interactions between the executor-monitor and the task analyzer comprise the first-order feedback-loop. Its primary function is performance and error detection.

This part of the community unit resembles the TOTE (Test-Operate-Test-Exit) unit of Miller, Galanter, and Pribram; the operate phase corresponds to the executor-monitor and the test phase to the task analyzer. The TOTE unit is illustrated ... by a man using sensory feedback as he moves his arm in the hammering task. A second-order feedback loop is used when all three members of the community unit interact. The primary function of this outer loop is the selection of operations and error correction on the basis of information from the first-order feedback loop. The task analyzer serves as a link between the two loops.

The task analyzer corresponds to the chief engineer in the machine shop and receives incoming requests either in appellative or descriptive form. Since the use of the appellative form assumes the corresponding program to be already in the memory, here we shall consider the descriptive form of the request with the unit having no previous experience directly relevant to the assumed task. Also we shall assume, for simplicity that the task analyzer has a built-in ability to find characteristic features of the task and to determine the proper problem category! The information thus extracted is then channeled to the program provider.

The program provider, corresponding to the design engineer, has a collection of available instructions and programs which is divided into two parts. One part is a permanent set, a standard repertory, which contains basic instructions, sequences of instructions or open subroutines, and closed subroutines, each represented by a single name. The other is a temporary set consisting of records of previously constructed programs. The manner in which members of the temporary set are abstracted and generalized to become members of the repertory represents an important kind of learning which will be discussed later.

Using the information received from the task analyzer, the program provider constructs a tentative program by modifying a previously stored program, by constructing a program from basic instructions, or by assembing a new program from previously constructed programs, modified or unmodified.

Items in the initially given repertory have their descriptions prestored, but the repertory changes as the community unit learns; some members of the repertory are combined to become one item; and some members of the temporary set are abstracted and generalized to be added to the repertory. Each time such a change takes place and each time the task analyzer records a change in current state as the result of its interaction with the executor-monitor discussed below, the description of the item involved must be reviewed and updated.

<u>The act of providing functional descriptions and improving them in the light of experience</u> is an important kind of learning which might be described as <u>constructing</u> and <u>modifying</u> a "<u>cognitive map</u>." It is the <u>utilization</u> of such a cognitive map which enables one to internalize overt action, e.g., considering possible chess moves and, on the basis of information in the cognitive map, internally determining what their consequences would be were they actually to be made.

The cognitive map of the program provider contains functional descriptions of items in the repertory; improvements in its cognitive map mean improvement of its ability to select proper instructions and routines to construct a required program. There are, however, considerable difficulties in describing the function of every item in the repertory. In order to make the utilization of the cognitive map effective, there must be an efficient system for internal coding with reasonably uniform format. Our current attention is restricted to the type of description which can be put in the descriptive request form.

Upon receiving the tentative program constructed by the program provider, the executor-monitor begins executing the given program in one or a combination of the following two modes. In normal, high-speed execution of a sequence of instructions, the executor-monitor transfers control to the address of the first instruction of the sequence. All instructions in the sequence will be executed in high-speed and control will not be returned to the executor-monitor until the end of the sequence is reached. This mode of execution is identical to that of the conventional computer. The second mode is monitored execution. Instead of transferring control to the program location the executor-monitor interprets the execution of each instruction. This mode of execution not only permits the executor-monitor to retain complete control during execution but also to use information on the action and the results of each instruction. Thus it can detect a danger <u>before</u> any destructive action takes place.

The executor-monitor and the task analyzer are the only two parts of the community unit with direct two-way communication. As the executor-monitor executes instructions, the picture of the current state changes. Since the executor-monitor's function is essentially execution, however, and its immediate attention is given only to the current instruction, it has no sense of direction toward the goal. This must be provided by feedback from the task analyzer.

Let us review the original request provided in descriptive form. It is comprised of the original state, the desired state, and information on the task. The task analyzer stores all three as the record of the initial task, but it also stores the current state, which is constantly being changed by the executor-monitor. The task analyzer, with the changed picture of the current state, will go through the analysis of the changed task for each monitored operation. If the analysis shows the category of the changed task is the same as before, the task analyzer will feedback to the executor-monitor a go-ahead signal so that the executor-monitor will proceed to execute the next operation. If the analysis of the current state changes the category, the task analyzer will feedback to the executor-monitor an interruption signal and then transfer control to the program provider with the information about the new problem category. Finally if the task analyzer is informed of a destructive operation which has been detected by the executor-monitor, an analysis of the error will be made. The information

will then be given to the program provider which will make an appropriate modification.

Another serious problem is to provide the mechanism with judgement capabilities comparable to "warmer" and "cooler" feelings of humans. Partial solution to this problem may be possible with a combination of good planning techniques, recognition of partial success, and good credit assigning methods for reinforcement.

Some interesting analogies can be drawn between learning processes of the human and those of the community unit. One is the development of high-speed performance following sufficient monitored experience. When a sequence of actions with which we are familiar is first proposed (either by our teacher or by ourselves) we consciously attend to each step of the sequence. However, once we gain familiarity and confidence, we run through a sequence of actions without being consciously aware of each of its parts.

Another similarity occurs in the progressive grouping of different elements into larger and larger complexes. Suppose we have acquired skills in a number of simple tasks (e.g., some sequences of finger movements on a piano). When we attempt a more complex task which is an integrated sequence of those simpler skills, we have to attend to each step of the sequence although we need not attend to the full detail of each of the basic skills.

Still another similarity between human and community unit experience is a tendency toward abstraction as experience builds up. In many motor skills, we observe that some component skills are very specialized and fit rigidly into a larger pattern. Some component skills, however, when used in a situation calling for variations, can quickly be adapted. Of course, the opposite effect may be evidenced, i.e., previous acquisition of a skill may interfere with the learning of a new task.

Hormann (1964, pp. 55-77) goes on two years later to discuss the internal mechanisms of an artificial intelligence system:

By planning as an aid to problem solving, we mean analyzing a given problem into a number of smaller subproblems.

A planning mechanism which views, at an abstract level, a given task as a whole and then suggests possible divisions of it into a number of subtasks, each of which can be attached by a smaller search (or be further divided), is proposed for the system.

Our planning mechanism is similar in structure to the community unit. In fact, the planning mechanism uses, in addition to its own records, the same record in memory which the community unit uses. We again assume that requested tasks are in descriptive form.

Induction may be defined as the formulation of general rules about observed cases of a phenomenon and the application of these rules to the making of predictions.

The inductive procedure observed in humans may be described in general terms: when a human wants to formulate general rules

about a class of phenomena, he first makes a guess to form a hypothesis; next he deduces certain consequences of his hypothesis and tests them against new and old evidence in the hypothesis, modifies the hypothesis, or forms a new hypothesis and repeats the procedure.

The first phase of any inductive process is performed by the task analyzer of the induction mechanism.

Using the information from the task analyzer, the conjecture generator, with the aid of its own subunit, produces programs which represent conjectures.

We now examine what the subunit does in the case of the top line. Since the cyclic pattern is requested, the task analyzer of the subunit looks for the first recurrent position of the first item on the list "1213131" and finds it to be the third item. It now takes the first two items "12" as defining a cycle phase and asks the program provider to construct a program which will generate "121212 ... ".

Interaction between the executor-monitor and the task analyzer this time shows the results agree with the given sequence "1212121." The task analyzer now outputs the program to its higher-level program, the conjecture generator with a "success" signal. As far as the subunit is concerned, the task is successfully accomplished, although the produced program is proved to be inadequate by the higher-level programs at the later stage.

The consequence generator, together with the task analyzer, step by step examines programs supplied by the conjecture generator. The examination consists of monitored execution. Each item proposed as a member of the solution sequence is in turn proposed to the environment by a task analyzer as a prediction of the next move needed to solve the four-disk case.

The mechanical trainer, serving as the environment of the mechanism first checks the legality of a suggested move by means of the legal move generator. If illegal, the information is fed back to the task analyzer. If legal, the trainer compares it with its stored "knowledge" of the puzzle, and feeds back information whether the move is right or wrong.

After the complete sequence of correct moves becomes known to the task analyzer, the unmatched elements in the suggested sequence and the correct-move sequence are then determined and given to the conjecture generator. The conjecture generator modifies previously constructed programs by parameterization, i.e., it replaces unmatched places with parameters. The resulting programs, when executed, would produce a sequence like this:

$$\underline{121P_1}\ 121P_1\ 12\ - - - -$$

$$\underline{BCCP_2\ AP_3}\ BCCP_2\ - - - -$$

Underlined parts represent cycle phases. P_1, P_2, and P_3 are names of sublists. P_1 contains 3 and 4, P_2 contains A and B, and P_3 contains B and C. The fact that 4 is used for the four-disk

> puzzle is consistent with the conjecture made earlier that successful moves for the four-disk case must contain the element 4. Up to this point, however, this conjecture has not been implemented. Our system learns! Next time it immediately makes use of the corresponding conjecture. When the five-disk case is presented, the task analyzer tentatively includes 5 as one of the possible values of P_1.
>
> ... Of course, the system itself will never know the fact unless told by the trainer. However, as the system gets more and more experience with the puzzle, and the conjecture (the program) is used successfully more and more times, utility values of the conjecture increase so that the task analyzer will tend toward directing or straightforward use of the program.

Man-machine relationships

Ideally, a computer-based information retrieval system should place the full resources of a universal data bank at the immediate disposal of the library patron. This is the overall system objective which the computer promotes. The more specific objectives of the system are determined by the desires of the library patron.

An information-retrieval or automatic abstracting system involves the processing of natural language messages. Garvin (1963, pp. 256-257) explains how an artificial intelligence system can accept natural language messages to retrieve information from library text:

> From the point of view of a machine, library text contains only strings of words and punctuation. Hence, this machine can accept search instructions from a human being only in the form of recorded words, together with certain specifications as to combinations, sequences, punctuation, and frequencies. (The machine may also be provided with a dictionary which can contain human-supplied codes for each word to reflect semantic or grammatical information about that word.) Thus, any attempt to retrieve information dealing with "concepts" or "subjects" must somehow be formulated in terms of words and their combinations. The problems that arise in attempting to do so are best explained with the help of a specific example. Let us consider an information requirement expressed as a question such as:
>
> <u>What</u> <u>factors</u> <u>are</u> <u>critical</u> <u>to</u> <u>the</u> <u>commercial</u> <u>practicality</u> <u>of</u> <u>nuclear</u> <u>power</u>?

> To decide whether a document, an article, or a book deals with nuclear power is, in general, a highly intellectual task, not at all amenable to rigorous formulation as would be required in order to instruct a computer to perform such task. Let us start with an aspect of this task which clearly is susceptible of mechanization and which ought to provide an approximate or partial solution to the problem. We hypothesize that any article dealing with nuclear power will probably contain the phrase <u>nuclear power</u> or some more or less synonymous equivalent of this phase, such as <u>nuclear energy</u> or <u>reactor</u>. The task of searching for a specified phrase is one that can be performed by a computer. The process of searching text for the occurrence of a particular word or a particular phrase is "machine-like" in nature. This phrase-searching task is in sharp contrast to the non-precise, intellectual, or nonmachine-like task of searching for material that is in some way or another "relevant" to the subject of nuclear power.

Dattola (1969) explains that many methods exist for ordering or classifying the elements of a library file. He describes the elements of such a file as being clustered into groups determined by the similarities of the attributes of the elements. He views the elements as documents in information retrieval, and the attributes as words relevant to the documents. He feels that the words describing a document can be thought of as concepts associated with a document.

Dattola (1969) points out that documents are allowed to move freely from cluster to cluster within an artificial intelligence system until a nucleus is created within each cluster. He concludes that the nucleus will thus consist of those documents which are most highly related to each other. He states that after a particular nucleus is formed, the documents which are a part of it will not move from their present clusters.

Garvin (1963) feels the basic problem associated with an automatic library system is the formulation of a mechanical method for identifying a class of documents which will satisfy an arbitrary request for information. He suggests that the conventional approach to an automatic

library system employs index tags representing the content of every incoming document. He describes index tags as a shorthand representation of the content of corresponding documents. He refers to them as "hooks" which the system uses to retrieve desired documents.

McAllister and Bell (1971) believe that computer systems in the future will tend to rely more on efficient interaction with library patrons, working at on-line terminals. Library documents within a computer system can be identified by index tags, but a library patron must be able to identify the proper index tag in order for the computer system to retrieve a relevent document. McAllister and Bell (1971) tell us that system designers and programmers still know very little about what happens when a library patron sits down in front of a terminal. They feel that research dealing with man-machine communication is still very limited.

Linderman (1967) states that the need for better understanding of the relations among inquirer, inquiry, and indexing method became more obvious as the possibilities of the use of mechanized methods for part of the labor of information retrieval became apparent. Linderman (1967, p. 27) goes on to state that if

> ... both the question as originally posed and what was actually wanted were recorded, a most revealing picture of the psychology of the inquirer and his interrogative habits might result.
>
> Documentalists have begun to realize the importance of the reference "interview" and the detailed analysis of what is wanted by the inquirer. The barricade to interpersonal communication set up by the computer has also started the investigation of the input operation and indexing procedures which can most economically, as well as adequately, put into the computer store the information which hopefully, may sometime be retrieved by a future user. (Parenthetically, I should like to insert here that I am sure

that the "feedback" to the maker and reference sources from the thesauri being generated for computer use and from the studies of semantics, syntax, roles, links, and conventional systems, should be of considerable use to reference librarians of the future, whether or not their services become mechanized).

Henley (1970) explains that a fully operational real-time information retrieval system can assist a library patron in his search for information, asking him for further classification where necessary, and consulting the librarian in cases of difficulty or ambiguity.

Machine communication

Bourne (1966, p. 21) tells us that words and concepts cannot be separated as he states:

> ... It is difficult even to think about any known concept without the immediate intrusion of its verbal associate(s) or description. Not only is it the case that most conceptual groupings have meaningful verbal labels but also some concepts are learned and used almost exclusively in a verbal context ... . This state of affairs has led at least one psychologist who has worked extensively in the area to the conclusion that concepts " ... are meaningful words which label classes of otherwise dissimilar stimuli."

Arbib (1972, p. 208) discusses how humans developed language:

> ... Let us speculate, in this vein, on how humans might have "invented" language, and then discuss some experiments which help us understand the functional capabilities the feat would have required. Initially, humans might have used conventional cries to draw attention to a single object, or to encourage the listener to undertake some particular action. It would then be natural to suggest an action with respect to a particular object and so <u>concatenation</u> - the chaining together of signals - could then evolve. Concatenating the typical warning cry of the mother to her child with the signal for some forbidden action might then be the basis for negation, and the first step toward logic. Here then is the beginning of language as a means for communicating perceptions, and trying to share properties of internal models of the world. Where many linguists have taken <u>syntax</u> (the grammatical rules of the language) as primary to the study of language, we would see it as secondary in the evolution of language. If we did not understand the passive construction and registered only the

> elementary meanings (semantics) of "apple", "eat", and "boy", our model of the world would lead us to understand their concatenation as meaning what in English we convey by "the apple was eaten by the boy," rather than "the apple ate the boy." However, as we put more and more "semantic units" together, our model of the world can no longer let us infer a unique relationship between. And thus we may hypothesize that syntax evolved as subtle modifiers became required to distinguish the possible meaning of long concatenations of signs.

Parsegian (1973) views language as based on the experience of macroevents. He believes the experiences themselves are the result of many microevents that are much too small to be observed individually. He gives as an example the ability of the brain to identify readily analogous geometrical patterns and the impossibility of giving unambiguous and complete verbal description of that simple visual faculty.

Garvin (1963) feels, then, that our task is to develop a computer program which will generate sentences in such a way as to characterize certain linguistic abilities and limitations of the speaker of a given natural language. He tells us that a program of this sort must have the ability to construct and understand sentences never heard or uttered before in the life history of an individual; it must have the capability to accept as grammatical or reject as ungrammatical any utterance. Further, he believes that a program with linguistic ability must be able to ascertain in more than one way the presence of grammatical ambiguity.

Garvin (1963) contends that the ability of the computer to make routine yes/no decisions gives it flexibility, permitting it to perform different processing operations in relation to its previous results. Garvin (1963, p. 84) states:

> Before discussing artificial languages, and more specifically computer languages, let us briefly define machine language. The

modern digital computer may be considered as a machine capable of carrying out a sequence of operations upon a set of data. The operations performed by the computer are determined by the fixed hardware, by a set of instructions, and by data themselves. The operating computer may thus be said to obey a sequence of instructions that are programmed by the coder. Let us define an admissible instruction as part of a set built into the computer by its designer. The execution of an admissible instruction is unambiguously defined in terms of a sequence of events which take place within the machine. The total repertoire of admissible instructions forms a finite, precise vocabulary which may be considered as a particular computer language in terms of which the programmer can communicate with the machine.

Newell and Simon (1961, p. 2016) describe a digital computer as a "general-purpose symbol-manipulating device":

> If appropriate programs are written for it, it can be made to produce symbolic output that can be compared with the stream of verbalizations of a human being who is thinking aloud while solving problems. The General Problem Solver is a computer program that is capable of simulating, in the first approximation, human behavior in a narrow but significant problem domain.

Newell and Simon (1961, p. 2012) continue to explain that:

> The instructions that make up the computer program, like the data on which it operates, are symbolic expressions. But while the data are normally interpreted as numbers, the instructions are interpreted as sequences of words--as sentences in the imperative mode. When the computer interprets the instruction "add A to B," it produces the same result that a person would produce if he were asked in English to "add the number labeled A to the number labeled B."

Parsegian (1973) explains that codes such as binary notation are capable of reducing numbers, letters of the alphabet, and even instructions to symbols that consist of a series of two signs, representing the "off" and the "on" condition. He further explains that a message made up of such symbols can then be "written," or punched, or given magnetic representation, on cards or on magnetic tapes.

Newell and Simon (1961) view a computer as more than a number-manipulating device. They feel that the symbols it manipulates may

represent numbers, letters, words, or even non-numerical, nonverbal patterns. They state that a computer has general capabilities for reading symbols, storing symbols in memory, copying symbols from one memory location to another, erasing symbols, comparing symbols for identity, and detecting specific differences between their patterns.

Garvin (1963) points out that natural languages play a role entirely different from that of computer languages. He explains that computer languages are used to formulate instructions; it is inconceivable that the natural languages could be used for that purpose. He concludes that the vagueness and ambiguity of natural languages preclude their use for addressing the computer directly. He suggests that natural languages should appear instead as data which must be translated, abstracted, sorted, and so on. Garvin (1963, p. 96) describes the typical steps in the computer processing of natural language:

> In accordance with the procedural plan initially fed into the computer, it can direct itself through these typical steps in the processing of natural language:
> Reading in a batch of running text in natural order.
> Forming word records for the batch of text.
> Sorting word records alphabetically.
> Calling up dictionary records from a file stored on magnetic tape.
> Collating or merging the word records with the dictionary records.
> Removing dictionary records not matched by word records.
> Re-sorting a merged file into the original text order.
> Repeating the same processing cycle for the next batch of text.

Hunt et al. (1966, p. 3) describe an intelligent device as "something capable of adjusting to its environment."

> ... To make such adjustments the device must continuously be classifying slightly different states of the environment as equivalent or not equivalent. The particular classifications may vary

> from time to time: sometimes we group whales with sharks. Still, the intelligent device must classify. Now suppose that we wish to design such a device. Unless we, the designers, know all the states of the environment which the device may encounter, we have no way of prewiring it with a capacity to develop classification rules from experience. We shall refer to such development as concept learning, and a device that can perform this act will be called a <u>concept learning system</u>.

Hunt (1962, p. 72) concludes that "concepts can be learned via symbols at progressively more and more abstract levels." He further supports the notion that concept learning is equated to the learning of names. He describes a name as a symbol used to refer to a set. He feels that in a natural language such as English it is easier to equate names with nouns. He contends that the idea of a name is more general than this; any phrase or descriptive sentence could also be assigned a symbol, and this would be its name.

Hunt (1962, p. 29) states:

> Church (1958) reasoned that a name has two properties, its meaning or concept and its denotation ... . Church's definition of concept and denotation can be expressed using the set-theoretic definition of description. The denotation of a name related it to particular elements in the universe of objects; the concept of a name relates it to a description of the objects. Specifically, the denotation of the name is the subset of the universe consisting of all objects to which the name can be applied.

We have noted earlier that the capacity for forming and dealing with abstract concepts seems to arise from language and the use of words symbolically to represent and to communicate ideas. Bourne (1966) describes words as "responses which have been associated with states of the world:"

> ... When multiple associations between a response and several dissimilar stimuli--exist for a subject, the word is a label for a concept and can be used symbolically. Insofar as these associations are the same for two or more people, the word may function as a sign in communication. When verbal labels do not

exist, either because the concept is arbitrary and unnatural or because the stimulus attributes do not lend themselves easily to verbal associations, the subject may have difficulty describing the basis for his category responses. This merely shows that words and concepts are independent, though often tied in natural circumstances.

Hunt (1962, p. 13) believes that "no natural (i.e., spoken) language is completely unambiguous. The closest approximation to an unambiguous language is the notation of symbolic logic. Although no presently speakable language is based on formal logic, we can conceive of thoughts as statements in symbolic logic." Hunt (1962, p. 16) continues:

> The notation of symbolic logic is a particularly appropriate language for describing complex mental processes. We can assign symbols to represent all our primitive undefined ideas. Once this is done for a particular problem, we have clear and unambiguous rules concerning the manipulation of these symbols into grammatically correct sentences. ... recent advances in computer technology have provided us with an automatic device for manipulating the formulas of symbolic logic. This has changed the status of symbolic logic from a theoretically possible to a practically feasible tool for theory construction.

List processing is a method which can be used to store data symbolically representing the elements of a natural language. Hunt (1962, 210) describes list processing:

> In list processing, data is stored in a rather different manner than it is in conventional programming. The distinction between data and stored program that is usually found in numerical analysis disappears. Everything, including the program itself, is stored as a list. The program list can be treated as a piece of data by other programs, including its own subroutines. This gives the program a capability for modifying itself, providing that the programmer specifies how such modifications are to take place.
>
> The principle difference between list processing and normal programming is in the method used to refer to items in memory. Digital computers refer directly to the location of a symbol. In list processing symbols are stored on lists of symbols. The name of the list is the name of the location of the "head", or first symbol on the list. As part of its contents this cell contains the address of the cell that contains the first symbol on the

list. The cell containing this symbol also contains the address of the cell containing the second symbol, etc., until the cell containing the last symbol on a list is reached. In this cell the "next location" is replaced by a list termination symbol. The head cell may contain a symbol that is the name of an associated list, or its contents may represent other information. Since the name of a list is a symbol, and may be stored in the head or body of other lists, a complex list structure, or cross referencing system between lists can be developed. Information is found by searching lists until the required symbols are found. Several entries may be provided to a single piece of information by placing a symbol on more than one list. Symbols can be reached indirectly by locating other symbols known to be associated with them.

Another advantage of list processing is that it can be used to program a computer for recursive computations. ... What we are concerned with is the idea of a recursive operation, since such operations are quite important in artificial intelligence research.

A recursive operation is one in which the function being computed contains itself as a subfunction. This means that the original function must, if it is to be nontrivial, contain three separate types of functions; test functions, argument generating functions, and value computing functions.

By convention, data can be stored on two types of lists. A description list is a list that is attached to another list to specify information about it. There is a close parallel between description lists and the idea of descriptions of objects. Description lists have dimensions (called attributes) and values. The description list alternates symbols which specify the type of information (attributes) and symbols which specify the information itself (values). Thus, as a value, an identical symbol may mean different things depending on the attribute with which it is associated. As an example, think of the different connotations of "red" as the name of a color of a traffic light and as the name of a political belief. Since value can be the names of lists, the attribute of a particular symbol may be used to provide entry to an extensive structure of information. In addition, description lists may, themselves, have description lists. A compounding of lists in any manner is called a list structure. The name of the list structure is the name of the list which provides the highest-order entry point in all lists. By "highest order" we mean that by entering this list, a path can be traced, via sublists, to any point in the structure.

Garvin (1963) believes that research into natural language programming will create a sophisticated form of communication between man and machine. George (1970) explains that linguistic analysis is an inductive process in that it attempts to formulate a listing of elements and a set of statements from the examination of written and spoken

language. He feels it is based on the hypothesis that in both of these sources of data, it is possible to derive regularly recurrent elements of different types and orders of complexity. Garvin (1963) concludes that the classification of these elements and the statement of their conditions of distribution resulting from this analysis is then considered to constitute an inductive description of language. He explains that the characteristic of the computer such as its self-sequencing ability, high speed, ability to perform routine decisions, ability to receive and transmit information in a variety of media and formats, ability to select and retrieve stored information at high speed, and its multipurpose adaptability give it many important implications for natural-language-data processing.

Henley (1970) feels that from the users point of view, what is required is something which he finds easy and natural. He concludes that the only thing which qualifies is some form of English. The possibility of natural language input to the system must receive strong consideration.

Stone et al. (1962, p. 484) describe the General Inquirer system:

> The General Inquirer system can be considered to have three main aspects:
>
> 1. Dictionary lookup. In order to ask about the appearance of a member of a particular category of words in a sentence, it is necessary first to look up all the words appearing in the text and tag each one with subscripts naming all the categories the investigator deems appropriate.
>
> 2. Question format. After the text has been tagged, a simple but flexible method of writing questions is used to specify the conditions under which a sentence should be counted or retrieved. Up to a hundred different questions may be considered at once, each question bringing back a separate count of the sentences retrieved and a listing of those sentences under its own heading. For efficiency, questions are grouped into sets with "leading probes" to determine first of all if the sentence satisfies the basic requirements of the entire set.

3. Syntax identification. Syntax problems are handled by providing a few simple marking rules for both preparing the original sentences on IBM cards and for writing the questions. If the investigator does not want to write syntax-specific questions, such markings may be omitted.

The General Inquirer system is written in COMIT, a higher order computer language especially developed for processing written text materials. COMIT was developed by the Mechanical Translation Group at the Massachusetts Institute of Technology and operates on the IBM 7090.

Tirsch (1964) believes that we must first try to decide what it is about the English language that can be described to a computer. He describes the English language as consisting of certain units and a set of allowable arrangements of these units. He states that our informally-defined unit will be called the "word." He feels that using this vague unit, we may consider the "word" to be the basic unit of English. He concludes that having done this, we are able to take the syntactical investigation of the properties of the English language to be an investigation into the allowable arrangements in the text of English "words."

Garvin (1963) tells us that one aim of linguistic science is to construct general rules capable of generating indefinitely many of the sentences of a language, and to predict that sentences never previously uttered will be characterized by the same set of generalizations. He concludes that we must ultimately determine the systematic properties of human language in their most general terms.

Garvin (1963, p. 212) describes an automatic system for grammatical analysis:

An automatic system for grammatical analysis is usually conceived as working its way upward from level to level. First morphological analysis is carried out in accordance with morphological criteria (and lower-level criteria as well; similarity of sound or spelling is used in deciding whether two forms are forms

of the same word). Next syntactic analysis is carried out, using morphological and syntactic criteria. Then semantic analysis, using semantic and syntactic criteria, is performed. How far the sequence of levels continues is still an open question, but the proposed automatic analysis programs pass from level to level in one direction only.

Garvin (1963) tells us that a finite set of rules which enumerates an indefinitely large number of grammatical sentences in a language is called a generative grammar. He feels that unlike other forms of grammar, generative grammar does not give the reader an opportunity to construct new sentences based on the "analogy" of those that are cited and analyzed. He explains that transformational grammar is a generative grammar; it is a grammar which attempts to produce all the sentences of a language to include all possible sentences as well as the ones actually recorded. He concludes that an adequate grammar of English should enable a person to produce not just those sentences that have been said in the past, but all the sentences that a native speaker is capable of creating or understanding.

Liles (1971, p. 8) describes transformational grammar:

> In some respects transformational grammar is similar to traditional grammar. Transformational grammar assigns each sentence an underlying structure that is called a deep structure. Some traditional grammars used a similar concept in speaking of "understood" elements. For example, they said that Tom is taller than I has the underlying form Tom is taller than I am tall and that imperative sentences such as Come here have an understood subject you. Transformational grammarians agree, but apply this idea of underlying structure to every sentence and express it in a more abstract form than traditional grammarians did.

Liles (1971, p. 30) describes transformational grammar as being organized into three sections or components:

> 1. The syntactic component contains the phrase-structure and transformational rules and provides the structure of the sentence.
> 2. The semantic component on the P-terminal string after entries from the lexicon have been added and gives the sentence its meaning.

3. The phological component operates on the sentence after all transformations have been applied and gives the sentence its final form.

Liles (1971, p. 43) concludes that phrase-structure rules can produce the structures underlying sentences:

> The phrase-structure rules can produce the structures of such sentences as <u>These boys might have been swimming in the lake</u> and <u>The manager wrote a letter</u>. They cannot produce such structures as the following:
> 1. The manager didn't write a letter.
> 2. Did the manager write a letter?
> 3. Who wrote a letter?
> 4. What did the manager write?
> 5. A letter was written by the manager.
> 6. Because the manager wrote a letter ...
> 7. The letter that was written by the manager ...
> 8. The letter written by the manager ...
> 9. For the manager to write a letter ...
> 10. The manager's having written a letter ...
>
> All of these structures seem to be related in some way to <u>the manager wrote a letter</u>. The same relationships are found in all of them: the manager is the one who performed the act of writing, and a letter is the result of this action. In spite of the differences in form, there is a similarity in meaning in all the structures. Transformational rules are used to produce these changes in form.

Liles (1971, p. 12) further believes that "in addition to rules that generate the sentences of English, we also have a means of representing the exact choices that are made in the derivation of specific sentences." He calls this representation a "tree." Liles gives as an example the following sentence:

"Yes, that man drinks milk."

Liles follows this example by stating:

> Sentences in English are not composed of mere sequences of words; rather, ... they are composed of words that cluster together often in complex hierarchies. In the above sentence, that man drinks milk is one cluster which in turn is composed of two subordinate clusters: <u>that man</u> and <u>drinks milk</u>. Notice that the tree (Figure 4) shows this arrangement.

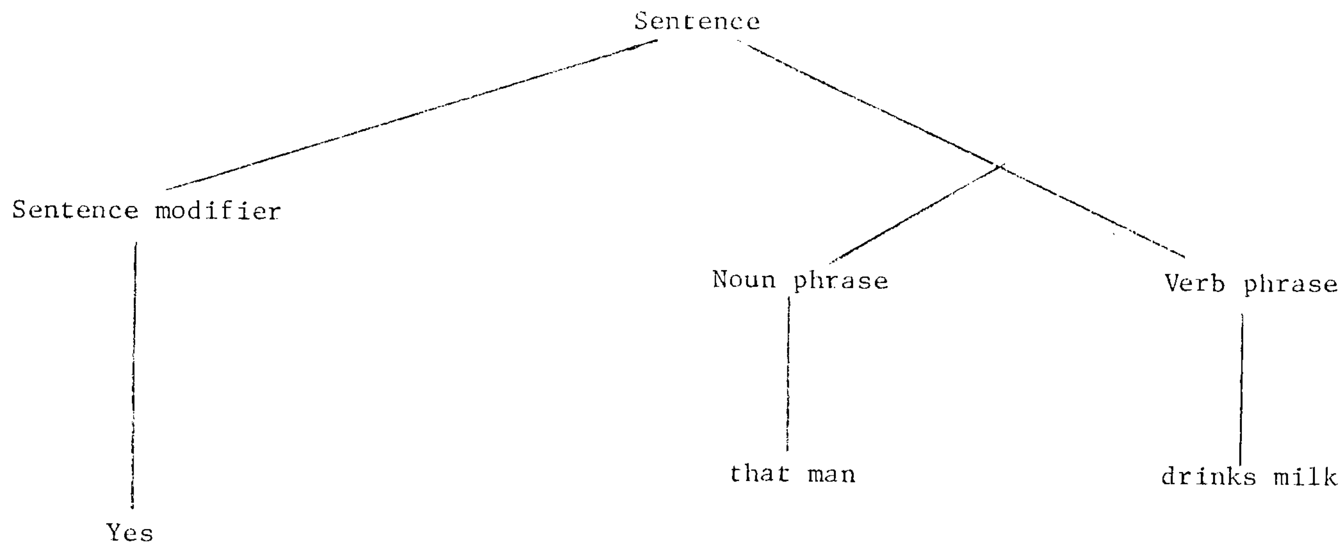

Figure 4. Transformational "tree."

Liles (1971) concludes that transformation is a process which converts deep structures into surface structures. He continues to explain that because transformations affect form, two surface structures may be different but share the same deep structure. Liles (1971, p. 67) states:

> ... On the surface, She read me a story and She read a story to me are different, but the native speaker of English understands them to mean the same thing. Our grammar shows how the sentences are related by saying that they have the same deep structure but that the optimal indirect object transformation has been applied to the structure of the first sentence but not to that of the second.

Liles (1971, p. 99) concludes that "surface structures are often structurally ambiguous; deep structures never are."

Garvin (1963) tells us that we can now see what the grammatical part of a machine-translation system must do. He feels that using the indicators of a natural language such as syntactic types, occurrence order, and punctuation in conjunction with transformational rules, the system must determine the structure of each input sentence. He believes that given the structure of a sentence, the system must find devices in the output language with which to indicate that structure. He concludes that on the input side, there may be ambiguities; sentence-structure determination can end with more than one possible interpretation of a given sentence. He contends that syntactic analysis through the use of transformational rules can reduce this ambiguity in most cases.

Salton (1970, p. 338) describes the SMART system:

> ... The SMART system is an experimental, fully automatic document retrieval system, operating with an IBM 7094 and a 360 165 computer. Unlike most other computer-based retrieval systems, the SMART system does not rely on manually assigned keywords or index terms for the identification of documents and search requests, nor does it use primarily the frequency of occurrence

of certain words or phrases included in the texts of documents. Instead, an attempt is made to go beyond simple word-matching procedures by using various intellectual aids in the form of synonym dictionaries, hierarchical arrangements of subject identifiers, statistical and syntactic phrase-generation methods, and the like, in order to obtain the content identifications useful for the retrieval process.

Summary

Henley (1970, pp. 3-4) describes a computer as a collection of "machinery or hardware" consisting of four elements. He goes on to state that "there is the store, or main memory, of the computer which holds items of information for as long as they are needed; a second component is the control unit, which examines the instructions contained in the program, and sends out the electronic signals which instigate the required operations; thirdly, there are the arithmetic and character-handling units, which perform the requested operations on items contained in the main store; fourthly, there are a number of input/output devices controlled by device control units, by means of which information is communicated to and from main store."

Hunt (1962) explains that a list of computer instructions taken as a whole is called a program. Feigenbaum and Feldman (1963) consider the instruction to "compare and transfer control" very important because it enables the computer to make a simple two-choice decision - to take one of two specified courses of action depending on the information found in the same cell of the memory. By cascading these simple decisions, highly complex decisions could be fashioned.

Kucera (1969) describes a computer as much more than a machine performing calculations. He believes that aside from their mathematical operations, computers can process, organize, compare, and manipulate

data of a non-numerical nature including textual information. He concludes that it is this capacity of computers to deal with letters, words, sentences, or even whole texts that has made them of considerable importance in the study of language.

Hunt (1962) tells us that mechanical concept learners can be viewed in the same manner as biological concept learners which acquire categorizations based on an internal representation of an external object. He believes that categorization in concept learning involves the manipulation of coded symbols representing the objects to be categorized. Hunt et al. (1966) describe concept learning as a hierarchial process - an organism must have a concept in order to learn more concepts. It follows then that any value of an attribute is itself a concept, and when we speak of concept learning devices, we are talking about devices which discover rules for combining previously learned concepts to form a new decision rule.

Shepard (1964) views the problem-solving ability of an organism as dependent in considerable measure upon the association structure of its memory and the consequent efficiency with which it is able to retrieve from memory that which is most relevant to a given situation. He points out that such associative connections which are not yet built into the hardware of modern computers is implemented in programming systems such as IPL and LISP. He states that these programs provide for the symbolic linking of each newly-stored item of information to any previously-stored items so as to form lists or "trees."

Hunt (1962) implies that problem-solving for an artificial intelligence system could consist of the application of "TOTE units." He describes a TOTE unit as a test to determine the difference between current knowledge and the desired state, operating to reduce these differences, and then testing again. He believes this type of cognitive psychology makes a strange appeal to the computer program as a model. A computer can be programmed to test data, to operate to reduce differences, and then to retest.

Linderman (1967) is convinced that the real problem is developing computer programs that not only organize information by subject but also are capable of logically reorganizing stored information in order to respond to the changing needs of library users. She feels the ultimate objective would be to extract underlying patterns of meaning from a complex information network. She believes the developments in programming suggest that a practical need will be felt more acutely in the future for a well-founded mathematical method of executing inductive inference, including hypotheses testing. She concludes that an artificial intelligence system would have to perform the entire inductive process, including the so-called "creative" work which is often considered a necessary ingredient of inductive inference.

Ideally, a computer-based information retrieval system should place the full resources of a universal data bank at the immediate disposal of the library patron. This is the overall system objective which the computer promotes. The more specific objectives of the system are determined by the desires of the library patron.

Dattola (1969) explains that many methods exist for ordering or classifying the elements of a library file. He describes the elements of such a file as being clustered into groups determined by the similarities of the attributes of the elements. He views the elements as documents in information retrieval, and the attributes as words relevant to the documents. He feels that the words describing a document can be thought of as concepts associated with a document.

Bourne (1966) tells us that words and concepts cannot be separated. Newell and Simon (1961) view a computer as more than a number-manipulating device. They feel that the symbols it manipulates may represent words or concepts.

Hunt (1962, p. 72) concludes that "concepts can be learned via symbols at progressively more and more abstract levels." He further supports the notion that concept learning is equated to the learning of names; a name is a symbol used to refer to a set. He feels that in a natural language such as English it is easiest to equate names with nouns. He contends that the idea of a name is more general than this; any phrase or descriptive sentence could also be assigned a symbol, and this would be its name.

Garvin (1963) points out that the vagueness and ambiguity of natural languages preclude their use for addressing the computer directly. He suggests that natural languages should appear instead as data which must be translated, abstracted, sorted, and so on.

Hunt (1962) believes the closest approximation to an unambiguous language is the notation of symbolic language. List processing is a method which can be used to store data symbolically representing the

elements of a natural language. Garvin (1963) feels that the characteristics of the computer, such as its self-sequencing ability, high speed, ability to perform routine decisions, ability to receive and transmit information in a variety of media and formats, ability to select and retrieve stored information at high speed, and its multi-purpose adaptability give it many important implications for natural-language-data processing.

Garvin (1963) tells us that using the indicators of a natural language such as syntactic types, occurrence order, and punctuation in conjunction with transformational rules, an artificial intelligence system must determine the structure of each input sentence. He further believes that given the structure of a sentence, the system must find devices in the output language with which to indicate that structure. He concludes that on the input side, there may be ambiguities; sentence structure determination can end with more than one possible interpretation of a given sentence. He contends that syntactic analysis through the use of transformational rules can reduce this ambiguity in most cases.

CHAPTER V

COMPUTERIZATION OF REFERENCE SERVICE

Communication

Katz (1969) tells us that a reference interview situation exists where a library patron is not certain what he wants or where there is a problem as to exactly what kind of information he needs. A computer-based information retrieval system just like a reference librarian must constantly be driving to clarify the question and to match it with the information source.

Katz (1969, p. 53) presents the steps a reference librarian and indeed an artificial intelligence system must follow to clarify a reference question:

> 1. Purpose. Classify the question in terms of purpose. This appears simple enough, but it is not always easy or advisable to ask a patron why he wants a particular answer. Frequently the librarian must ask *himself* what would the patron do with the answer if he had it. In many cases the purpose may be relatively apparent. The age, education, the experience, or even the sex of the user may indicate purpose.
>
> 2. Scope. Classify the question in terms of scope. How much material is required to answer the query - an encyclopedia article, a magazine article, a book, several books, or what? Scope will depend upon the need of the patron and the difficulty of the question.
>
> 3. Time. Classify the question in terms of time. Is this a current or a historical topic? If it is a current topic, what are the limits on the age of the materials in which the answer may be found - one month, one year, or several years?
>
> 4. Key words. Classify the question in terms of descriptive expressions or key words. Have the terms been encountered before? The librarian should not hesitate to confess that he does not really know what the terms mean.
>
> 5. Subject. Classify the question in terms of subject. ... the majority of questions clearly indicate what the subject is. ... The essential problem with subject is a matter of scope. How much material is required, at what level, and in what specific area of the larger subject?

6. Need for "bridge." Classify the question in terms of whether it requires a "bridge" in the form of an index or bibliography, or simply one or two reference works that contain the answer. ... The fact question, "What are the dimensions of the moon?" can be readily answered in an almanac, an encyclopedia, or some other reference book specifically geared to astronomy. Once the distinction between the "fact" and the "bridge" type of question is clear, it is primarily a matter of knowing the broad sources and then narrowing them as rapidly as possible.

7. Form. Classify the question in terms of form. Most patrons have an idea of the form in which they expect the answer --a book, chart, map, picture, etc. ... A major problem here is that when a patron knows he wants an exact reproduction of an item, that particular item cannot be found through the card catalog because it is part of a larger unit. For example, the user who wants a specific poem rarely can find it through the catalog but must resort to an index of poetry.

8. Language. Classify the question in terms of language. Can the user read more than one language? ... Another aspect of language is the level of reading comprehension. The specialist will require one approach, the layman quite another, and the young student still a third.

9. Availability of material. Classify the question in terms of availability. Is the material to answer the query in the library? If not, can it be retrieved quickly from another library? Is the patron willing to wait, and for how long, for the answer from another source?

Henley (1970, p. 17) is convinced that user-orientation or openness to his needs must receive high priority in the design of a computerized information retrieval system:

> Apart from the lending library type of function, three separate requirements may be discussed, connected with three different types of library user. They are:
>
> 1. Browsing. The user who has no specific information or document in mind, and merely wants to look around for something of interest.
>
> 2. Information retrieval. The user who has an occasional or periodic need for specific information or documents of one kind or another.
>
> 3. Regular notification. The user who expects to be informed of recent literature in his own particular field.

West (1975) contends that the education of librarians to become "information intermediaries" is an immediate and difficult problem. She feels that this problem goes beyond teaching librarians how to

initiate commands on a computer terminal. She believes the basic problem is teaching librarians how to approach information per se. West (1975, p. 276) explains this basic problem:

> ... The traditional reference method in a public or academic library is to respond to a question by supplying an answer from a "reference book." Further effort in the academic library is directed toward educating the patron to use the tools; the arduous literature search on behalf of the user takes place only in the special library or information center. In effect, reference librarians must be retrained as special librarians - accustomed to structuring search, employing a variety of search strategies, and being familiar with a large number of data bases in various subject fields.
>
> This retraining may take place in a variety of ways: formal course work in a library school environment, workshops or institutes sponsored by professional associations, in-service training sessions in the libraries themselves. In whatever form, it is essential if libraries are to survive as information suppliers and not be forced to retreat to the role of mere information warehouses. One of the statements of the National Commission on Libraries and Information Science with which we can certainly agree is that "It is essential ... that all librarians understand the potentials of new technologies, and this is especially true for those librarians who serve the user directly."

Advanced computer models

Meredith (1971) describes REFSEARCH as a machine-assisted approach system which attempts to bring the library patron to a position from which he can take the final step to retrieving the information he is seeking. REFSEARCH is based on the assumption that every reference question has a "handle" or specific noun central to the sense of the question and indexable somewhere in the general reference collection. It translates the handle to some category that fits the notion of the kinds of things indexes are about. The library patron must translate his information needs into handles which are suitable for use as categorical terms controlling specific approaches to data. Meredith (1971, p. 177)

chose the following handles or categories as the most appropriate for general reference purposes.

FIELDS
NON-LIVING OBJECTS
PRODUCTS
HUMAN PROCEDURES
CONCEPTS
NATURAL PROCESSES
LIVING OBJECTS
ART WORKS
CORPORATE BODIES
WORDS
PLACES
PERSONS
EVENTS
DATES
ERAS
LAWS
LANGUAGES

Meredith (1971) states that the next step in developing these access categories was to divide or qualify them in such a way that they could be narrowed to correspond more closely with the information needs implied in a query. Victor Hugo, for example, would be categorized as a PERSON (category), then as DEAD (qualified), REAL (qualifier), PROPER-NAMED (qualifier), and an INDIVIDUAL (qualifier), thereby acquiring subject specification that would be accommodated quite well by some reference works and not by others. From this point, REFSEARCH would provide the library patron with a list of reference works most closely matching the subject specification of his query.

The Educational Resources Information Center (ERIC) employs the Boolean search technique to sort out only those citations which satisfy the needs of a particular research problem. The Boolean search technique is important to us as an example of a computer program which sorts "sets" of information on a given subject and then combines these

sets to retrieve relevant publication citations. Brown (1975, pp. 17-18) describes in detail an ERIC computer search:

> In order to have an effective computer search performed, you should be familiar with some of the basic components of the process. The first component is the "search strategy"--the statement of the research problem formulated in terms that the computer is able to recognize and deal with. In the ERIC system the problem must be translated into ERIC descriptors and set up using a Boolean search technique.
>
> A Boolean search technique allows the computer to sort out only those citations which satisfy the needs of the particular research problem. In order to accomplish this sorting, the computer is instructed to establish "sets" of information on a given subject and then to combine those sets to retrieve the relevant items. Drawn below is a "Venn diagram" consisting of three overlapping circles. We can visualize these circles as sets of information about a given subject. Circle A might contain citations about educational films; Circle B, information about secondary education; and Circle C, information about Spanish speaking persons.

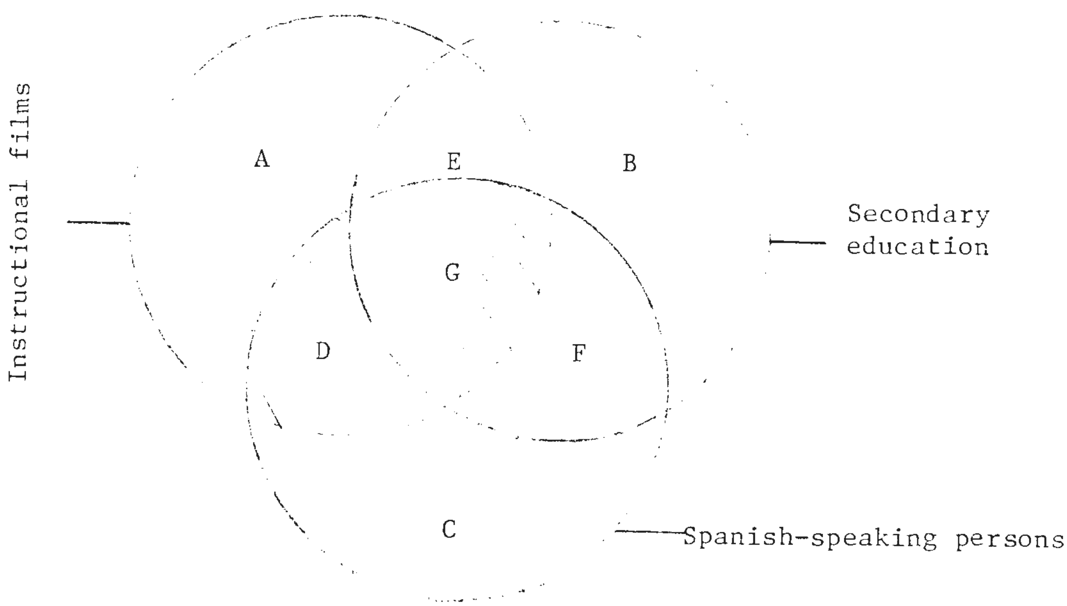

Figure 5. Venn diagram.

By looking at the diagram it becomes obvious that information about using instructional films at the secondary level would be contained in the area marked E + G. Information about using instructional films with Spanish speaking individuals would be found in area marked D + G; and information about using instructional films with Spanish speaking students at the secondary level would be found in the area marked G. It is also obvious from the diagram that the more narrowly defined the topic, the smaller the number of items in the set. Each report in such a narrowly defined set should be highly relevant.

With this background it is easy to see that you must be very clear about the information needed to answer the question. The search analyst who conducts the search for you will probably ask questions or have a form that is designed to elicit information that can be translated into a Boolean search formula. Typical questions are:

What age or school level will you be dealing with?
What media or teaching method are you interested in?
What type of document (journal article, conference report, curriculum guide) are you most likely to need?

Other questions may be designed to find out whether you desire broad general coverage of the topic with the possibility of retrieving some irrelevant information, or a tightly defined coverage with the possibility of missing a few relevant items.

Information science

Shera (1972, p. 789) cites Harold Borko's description of information science. Harold Borko sees in information science a true discipline ...

> ... that investigates the properties and behavior of information, the forces governing the flow of information, and the means for processing information for optimal accessibility and usability. It is concerned with the body of knowledge relating to the origination, collection, organization, storage, retrieval, interpretation, transmission, transformation, and utilization of information. This includes the investigation of information representations in both natural and artificial systems, the use of codes for efficient message transmission, and the study of information processing devices and techniques such as computers and their programming systems.

He further maintains that information science is interdisciplinary in that it derives from and relates to such fields as mathematics, logic, linguistics, psychology, computer technology, operations research,

the graphic arts, library science, management, "and similar fields." Shera (1972, p. 789) further contends that

> ... information science is an area of study and research which draws its substance, methods, and techniques from a variety of disciplines to achieve an understanding of the properties, behavior, and flow of information. It includes systems analysis, environmental aspects of information and communication information media and language analysis, organization of information, man-systems relationships and the like." Thus [we] arrive at a definition of information science as the "investigation of communication, phenomena and the properties of communication systems." Such a definition which has the virtue of brevity and sharpness, would seem to be the most satisfactory of any yet devised, provided it is understood that by "communication" is meant the transfer of any kind of knowledge through any medium or environment.

Linderman (1967, p. 161) concludes that "since information is by definition something that is or can be put into linguistic form, there is a presumption that computers will someday take over the job of receiving, assembling, analyzing and inferring from it."

Systems design

Linderman (1967, p. 177) believes that an "important current development for the future of reference work has been the introduction of systems thinking into library procedures work." Linderman (1967, p. 183) continues:

> Systems thinking - with its new formulation of problems, its choice of more appropriate objectives, its hope for ingenuity in inventing new systems, and its recognition of the principle that library procedures are basically information processes - opens up whole new areas of thought about libraries. Perhaps the most important concomitant of systems thinking will be the increasing comprehensiveness of library systems which alone stimulates a whole new intellectual approach to library problems. ... However, were it not for the advent of the computer, it would not be possible to do much systems activation, for it is the computer which will enable librarians to manipulate information in library systems.

Warheit (1970, p. 74) suggests that "from a practical point of view, one can develop and implement only one application at a time. ... It is necessary, therefore, to develop single applications and to design them in such a way that they can become of an integrated system." Warheit (1970, p. 76) further states:

> With knowledge of how he wants his system to develop, the librarian is now able to establish priorities and allocate his resources. The emphasis will be on file building, on capturing the record. Acquisitions programs or circulation control systems will come first. Work on the display terminal and communication will come later after searchable files have been built up.

Henley (1970, p. 72) feels that "real-time brings all the techniques necessary for an efficient retrieval system almost within the bounds of practicability, at the expense of a new burden of programming which the computer specialist must accept." He further states:

> ... System design in libraries may be as complex as it is anywhere else. The ideal should be an efficient, easy to use document analysis and retrieval system, with ample media for user contact, participation and feed-back; computer conversations, with machine acting the part of interviewer or asking the librarian for assistance in difficult cases; and a combination of the speed, accuracy and scope of the machine, with the expert judgement and experience of the librarian.

Burns (1971, pp. 297-302) describes the "four steps or phases of a systems survey" which he labels "the systems analysis phase, the systems design phase, and the implementation/evaluation phase:"

> The systems effort begins with a problem defined by the analyst as a system existing in an environment of other systems and bound by certain constraints. The first step is to isolate the system under review so that it can be described in an unambiguous fashion. This is the systems survey stage and marks the beginning of a series of successive partitionings which take place until the system has been divided into the smallest logical component still capable of being identified with the system being studied.
>
> ... After dividing the system into its molecular components, the analyst then proceeds to delineate the alternatives he has created by rearranging these component parts in whatever fashion

the resources and goals of the system will allow, always being careful to work within the constraints which the system's environment dictates. The analyst then proceeds to evaluate these alternative solutions in the light of the stated goals or objectives and selects from them a preferred course of action which he recommends to the decision-maker.

... But how does all this apply in a library environment where the goal is that nebulus entity "service?" In order to answer this question realistically, one must first decide what constitutes the library's service goal. The author has chosen to adopt the definition of the library's goal that Mackenzie has used: "to assist in the identification, provision and use of the document or piece of information that would best help the user in his study, teaching or research, at the optimal combination of cost and elapsed time. ... "Efficiency, when used in this context, becomes either answering more of the "needs" of a reader while holding costs and elapsed time constant, or meeting the same needs while cutting down costs and elapsed time.

In the first phase of the systems study, the analyst conducts what is called the systems survey, during which he relates the system under review to other systems in which it is embedded - to its environment if you will - by determining what is germane to the problem being studied. Once these boundaries have been established, the analyst begins to lay out the problem in very general terms, specifying the goals and functions of the system under review.

... The analyst is now ready to begin the second phase of his study, preparation of a block diagram or system schematic, which outlines in a very general way the tasks performed by the system and the relationships which exist between the subsystems.

... Construction of the block diagram and the flow charts are the first concrete expression of an analysis effort which up to now has been primarily a data gathering and intellectual exercise.

... There still remains the difficult problem of evaluating intangibles - those factors which cannot be quantified, such as convenience, availability, prestige, etc. - and if the cost studies have been close, intangibles become crucial to the decision-making process.

... The next phase, systems design, usually follows when the analysis efforts have been completed and carefully digested. In theory, these steps should be discrete. In actual practice, however, they seldom are, for the decision efforts will often overlay the analysis studies.

... The final phase begins with the implementation of the prototype system and its test/evaluation. This is often the most expensive single phase and its success depends on all earlier phases being in a state of completion.

... It is obvious that such work is a prerequisite to library automation, but it does not necessarily follow that automation will automatically succeed the systems efforts. Indeed, the study

> can easily indicate that library automation is not appropriate given the existing resources of time, money, staff, or space. In essence then, systems work is a method - part science, part art - whereby one determines the correct balance between constraints and the resources necessary to realize predetermined goals, and leads to the establishment of realistic priorities based upon a thorough understanding of the total system being studied and its relationships to all other systems having a common interface.

Avram (1970, p. 487) brings the concept of "systems design" as it relates to the computerization of library reference service into focus when she states: "The problems facing the planners of automated library networks are rooted in the complexities of organizing and managing a vast flow of bibliographical information and its interface with users."

Costs

Cost is presently a primary factor limiting the computerization of library reference service, and indeed the computerization of all library functions. Garvin (1963, p. 284) believes that the cost of experimental testing is significant, particularly in the field of information retrieval.

> ... Some of the experiments which are now underway are very valuable experiments, very important experiments, very necessary experiments, but also very expensive experiments. The cost of getting literature into mechanized form for language translation, or for running experiments in information retrieval, are substantial. If any barrier really exists in the application of scientific method to this field, it is probably this one.

Shoffner (1970, p. 450) summarizes some of the cost and size characteristics of library automation efforts:

> ... the libraries: 1) they are small organizations (in relation to industry), 2) there are a large number of them, 3) personnel constitutes the major cost (two-thirds) of library operations, 4) taken together, libraries are a noticeable portion of the national economy (approximately 0.1 percent of the GNP), and 5) libraries are growing.

Shoffner (1970, p. 451) is not optimistic about decreasing library expenditures:

> ... Over the fifteen-year period from 1951 to 1966, salary scales were increasing at the rate of 4 to 5 percent per year. Because of this, the cost per unit of library operation has risen at the rate of 2.5 percent per year. So long as the technology of library operations remains the same, costs are likely to increase in this manner, even without changes in volume of operation. However, there are also changes in volume of operations as a result of increases in purchasing levels in response to increasing publication and increasing demand. The rate of publication is said to be doubling every fifteen years. Library patrons are placing an increasing level of demand on libraries, and by the end of the century there will be 100 million more people in the United States. The implications of this are enormous for libraries as well as for all public services.

Continuing this discussion, Shoffner (1970, p. 459) points out that "libraries are in a position in which the penalties for failure for both the library and the administrator are far greater than have been the possible rewards from the successful application of computers to library operations." He believes that federal funding is an important factor in simulating library automation because it provides the development capital and thereby reduces the risk to the library.

DeGennaro (1970, p. 539) outlines the cost factors involved in the development of an automated information retrieval system:

> ... Input keyboarding is only one of the costs and by no means the major one. Tagging the elements and editing the copy require the greatest effort and are the most difficult to accomplish since they demand personnel with training and experience in bibliographical work, and such persons are in extremely short supply. Computer and other machine costs are also significant, as well as project direction, administration, space, and other overhead costs. Another major category of expense which is frequently overlooked or misunderstood is the very high cost of software development - systems design, programming and program maintenance. Expense is not the only problem; it is difficult to find and hold the highly skilled persons who are needed to do this complex technical work.

DeGennaro (1970, p. 547) describes the cost factors involved in the RECON study conversion method:

> Applying the unit cost of the least expensive RECON Study conversion method, i.e., $1.51, and 386,000 English-language records in the record set from 1960 to March 1969 could be converted for an estimated $581,000. The cost of converting the 1,728,000 English-language records from 1898-1959 would be $2,602,000. To convert the estimated total of 2,114,000 English-language records would cost nearly $3,100,000. Since this is approximately half of the entire LC record set, the cost of converting the whole set would be on the order of $7 million.
>
> The cost of systems design and software for a conversion system is estimated at $569,000 and is constant regardless of the number of records to be converted. The cost of hardware is based on the total number of records to be converted over a period of years and is therefore an extremely complex factor. However, for purposes of this discussion, the conversion, storage, and manipulation of the four million entries in the record set would require a two-shift computer system costing an estimated $7 million over an eight-year period. This system would support more than mere conversion operations; it would provide equipment for a national bibliographical service.

DeGennaro (1976, p. 177) describes the Stanford system and what is being done to reduce costs:

> ... the Stanford system, called BALLOTS, is an online interactive system with multi-file and multi-index capabilities and using video display units in such a way as to allow for its extension, in phases from technical processing support to other areas of library operations and eventually to serve as a central system for a library network. Although it has been supporting the day-to-day acquisitions and cataloging operations of the Stanford libraries since November 1972, operational costs in this mode are excessively high and efforts are currently underway, as a result of a recent CLR grant, to make the expansions necessary to permit the system to support a large-scale network for California similar to OCLC.
>
> ... Stanford is actively trying to promote BALLOTS as a node for a western library network and this is undoubtedly where its future lies.

Parker (1969, p. 312) concludes that "it seems probable that co-operation between libraries will provide the most efficient means of procuring the computer capacities required. Their similar problems can use the same programs and utilize the same peripheral equipment. Since

the data stored are of the same nature and much is common to many libraries, more economical use can be made of the mass storage devices."

National library system

Parker (1969, p. 309) points out that library resource sharing is based upon two assumptions: "the first, that libraries are not alike; the second, that the holdings of any one library which are distinctive are likely to be lesser used and therefore available for use by the clientele of the other co-operating institutions."

Parker (1969, pp. 314-315) describes a national library system:

> Let us look for a moment at the schematic organization of such a bibliographic network. Ideally there would be a central data bank which would serve the entire area, whether it be a political unit or merely a convenient geographical one. At this highest level would exist standardized bibliographic descriptions of all materials held anywhere within the limits of the system. Each record would be keyed to the regional data bank or banks within the total area which recorded the item.
>
> Regional bibliographic centers would be connected by trunk lines to the area data bank; in turn, each center would be connected by terminal to each library participating in the system. There would be an auxiliary data bank for the region, containing the records of those bibliographic items owned by the participants. The direct on-line inquiries made from the individual library to the regional bibliographic center would be essentially of two types. The first would be related to the acquisition of materials, in which case the bibliographic data itself would be the most important element. Occasionally, knowledge of which library already owned the material would be of significance in determining the desirability of acquisition. The regional center would perform various services related to acquisition for the member libraries, including creation of purchase orders, accounting work related to them, preparation of new book lists, special indexes, and the like.
>
> In either kind of situation, if the item desired were not within the regional center there would be an automatic switching to the central data bank. If acquisition is the object of the inquiry, the process can stop at this point. If the object is interlibrary loan the central computer would transfer the inquiry to the regional center closest to the requisitioning library. The process would then lead to a message to the library owning the book, requesting its loan or transmission of a fascimile image.

> The great rewards of cooperation are becoming feasible technologically as a result of developments in computers and in communication. They will be realized only with interlibrary cooperation on a scale not yet experienced, cooperation which must bridge language, nationality and the seven seas.

Parker (1969, p. 312) cautions, however, that "under the pressure of absolute conformity, if there is to be cooperative use of computers, standardization which has appeared to be an unattainable ideal becomes an absolute necessity." Avram (1970, p. 491) concludes that "the dominant purpose of standardization of the bibliographic record and the provision of means of rapid communication is to facilitate the pooling of bibliographic information. If these conditions are met, the amount of information in the network will tend to equal the sum of the information in all of the individual libraries."

Summary

Katz (1969) contends that a reference interview situation exists where a library patron is not certain what he wants or where there is a problem as to exactly what kind of information he needs. A computer-based information retrieval system just like a reference librarian must constantly be driving to clarify the question and to match it with an information source. Katz (1969) presents some of the steps a reference librarian and indeed an artificial intelligence system must follow to clarify a reference question. These steps are: purpose, scope, time, key words, subject, need for "bridge," form, language, and availability of materials.

Meredith (1971) describes REFSEARCH as a machine-assisted approach system which attempts to bring the library patron to a position from which he can take the final step to retrieving the information he is

seeking. REFSEARCH is based on the assumption that every reference question has a "handle" or specific noun central to the sense of the question and indexable somewhere in the general reference collection. It translates the handle to some category that fits the notion of the kinds of things indexes are about.

The Educational Resources Information Center (ERIC) employs the Boolean search technique to sort out only those citations which satisfy the needs of a particular research problem. The Boolean search technique is important to us as an example of a computer program which sorts "sets" of information on a given subject and then combines these sets to retrieve relevant publication citations.

Henley (1970) is convinced that user-orientation or openness to his needs must receive high priority in the design of a computerized information retrieval system. Three separate requirements may be discussed which are connected with three different types of library user. These requirements are: browsing, information retrieval, and regular notification.

Shera (1972) cites Harold Borko in describing information science as a true discipline. Shera (1972) goes on to maintain that information science is also interdisciplinary in that it derives from and relates to such fields as mathematics, logic, linguistics, psychology, computer technology, operations research, the graphic arts, library science, management, and similar fields.

Linderman (1967, p. 177) believes that " an important current development for the future of reference work has been the introduction of systems thinking into library procedures work." Burns (1971, pp.

297-302) describes the four steps or phases of a systems survey which he labels "the systems analysis phase, the systems design phase, and the implementation/evaluation phase." Avram (1970) feels that the importance of systems design for the computerization of reference service is understood when we realize that the problems facing the planners of automated library networks are rooted in the complexities of organizing and managing a vast flow of bibliographic information and its interface with users.

Cost is presently a primary factor limiting the computerization of library reference service, and indeed the computerization of all library functions. Shoffner (1970, p. 459) points out that "libraries are in a position in which the penalties for failure for both the library and the administrator are far greater than have been the possible rewards from the successful application of computers to library operations." He believes that federal funding is an important factor in stimulating library automation because it provides the development capital and thereby reduces the risk to the library.

Parker (1969 concludes that "cooperation between libraries will provide the most effective means of procuring the computer capacities required. Libraries with similar problems can use the same programs and utilize the same peripheral equipment. Since the data to be stored are of the same nature and much is common to many libraries, more economical use can be made of the mass storage devices."

CHAPTER VI

THE FUTURE OF REFERENCE SERVICE

Weber (1971, p. 33) believes that "the librarian who carries the responsibility for major mechanized data processing programs will probably have taken at least half a dozen courses in various aspects of data processing in order to be able to state reasonable requirements, to comprehend economic and technical limitations, discuss file organization problems with the systems designer, and be sufficiently informed to help explain the new system to the library staff that will operate or make use of it."

Linderman (1967, p. 151) points out that "library reference work demands a high order of intellectual activity, and its subtleties have thus far proved too elusive for computer programming. I say 'thus far,' because I believe the time will come when some ingenious person will supply the missing algorithm that will make machines as vital to the support of the reference function as they already are to technical processing." Linderman (1967, p. 7) concludes that "already there is writing on the wall. (It is actually the trace of a light-pen on the face of a cathode-ray tube). What the writing says is, 'You are now on-line to the national reference system.'"

Warheit (1970, p. 74) comments that mechanization will affect all operations of the library:

> ... Suffice it to say that an increasing number of librarians are becoming convinced that library mechanization is inevitable, that it will affect all operations of the library, that it will provide the highest level of service through direct, on-line interactive systems and that, whatever today's limitations may be,

these changes are coming so fast that plans must be made now. These individuals are also convinced that whatever is now undertaken in the way of mechanization will evolve into an integrated system with many basic functions operated in a real-time, on-line mode.

DeGennaro (1976) views the 1960's as an era when library automation was primarily localized. He views the 1970's, however, as an era characterized by library membership in computer networks such as OCLC. He contends that a highly qualified in-house technical staff is less essential now as librarians become more familiar with package systems such as OCLC. DeGennaro (1976, p. 183) further comments that

> ... we have seen the main thrust of library automation evolve from building total or integrated systems for individual libraries using local systems staff and equipment, to building regional library networks using the systems, facilities, and staffs of a few major centers such as the Library of Congress, New York Public Library, OCLC, Chicago, and Stanford. We have also seen the parallel emergence of a new concept at Minnesota, namely the development of a powerful, flexible, and inexpensive mini-computer system for use in a single library. If this concept proves itself, it could combine some of the best features of the total systems goal of the 1950's with the major success of the 1970's - the cooperative network. This marriage could produce what may become the dominant thrust of the 1980's - the development of cost-effective in-house library mini-computer processing and catalog access systems capable of interfacing synergistically with an effective national library network for sharing bibliographical data and library resources.

Shera (1969, p. 2280) quotes Kenneth Boulding:

> "We see this ... in what may be the most serious social by-product of automation, a loss of self-respect and 'manhood' on the part of those whose skills are being displaced. The greatest human tragedy is to feel useless and not wanted, and with the rise in the intelligence of machines, we may face a period in which the human race divides into two parts, those who feel themselves to be more intelligent than machines and those who feel themselves to be less ... .
>
> ... The educational system is peculiarly specialized in the production of people, and it must never lose sight of the fact that it is producing people as ends, not as means. It is producing men, not manpower, people not biologically generated nonlinear computers.

Feigenbaum and Feldman (1963, p. 19) bring us back to one of our original questions when they state:

> ... "Can machines think?" I believe to be too meaningless to deserve discussion. Nevertheless, I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted. I believe further that no useful purpose is served by concealing these beliefs. The popular view that scientists proceed inexorably from well-established fact, never being influenced by any improved conjecture, is quite mistaken. Provided it is made clear which are proved facts and which are conjectures, no harm can result. Conjectures are of great importance since they suggest useful lines of research.

Summary

Weber (1971, p. 33) believes that "the librarian who carries the responsibility for major mechanized data processing programs will have taken at least half a dozen courses in various aspects of data processing. Linderman (1967, p. 151) points out that library reference work demands a high order of intellectual activity, and its subtleties have thus far proved too elusive for computer programming." But, he feels that the time will come when the missing algorithm will be supplied that will make machines as vital to the support of reference service as they already are to technical processing.

DeGennaro (1976) believes that the 1970's will be an era characterized by library membership in computer networks such as OCLC. He contends that the result will be a highly qualified in-house technical staff supplemented and even replaced by librarians more familiar with "package" computer systems.

Feigenbaum and Feldman (1963, p. 19) present the question, "Can machines think?" This is a question which should be left open; for

research is moving in a direction which seems to indicate that the realization of a "thinking" machine could soon be developed at some defined level.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on an analysis of the literature, the following conclusions are made regarding the feasibility of a computer-based library reference interview.

1. The development of computer hardware and software has not reached adequate advancement for the realization of a computer-based library reference interview.
2. A deeper understanding of human communication will be required to support the feasibility of a computer-based library reference interview.
3. Research for the advancement of computer technology and a deeper understanding of human communication is progressing in a direction which indicates that the realization of a computer-based library reference interview will be feasible in the near future.
4. It follows that librarians in the near future will need computer training to cope with impending library automation.
5. The information explosion presently demands the advancement of computer technology to support the feasibility of a computer-based library reference interview.
6. Cost is a primary factor limiting the feasibility of a computer-based library reference interview.

7. The advancement of computer technology together with the realization of a national library system and Federal funding will reduce the cost factor which is preventing the realization of a computer-based library reference interview.
8. A computer-based library reference interview will be entirely objective, reserving the subjective aspect of intelligence to man alone.

Recommendations

Based on an analysis of the literature and the foregoing conclusions, it is recommended that:

1. Librarians begin acquiring a working knowledge of the machinery presently available for automating library reference service.
2. Librarians investigate all aspects of communication involved in a library reference interview for deeper understanding and ultimate support of the automation of library reference service.
3. Librarians become familiar with systems analysis and design to reduce error in determining their particular automation needs.
4. Librarians take steps to acquire Federal support for funding the automation of library reference service.
5. Librarians standardize all aspects of library operations, thereby making a national library network possible, eliminating the duplication of effort, and ultimately reducing the cost of automated reference service.
6. Librarians begin learning their role as a subjective interface between library patrons and the objective or totally logical machinery which will automate reference service.

7. Librarians become "information scientists" acquiring empirical data for better understanding and ultimate realization of a computer-based library reference interview.
8. Chaos be reduced in the national information network through the realization of a computer-based reference service.

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