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ABSTRACT

Psychological and physiological concepts about information transmission are reviewed with a view toward uncovering principles useful to the design of audiovisual teaching materials. Audiovisual materials which transmit information via the visual or auditory channels are considered, including sound motion pictures, film strips, and audio recordings. Since the focus is limited to teaching and learning situations involving information transmission, audiovisual devices used to provide aesthetic and affective experiences are excluded. Nine chapters deal with: 1) current conceptions of the role of audiovisual devices in learning; 2) the implications of research on audiovisual devices for the design of learning situations; 3) the relative efficiency of auditory and visual transmissions of information and studies of multi-modality transmission; 4) the mechanics of the transmission of information in the central nervous system; 5) the perceptual system as a single channel system; 6) channel switching; 7) concept learning; 8) attention; and 9) a model for information transmission by means of audiovisual materials. An appendix reviews some major concepts of information theory. (PB)

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RESEARCH AND THEORY RELATED TO AUDIOVISUAL INFORMATION TRANSMISSION

(Revised Edition, 1967)

Robert M. W. Travers–Principal Investigator

with contributions by:

Mary C. McCormick

Frank B. Nelson

Ian E. Reid

Adrian P. Van Mondfrans

Keith R. Van Wagenen

U. S. Department of Health, Education and Welfare

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Preface

Audiovisual techniques for the transmission of information represent an impressive array of creations designed to facilitate the conduct of education. These classroom devices are the products of ingenious and creative persons who have sought to bring about what almost amounts to a revolution in techniques for educating both the young and old. These techniques imply a theory concerning the way in which procedures for transmitting information bring about learning, though those who produce them would be hard pressed to state the underlying theory in precise terms. This is hardly surprising, for those engaged in creative arts are typically intuitive in their approach.

While the arts connected with audiovisual education were developing, psychologists and physiologists were at work on the study of the transmission of information through the senses. From this work a body of knowledge has emerged which has potential for influencing the design of classroom procedures for the transmission of information. This monograph is an attempt to bring together such information and to point out the implications it may have for educational practice.

The authors express their appreciation to the many who have been helpful in this project. Special mention must be made of the help received from Dr. Donald E. Broadbent, Director of the Applied Psychology Laboratory, Cambridge, Dr. Collin Cherry of the Imperial Institute, University of London, Dr. C. R. Carpenter of Pennsylvania State University, Dr. Malcolm Fleming of the University of Indiana, Dr. Henry A. Bern also of the University of Indiana, Dr. James Finn and Dr. William H. Allen of the University of Southern California, Dr. Richard Lewis of San Jose State College, Dr. Jack V. Edling of the Oregon State System of Higher Education, and Dr. Lyle Bourne of the University of Colorado, all of whom gave generously of their time in discussing the problems involved.

The contributions of those who have participated in the preparation of the work have been varied. The review of traditional approaches to the study of problems of audiovisual education reported in Chapter 2 was undertaken largely by Frank E. Williams. Chapter 7 on concept learning and the appendix on information theory was the responsibility of Adrian Van Mondfrans who also made other minor contributions scattered through the volume. The material included in Chapter 8 on problems of attention was assembled partly by Mary McCormick and partly by Keith Van Wagenen. Chapter 6 on channel switching emerged as an outgrowth of a doctoral dissertation by Ian E. Reid who wrote the chapter as it is reproduced here. Frank B. Nelson made contributions to Chapter 4 by spending many months searching the literature of physiology or neurology.

Other members of the staff of the Bureau of Educational Research, University of Utah, cooperated in the production of these materials. Special mention must be made of the help given by Dr. Kent Myers and Miss Virginia Knowlton who provided editorial assistance.

Without the help of Mrs. Jeanette Jackson and Mrs. Patty Jo Taylor and their expert skill in deciphering the hieroglyphics of the authors this monograph would still be in the file cabinet.

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Introduction

The review presented in the chapters of this book is an attempt to bring together available knowledge which may be of value in the design of audio-visual teaching materials. It represents a search for psychological principles which might be used as a basis for planning such materials. The audiovisual materials considered in this discussion are any which involve the transmission of information through both the visual and the auditory channels and include the sound motion picture, the filmstrip and sound tape or record combination, and television transmissions as well as those in many other situations. In order to limit the study to a problem of reasonable size, the teaching and learning situations considered are those in which information is to be transmitted. Audiovisual devices designed primarily for providing aesthetic and affective experiences and those designed to change attitudes by means other than that of providing information are beyond the scope of this study.

The writers of textbooks on audiovisual materials have certainly been acutely aware of the need for basing the design of such materials on sound psychological principles and have conscientiously searched the literature to find any that might apply, but the search has generally ended in the statement of commonplace generalities. Authors in the area are not to be blamed for this outcome, but rather are they to be commended for their realization that a set of psychological principles is a vital necessity for the design of learning situations.

Within the last decade research in psychology has taken a turn which may end the impasse and which may lead to a close working association between those concerned with the design of audiovisual aids and those engaged in psychological research. Reference is made here to renewed interest on the part of psychologists in research on perception, attention, and concept learning. Some of the research which has been undertaken in the latter areas has been undertaken at a highly sophisticated level and often has involved technical terms and constructs with which the audiovisual expert can hardly be expected to have familiarity. This means that the results of such research and its implications will need to be interpreted to those, in education, concerned with the development of audiovisual materials. This monograph is an attempt to provide such an interpretation.

Before proceeding further, the position of the authors with respect to certain aspects of the problem must be made clear. The problem of designing audiovisual materials is analogous to that of the engineer confronted with the problem of designing a bridge. In working on structural problems, the engineer relies heavily on principles of classical mechanics which physicists have evolved. The engineer realizes full well that these principles of physics apply only to a limited degree to his problem and generally make certain simplifying assumptions. However, there are no substitutes for these principles, and so he must work with them despite the fact that the practical bridge design problem violates many of the assumptions on which they are based. For example, if he is building a truss-type bridge, he will have to make the assumption that all of the members are held together by smooth and frictionless pins, an assumption which is clearly violated if the members are welded together. Despite the violation of many important assumptions, the engineer continues to use principles of physics and, in order to take care of the limited validity of this procedure, he generally introduces a factor which involves making the bridge much stronger than the minimum necessary strength derived from his calculations. This is what is called the safety factor.

One can hope that, in the not too distant future, the design of audiovisual materials will be based on an analogous procedure. When that happens, the designer will base his design on certain psychological principles and will introduce a factor analogous to the safety factor of the engineer. The factor in the design of audiovisual materials which corresponds to the engineer's safety factor is the redundancy factor. The educator introduces redundancy into a series of learning experiences so that learning opportunities are multiplied. Redundancy in the design of teaching situations is used in a manner analogous to the safety factor in engineering.

The engineer almost certainly designs better bridges by basing his design on well-established scientific principles despite their limited applicability to his problem. It does seem reasonable to assume that audiovisual teaching materials will be improved when they too are designed on the basis of sound psychological principles as these are developed. (The procedure, of course, involves fallible judgments.) Such a procedure for designing audiovisual materials involves fallible judgments just as it does in the case of engineering. One needs to be reminded of the fact that many bridges designed in terms of the principles of physics have collapsed, because the designer failed to note that one of the assumptions used in applying the principles was not valid.

Theoretical Positions in Audiovisual Literature

Audiovisual specialists have had a long history of struggling to produce a theory of audiovisual instruction. The technical literature of the field shows many steps that have been taken to achieve this goal. One approach has been to obtain reviews of what appear to be related areas of psychological knowledge. For example, an entire issue of the AV Communications Review (1962, Vol. 10, No. 5) has been devoted to the problems of audiovisual education. The issue provides some excellent accounts of a number of different positions taken by psychologists concerned with problems of perception, but the presentations are popular rather than technical and are remote either from empirical research findings or from problems of audiovisual education. Except for the article on the "Psychophysics of Pictorial Perception", the series of articles raises questions rather than answers them. Asking questions is, of course, a healthy activity, but serves a different purpose from that of providing a clear and concise theoretical position.

An earlier issue of the AV Communications Review had dealt in a similar manner with learning theories and audiovisual communications (1961, Vol. 9, No. 5). This latter issue also presented an excellent series of articles written from a number of different positions. The papers provide well-presented positions but show clearly the gulf that exists between the psychologist and the audiovisual specialist. The contributors make excellent presentations, but show a certain reluctance to give answers to questions that the audiovisual specialist is likely to raise.

The literature of audiovisual communication also provides theoretically oriented articles related to more specific topics than those which have just been considered. For example, Fleming (1962) has written of the plight of pictorial communication and makes an appeal for the development, through research, of a set of unifying principles which might guide pictorial communication. Another specialized article by Hartman (1963) has attempted to bring together knowledge of verbal communication and to summarize the knowledge thus accumulated in a set of 28 postulates. However, his work does not present, and is not intended to present, a theory of audiovisual communication. An earlier article by Hartman (1961) comes much nearer to presenting such a theory. However, the latter article does not present so much a theory of audiovisual communication as it does a set of six generalizations derived from research. A theory is generally considered to require a certain unity among the postulates and to be more than a set of empirically derived generalizations. Of course, the article does not claim to present such a theory, but only a model, but models are also required to have a certain unity.

Some books on audiovisual instruction provide far more complete and comprehensive theories of audiovisual education than do journal articles, though others are almost theory free. The text by Edgar Dale was the first major theory oriented book in the area and many which appeared later showed his influence. The classic text by Dale (1954) has also certainly had a vast influence on the production of audiovisual devices and on their use in teaching situations. The first section of Dale's book is entitled "Theory of Audio-Visual Instruction" implying that the construction and use of the devices to be discussed is based on a set of principles. Dale points out that the teacher can transmit to a limited extent his life experiences, but that there are limitations placed upon what can be done in this respect. Dale talks about the "life-time" and "life-space" experiences upon which the teacher draws, but these terms are used somewhat vaguely. He states that audiovisual materials are "one particularly effective way of extending the range of our vicarious experience. . ." (p. 7). The argument is that such materials bring "the world to the classroom." The argument is presented that many who drop out of school do so because their work is "bookish" and lacks contact with reality. The implication is made that the use of suitable audiovisual material will make school work more interesting and, hence, reduce the dropout rate.

The section on the general uses of audiovisual materials is followed by a discussion of a general theory of education which stresses the importance of relating learning to pupil needs, the use of knowledge and the development of meaning, forgetting and remembering, and a section contrasting effective learning and verbalism. Words are described as names for experiences, but the rather dubious distinction is made between the names given to objects and the names given to generalizations. Dale does not tie together language and concept usage, though he implies a relationship, but education is defined as "building concepts." Audio-visual materials provide specific instances from which generalizations, and presumably concepts, are derived. Various examples are given of the way in which concepts may be derived through the use of audiovisual materials.

In order to express the relationship between experience and knowing, Dale presents what he refers to as the "cone of experience" (p. 43). In the book a cone is drawn in which the sections are labeled from the point to the base as follows:

Verbal Symbols
Visual Symbols
Recording, Radio, Still Pictures
Motion Pictures
Television
Exhibits
Field Trips
Demonstrations
Dramatized Experiences
Contrived Experiences
Direct, Purposeful Experiences

The cone is supposed to represent experiences as they are ordered from the most abstract to the most direct. Just what constitutes an abstract experience is not clear. This is a knotty philosophical problem. The difficulties involved in the use of their dimension become evident when one encounters statements that "'verbal symbols' are more abstract than 'visual symbols'," or that "'visual symbols' are more abstract than such 'one-sense aids' as recording, radio, and still pictures" (p. 42). While Dale does caution the reader about taking the representation too seriously, the fact remains that the cone is used to structure a substantial section of his book. There appears to be implied in the model the idea that auditory experiences are less real than visual experiences for the auditory are generally placed higher on the cone than are the visual. While the concept of a dimension of experience which varies from abstract experience to direct experience has wide usage, in later chapters of this book opposing ends of the same dimension will be discussed in terms of differences in the coding process involved. The latter position avoids many of the difficulties important in the abstract-direct dimension as used by Dale.

Dale cites the following as proven contributions of audiovisual aids (p. 65):

"1. They supply a concrete basis for conceptual thinking and hence reduce meaningless word-responses of students.

"2. They have a high degree of interest for students.

"3. They make learning more permanent.

"4. They offer a reality of experience which stimulates self-activity on the part of pupils.

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"5. They develop a continuity of thought, this is especially true of motion pictures.

"6. They contribute to growth of meaning and hence to vocabulary development.

"7. They provide experiences not easily obtained through other materials and contribute to the efficiency, depth, and variety of learning."

The contribution made by Dale in attempting to provide a theoretical structure has been substantial for it has emphasized the need for audio-visual instruction to be based on something more than a strictly empirical approach. Any criticism made here should not be taken to indicate a lack of appreciation of his contribution.

Another book by Wittich and Schuller (1953) also attempts to provide an analysis of the essential elements in audiovisual communication. The first chapter of this book outlines what the authors consider to be some of the barriers to communication but this analysis implies a theory of communication. The barriers are presented under the following categories:

1. Verbalism - The point made is that "excessive verbalism can no longer be condoned" (p. 8). The suggestion is that other and more effective means of communicating are available. The point is presented in somewhat obscure terms. The reader is left asking the question "when should verbal communication be used and when should it not be used?"

2. Referent confusion - The essential point here is that the words used by the teacher may refer to one set of ideas, but the same words used by the pupil may refer to a different set of ideas. Communication theorists would say that under these conditions the teacher and pupil are using a different alphabet.

3. Daydreaming - This is a failure-to-attend factor. The argument presented by the book, is that if the information supplied by the learning situation is dull, the learner will find more interesting internal experiences.

4. Imperception - This is a rather obscure concept as it is presented. The authors of the book make the point that perception can be trained with respect to speed and span, and the implication is that such training will improve learning in those situations involving similar perceptual processes.

5. Disinterest - It is not clear how this is distinguished from the daydreaming factor, except that daydreaming implies that the pupil is distracted by a more interesting activity while the disinterest factor implies no such conflict.

6. Physical discomfort - This is implied to be a factor in learning though most of the evidence goes against such a position.

Further on in the first chapter the following point is made, "Ideally, learners should have available combinations of audiovisual experiences which reinforce one another if we are to provide the most efficient paths possible for the mastery of understandings and concepts" (p. 22). It is believed that the term reinforcement is used here in a different meaning from that with which it is used by psychologists in the area of learning. Additional discussion in the book suggests that the term reinforcement implies that experiences reinforce one another if they present a similar concept through different sense modalities. This concept of reinforcement is rather different from that used in the psychology of learning, but it is not necessarily imcompatible with it. The mechanisms of learning which the concept implies suggests a number of interesting problems for research.

Not all books on audiovisual instruction attempt to formulate a theoretical position on how learning takes place. For example, Brown, Lewis and Harcleroad (1959) virtually avoid any theory of perception or learning. They do briefly emphasize the importance of activity in learning and also make passing reference to the transmission of information by means of a visual language, but these occupy only a very small fraction of the text. The omission of a theoretical position in such a text is not necessarily a weakness. Perhaps in the present state of knowledge one can legitimately take the position that certain facts have become empirically established about the worth of particular teaching practice and the purpose of a text may be that of transmitting the practical knowledge thus derived. Such a position can be well defended in an area where relatively little scientific knowledge is available. Since our interest here is in the development of a theoretical basis for audiovisual instruction, this reference to the Brown, *et al.*, text can be no more than a passing one. A final comment might be that one can as well admire the boldness of those who avoid all theoretical issues as one can admire the equal boldness of those who attempt to formulate a theory of audiovisual instruction.

Another book, which will be briefly reviewed here, is that by Peters (1961). This book is not a textbook for students of education and, unlike those previously described, restricts its discussion to the film. While it discusses the instructional value of the film, the book is largely focused on problems of communicating to an audience seeking entertainment in a theatre. Our interest in the volume stems from the fact that it attempts to state a moderately elaborate theory of audiovisual instruction. The basic concept of audiovisual education presented in Peters' book is that "the film not only represents reality almost true to nature, but also places the spectator emotionally right in the center of the life that is going on within this reality" (p. 16). In a further elaboration of this position, Peters points out that the film represents reality in much the same way that the virtual image of a candle produced by a mirror represents reality though, in a sense, it is not reality. In addition, Peters states what emotional participation as he defines it involves the process of projection and identification. Peters states that on the one hand "the spectator looses himself mentally in the screen; on the other, he incorporates the world of the film into his own person" (p. 18).

A second point made by this volume is that a film presents its information through a film language. This concept of a film language is not entirely clear, even Peters has questions as to whether it is anything more than an analogy as is implied in the following quotation:

> "I use the term 'film language' (and 'visual language') analogically. The analogy between verbal language and film language is very plain. Both words and film images may be used to convey 'ideas about something' and in both cases there are more or less definite rules and laws that govern this process, so that we may speak about a system of forms to convey ideas. This comparison does not, however, include any suggestion that the two form-systems are identical. I do not feel any need to carry the comparison further, and realize that to suggest a parallelism between separate images and combinations of images on the one side and between words and sentences on the other side would go too far." (p. 22)

According to Peters, an instructional film consists of short fragments. Each shot, in a sense, represents a term in the film language. How the terms are connected is not particularly clear in Peters' account. Sometimes, it seems the connection is made by implication from the shots that have preceded it. Sometimes it depends upon the film-viewer relationship, whatever that may mean. In any case, Peters indicates that the viewing of a film may be a difficult task. Peters suggests that the task of the viewer is to read meanings into the various shots. For example, he shows a picture of two boxers, one of whom is on the floor of the ring, and says that it "does not merely represent two boxers, one of whom has just knocked out the other, but it says; something which could be rendered in such terms as: "The winner dominates the whole situation, the loser's defeat is absolute." (p. 32). This is asking the viewer to perform quite a complicated operation on the data provided by the film.

The operation of understanding a film is said to involve the following processes (p. 34):

1. "Establishing the relations between two or more objects or persons in a separate picture."

2. "Making comparisons; establishing causes and consequences."

3. "Realizing one's viewing point."

4. "Putting oneself in the place of somebody."

5. "Decentering oneself continually."

6. "Filling up gaps between the pictures."

7. "Foreseeing what will happen, and anticipating."

8. "Remembering what has happened already."

9. "Making time leaps."

While Peters' book is concerned with the film in general, he has much to say about films developed and used for instructional purposes. He makes the point that before the film can be effectively used for teaching, the pupil must acquire a knowledge of the film language. He suggests that some of the features of films be compared with the features of verbal language so the pupil may grasp some of its subleties. Film aesthetic should also be studied from this point of view. He even suggests that expression in film language could be learned along with written compositions were it not for the expense of film production.

There appears to be some inconsistency between the position that a film is an image of the real world and, at the same time, that the film used a language of its own which has to be learned before effective viewing takes place. Insofar as the latter is true, the film is different from real life for the cue system of real life must surely be different from the cue system used by the movie producer. One is also left wondering whether movie producers, as a group, would agree on the film language they use.

Some Impressions From Visits to Producers of Instructional Films and to Experts in the Field

Another point of departure for the project involved visits to persons who either produce teaching films or who are recognized experts in the area. It was hoped that from such visits there would be derived a set of principles of design which could be used as a guide in our own study of psychological literature. Textbooks show some agreement in what they consider to be important factors in the transmission of information through audiovisual materials. A similar agreement was anticipated among other experts. Such an agreement would have made our task the delightful one of linking practice with theory.

Visits to four procedures made it absolutely clear that there was no agreement among the four concerning the principles that should be followed in the design of such materials. Our visits involved two university producers and two commercial organizations. All four organizations have earned the reputation of producing materials of quality and some would say that their educational products are among the best available. For the purpose of discussing the principles which each claims to follow in their work, we will refer to the two university producers as A and B and the commercial producers as C and D.

While our sample was limited to four, the variation in point of view was startling. One presumes that if other producers had been visited that still further different positions would have been found. The purpose of our discussion here is not to generalize from the four producers to other producers, as it is that of showing the diversity of professional opinion in the field.

Let us consider first the two university producers, who provided information of special value, since they represented completely opposite positions. The guiding principle underlying the work of A was that if the objective of a sound motion picture was to transmit information, then it would be better to attempt to do this in an direct a way as possible. Discussion with those involved in the actual production of motion pictures in center A brought out the point again and again that there was no place for subtle innuendo or the use of artistic embellishment. For this group a movie should present what it has to present in a business-like manner. This does not mean that a movie cannot be artistic even when it is presenting factual information, but such factors should not prevent the transmission of information in a direct and business-like way.

In contrast, producer B took the position that much important information was transmitted indirectly and that care should be taken to ensure that every aspect of a movie should lead to correct inferences. If the movie was to be introduced with music, then the music should provide information about the subject matter and be completely appropriate. From this point of view the movie provides the viewer with data from which he makes inferences. Artistic skill on the part of the producer is the factor that determines whether communication will or will not take place satisfactorily.

The two commercial producers showed less preoccupation with the theorectical problems discussed by the two university producers. They discussed their problems in very concrete terms and made six main points. First, a topic is worth filming if it is both included in the curriculum and also involves visual phenomena. Second, film presentations should not be attempted where the subject is primarily abstract, or where the phenomena are nonvisual. Third, the producers point out that nearly every key concept included in any school curriculum has been covered by a short movie produced by some organization. Since this is so, the task of the commercial producer is to find improved ways to presenting concepts through the film medium rather than to identify concepts that have not already been filmed. Fourth, film production should be preceded by a thorough examination of textbooks and other school materials and care should be taken to match the vocabulary of the narration with the vocabulary in the teaching which is ordinarily undertaken. Fifth, the planning of the video involves a choice between the live action and animation. While such a choice should be made in terms of the requirements of the learning situation, the fact is that the choice often has to be an economic one since animation costs at least twice that of live action. Sixth, producers stated that there are problems of fitting together the audio and the video, but that they have to do this on an intuitive basis since there are no accepted principles concerning how

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this should be done.

Our contacts with the two producers left a clear impression that they knew of no widely accepted principles which are used for the planning of instructional films. Other producers that we did not contact might think differently, but a further check on this finding was provided when the staff of the project viewed a number of instructional films in an attempt to determine whether principles of instruction were implicit in their design.

Two groups of films were viewed. One group consisted of the films most commonly requisitioned from the University of Utah Film Library by the secondary schools of the area. A second group was provided by a commercial producer and consisted of those films of which they were most proud. A study of these films showed that a great variety of assumptions concerning the best methods of transmitting information were involved. Some of the movies carried most of the information through the audio, but some used primarily the video. Some transmitted different information simultaneously through the audio and the video while others transmitted simultaneous redundant information through the two media. Some used elaborate embellishments involving music in the audio and art work in the video, others were free of such embellishments. Some required the viewer to perform while the projector was stopped, while others demanded no more than passive observation. Some used color for the sole purpose of attracting attention, but others used color primarily to transmit information. Some required the viewer to make inferences, while others were so explicit that no inferences were necessary. Some involved written verbal material while others involved verbal material only in the audio. A review of these materials confirmed fully what the producers had said, namely, that in producing an instructional movie, decisions are made in terms of hunches and intuition rather than in terms of a set of well-defined production principles.

There is also some disagreement among experts both concerning the features that should be incorporated in audiovisual teaching devices and the most favorable methods of presenting the material. Experts in the field with whom such matters were discussed recommended methods of presentation which varied from flooding the learner with information through simultaneous multiple presentations to those who advocate the presentation of information at a relatively slow rate through one sensory channel at a time.

The conversations which were held with producers and with other experts in the field yielded few well supported and widely accepted ideas. This result is to be contrasted with that obtained from some of the texts which we have examined. The ideas expressed by the texts, appeared, to some extent, to support one another in the ideas advocated and hence these form a point of departure for the present inquiry.

A Psychologist's View of the Audiovisual Field

A psychologist who reads the literature on the design and use of audiovisual materials is struck by the fact that they are written in a language which shows little of the impact of psychology and that the language reflects a vocabulary which is peculiar to the field. The psychologist probably has as much difficulty in translating audiovisual literature into psychological terms as the audiovisual expert has in translating psychological literature into terms which have relevance for his own field. Some terms are used with rather different meanings in the two fields as is seen in the case of the word reinforcement. While the previous review included among other materials three of the most influential and outstanding texts in the area, the language of these three texts and the concepts they discuss are believed to be representative of the literature of the area. Certainly, they can be believed to be representative of the literature of the area. Certainly, they can be considered to cover nearly every major concept found in current audiovisual literature and to present, fairly, the claimed advantages of audiovisual techniques over traditional techniques and the special functions which such techniques are believed to serve. The pages that follow present a discussion, in psychological terms, of some of the concepts and guiding principles of the area since they provide a springboard for our own inquiry. These ideas, derived from the audiovisual field, suggest questions to which answers must be sought in related scientific literature.

The Proposition that Audiovisual Materials Have High Value for Relating the Learner to Reality

A position taken by most of the writers on audiovisual materials is that they bring the learner into close contact with "reality." This means that audiovisual materials have the capability of presenting stimulus patterns in much the same way as they are presented by the environment and that the visual presentation can avoid symbolic representation of phenomena. The video portion of a display sometimes do, but often do not, present "reality" (as the term is used in the audiovisual field). but the audio portion typically makes use of language.

Representations of "reality" may be simplified in various ways. Video presentations of natural phenomena may be taken out of context as when the condensation of rain in a cloud is demonstrated by steam striking a cold surface. Natural phenomena themselves may be simplified as when laws of motion are demonstrated with small steel balls moving on a flat surface. Artists' representations and animation techniques introduce other forms of simplification as when line drawings are used to represent the essence of phenomena omitting all relevant details. Such representations are a far cry from reality, but the fact is that many instructional movies which are reviewed as a part of the present project involved the use of gross simplifications which took them far from naturally occurring phenomena. Indeed, those which were judged by the group to be the best learning devices involved the greatest amount of simplification through animation. Perhaps the objective of such teaching materials were not so much to bring the pupil into close touch with reality but to help the student to become more effective in dealing with reality. These two concepts should not be confused.

Discussions of the "realism" provided by audiovisual devices also tend to imply that exposure to the environment, or to equivalent sets of stimuli such as are provided by sound movies, results in the full absorption and retention of information in a form isomorphous to that which has been presented. As will be clearly shown later on, inputs of information are coded and most of the information available to the senses not only never enters the perceptual system but is not retained by the system. In addition, information is not only coded into nerve impulses when it enters the nervous system but it may undergo other coding processes such as the transformation of the information from a visual pattern system into a word system.

The amount of information about natural phenomena that can be retained without the use of some system of coding, in addition to coding of the inputs into nerve impulses, is probably very small. Merely confronting a person with stimuli identical with those emitted by the real environment is no guarantee that useful information will be retained. The problem is that of arranging experiences in such a way that those aspects of the display that carry most of the information are perceived. Research which throws light on this particular problem will be reviewed, for the problem of the reality value of audiovisual materials is one of focal importance and also one of great complexity.

Before leaving this over-all discussion of the reality issue, the point should be made that audiovisual materials as Dale points out permits one very important relationship to environmental events by providing direct operational definitions in which the operations directly represented by a symbol are made available for inspection. When the audio says "This is a volcano" and a volcano appears on the screen, the presentation provides a direct operational definition of the word volcano. The importance of such an experience is not just that it brings the student in touch with reality, but it provides him with a symbol that has an operational definition. Research which throws light on the development of association between symbols and their referents would be valuable for the design of many audiovisual situations. Unfortunately, such research has hardly begun.

The Proposition that Visual Teaching Materials Involve a Language of Communication and Represent a Channel of Communication Distinct from that of Ordinary Language

Statements in books on audiovisual teaching to the effect that films communicate in a visual language are provocative in that they suggest a series of problems for research on the use of such devices. If a language is involved in the video presentations, then a number of questions can be asked such as the following: What elements in the visual display constitute the vocabulary of the language? How is the language learned? What connectives are used in the language? What is the syntax of the language? How does one distinguish clearly formulated statements from vague statements in the video language? If these are real and important questions, then they are important points from which research should begin. Let us examine them briefly.

First, one cannot argue the point that a sequence of visual displays has the capability of transmitting information if it is properly designed. The transmission of information by such a means may involve processes of varying complexity. The simplest form of this kind of transmission is found in Brogden's (1939) sensory conditioning. First, stimulus X is presented a large number of times in conjunction with stimulus Y. Then a response is conditioned to X. Finally, it can be shown that the same response will then be elicited to Y to which it has not be conditioned. In this case the animal learns to substitute one stimulus for another through what has come to be referred to as perceptual or S-S learning. One may assume that the mere presentation alone does this. The latter point needs some further elaboration. Consider the case in which an observer sees event B follow event A a large number of times. In a sense, he may learn that such a sequence exists by learning to make anticipatory responses related to event B whenever even A occurs. This type of learning may occur without the learner ever translating the information into a verbal form and saying to himself "If event A occurs, then event B will occur." Animals learn such event sequences without ever resorting to the use of words and, presumably, humans can also some of the time. Some writers in the audiovisual field would say that a visual language had been used to communicate this information, but surely it is quite unnecessary in describing this learning to introduce the concept that a visual language is involved. If one does, then one should also say that a rat learning a visual discrimination task is learning to use a visual language. Such learning may well be considered to involve the learning that certain visual stimuli are the signs for certain other events, but to refer to this as a language hardly seems useful. It would seem to be much more profitable to consider that nonlinguistic learning can occur but that there are perhaps advantages in linguistic learning which the nonlinguistic learning does not have. There may be advantages in a person being able to summarize his learning by making the statement, "If A occurs then B will occur," rather than leaving it at the level where the stimulus A produces anticipatory responses related to stimulus B.

This whole problem arises because of the assumption made in so many books on audiovisual material that since such material involves the use of symbols it necessarily involves the use of a language. In a sense all animals respond to events in their environment as if they had symbolic significance. Any organism capable of learning does this even at the lowly invertebrate level. To identify language with learning hardly seems to be profitable and may obscure an important difference between linguistic and nonlinguistic learning when language is otherwise defined.

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Now let us return to the case of the learner who learned to produce expectancy reactions with respect to B when A appeared, and the case of the learner who after exposure to the same situation was able to demonstrate his learning by making the statement, "If A occurs then B will occur." The latter type of learning may be referred to as learning involving language, or L learning, while the former may be referred to as non-L learning. They differ in many respects. The one involves a communicable form of knowledge, the other does not. The L learning involves the summarization of a sequence of events in a statement. The formulation of the statement requires the learner not only to summarize information acquired through direct experience but the information is translated (or coded) into a different form. Finally, the coding of the information requires that the terms of the code be assembled according to certain rules which are referred to as the rules of syntax.

In this report the problem of the role of language in learning through the use of audiovisual experiences will be explored and some attempt will be made to identify some of the phenomena involved and the relationship which they have to learning.

The Proposition that Audiovisual Materials Provide Concrete Instances Through which Verbal Concepts can be Learned

This is one of the more clear-cut and well defined uses of audiovisual materials found in textbooks on the subject. The point made is that the viewer can learn concepts defined in terms of the visual attributes of objects and events and that these concepts can be given verbal labels. Concept learning tasks of this kind are discussed in Chapter 8. They have been carefully and meticulously studied by psychologists and some of the conditions which add to or detract from the efficiency of the learning process have been identified. This is an area in which the research of psychologists has been concerned with problems of direct interest and concern to those designing audiovisual materials. This does not mean that the work of the psychologists is directly applicable to the solution of problems faced by the audiovisual expert; for the psychologist, in the tradition of experimental science, studies phenomena in highly simplified situations. The problem of generalizing from these restricted and simplified situations to the complex situations of daily life is one faced by every scientific area.

Since the literature on concept learning is extensive and relevant, a chapter is devoted to the topic and is included in the monograph but cautions are given concerning generalizing from the findings. This notable point of contact between the audiovisual area and the area of psychological research may represent a point of departure for extended research related to the design of audiovisual devices.

The Proposition that the Transmission of Information Through more than One Sensory Modality Provides Reinforcement

In a previous section it was pointed out that the term reinforcement as used in this context may have a different significance from the term reinforcement as it is used within the context of learning theory. The effect suggested by the term and its accepted usage in the audiovisual framework is that inputs of information through different sensory modalities results in more efficient learning than inputs of information through a single channel. The concept appears to be related to mechanisms which psychologists have proposed in the area of perception. For example, Solley and Murphy (1960) suggest that when perception results in the structuring of the sensory inputs that this achievement of structure is reinforcing. The transmission of information through two sensory channels may sometimes result in greater structure than when one channel is used and hence may result in reinforcement in the sense in which this term is used by perceptual psychologists. For example, in one instructional movie, the foot of a living frog is shown under the microscope. While this is happening words similar to the following are presented by way of the audio channel, "Look at the small section of the foot of the frog as it is seen through the microscope. If you study it carefully you will see the small blood vessels and the blood flowing through them. The magnificationis sufficiently high that you can see the red blood corpuscles as they move through the small vessels. Such information given through the audio channel facilitates the structuring of the visual perception which may have a reinforcing effect in the sense in which some perceptual psychologists use this term.

This conception of reinforcement evolved by audiovisual specialists suggests many important problems related to the design of audiovisual aids. One problem is the extent to which the nervous system is so designed that it can handle inputs of information through multiple channels. Literature on the design of audiovisual aids has generally taken the position that the greater the number of sense modalities that are used in learning the better will be the learning. This is an assumption which needs to be examined since it represents a vital issue related to the design of audiovisual materials. Simultaneous transmissions of information through the eye and the ear may not be as effective as the alternating transmission of information through the two sensory modalities.

The problem of the efficient use of multiple sense channels for the transmission of information is, in turn, related to the problem of the information handling capacity of the nervous system. If the nervous system can handle information only at a limited rate regardless of the channels through which the sensory inputs are transmitted, then slower rates of input per channel may be necessary when two sensory channels are involved than when one is involved. This is obviously an important problem to explore and any light that psychological research can at present throw on the matter could be helpful.

The Proposition that Audiovisual Materials Attract the Attention of the Pupil and Motivate More Effectively than Other Materials

This proposition or the equivalent is found in most textbooks in the area, some even suggesting that it is solidly supported by data. It raises many questions concerning the reasons why such presentations command attention, if they actually do. Factors related to stimulus intensity may sometimes be the reason for the high attention-attracting quality of such displays. It is quite evident that movies and film strips provide a high level of light intensity and the colors used generally have a higher level of saturation than those that are typically found in nature. The audio part of such presentations generally exceeds in intensity that produced by the teacher's voice.

Other factors may also operate to command the attention of the pupil. One of these is the possibility that the child has been conditioned to attend to audiovisual displays since these are associated with entertainment both at the movies and on the home television. Whatever conditioning takes place to attend to such displays may well carry over to formal learning situations in which similar displays are used. The conditioning of attention presents an interesting area of research which should yield important information for the design and use of audiovisual teaching devices.

One could speculate at great length on the factors that attract attention in an audiovisual display but such speculations would have little value. What is needed is a review of stimulus conditions that have attention-attracting and attention-holding value in order that the knowledge they provide may be made available to producers of teaching materials.

The Search for a Theoretical Basis for the Design of Audiovisual Materials

An examination of books and articles in the audiovisual field shows a persistent striving for the development of a theoretical basis for the design of teaching materials. The principles that are commonly given as cornerstones of audiovisual teaching practices are, at this stage, based largely on practical experience rather than on research. In the following chapters an attempt will be made to find out the kind of principles that are suggested by research, and particularly research related to behavior. In attempting to derive principles from research, the reviewers will keep in mind the propositions that have been reviewed in this chapter because they represent the kind of guiding principles that both producers and users need for making important decisions. The propositions also raise many questions to which some partial and tentative answers can be found in contemporary research literature.

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CHAPTER 2

THE IMPLICATIONS OF RESEARCH ON AUDIOVISUAL DEVICES FOR THE DESIGN OF LEARNING SITUATIONS

Introduction*

Two different approaches can be taken to the study of factors that influence the effectiveness of the transmission of information through audiovisual devices. One of these involves a direct attack on the problems and calls for research utilizing audiovisual instructional materials. An alternative approach is that of studying problems related to the transmission of information through the auditory and the visual channels but with very simple materials, that is to say, with materials which are much less complex than those which have been developed for instructional purposes. The former perhaps represents the typical approach which has been undertaken by those engaged in traditional types of educational research; the latter approach is more typical of those trained in the tradition of experimental science, who have studied phenomena in the general area of the psychology of perception.

At this time one cannot say with any definiteness that research is more likely to be of value to the improvement of teaching if it is of one kind rather than the other. In the history of science it is as easy to point to important developments which have occurred in a practical setting as it is to indicate important practical outcomes of research carried out in the laboratory and remote from ordinary affairs. On this issue there would be little point in taking sides. Our task here is to review in the remainder of this chapter the findings which have emerged from research conducted with materials similar to those used in actual instruction. In later chapters the results of research derived from laboratory studies will be reviewed. Although the latter studies involve the use of tasks far removed from instructional programs one would certainly expect the results derived from them to be consistent with those from the more practically oriented research. Such will be seen to be the case.

The research included in this chapter does not cover the entire range of studies undertaken with audiovisual materials. Certain classes of studies have been excluded because they are believed to provide information which is nothing more than trivial. Of particular mention in the latter category are those studies that compare a traditional lecture with similar content presented by means of a sound movie. Studies of these are inconsequential, and it seems unnecessary to elaborate on this point except for the fact that such studies keep on appearing in the literature. The lecture-versus-film type of study generally compares the effects of

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*An excellent review of the material covered here together with material in other areas specifically excluded from this review appeared at about the same time when this chapter was completed. Reference is made here to the chapter by A. A. Lumsdaine entitled "Instruments and Media of Instruction" which is published in the Handbook of Research on Teaching edited by N. L. Gage and published by Rand McNally.

one ill-defined conglomerate of presented information with another. The comparison is rarely, if ever, an attempt to present the same information through two different procedures, the times of presentation are rarely equated, and differences between lecturers and differences between different versions of the same film cannot be estimated. Such studies generally illustrate most of the technical weaknesses which can be found in experimental designs, and the results cannot be generalized beyond the limits of the particular study.

This review is largely concerned with those studies in which particular aspects of a presentation are varied in order to determine the effect on learning of that particular aspect. Thus one can present the same film in a black-and-white and color version and determine the effect of color upon learning in the particular situation. Such studies at least have the merit of providing empirical information concerning what contributes or detracts from learning with particular tasks.

A large percentage of the studies reviewed in this chapter were developed under the sponsorship of the U. S. Naval Training Device Center, Port Washington, New York. The studies were developed under the direction of C. R. Carpenter with the help of his associate L. P. Greenhill. Other able research workers, many of whom have since become notable in the field also contributed to the program. The series of studies which they undertook represents the most ambitious attempt yet to develop, on the basis of research, a set of principles which can be used in the design of audiovisual materials.

A Classification of Forms of Information Transmission

While a very substantial amount of research information has been accumulated concerning factors which influence the transmission of verbal information, either through the auditory or visual channels, much less is known about the area of transmitting information by means of pictorial representation. This defines the first area of research studies reviewed in this chapter. Forms of information transmitted by audiovisual teaching devices are represented in Table 1 .

In terms of this table, the speech and print transmissions are relatively well investigated areas but research on the transmission of information by nonverbal means is comparatively new. Despite this relative lack of information about the nonverbal transmissions of information, the literature of audiovisual education has much to say both about its value and about what it involves. Such works stress the idea that the visual presentation of an object is important for showing the appearance of an object, and particularly when it is one which is not easily described. Some writers have even claimed that pictures represent a language for the transmission of information and that this language can sometimes transmit information not easily transmitted in words. The comparison of pictorial material with language is, at the best, a weak analogy. True, pictorial sequences have been used since the earliest civilizations for the transmission of stories, but pictorial material generally lacks the structure which is typical of language. There is no syntax of pictorial representation; at the best, a series of pictures are organized in a time structure. If pictorial material constitutes a language at all, it is only at a very primitive level.

TABLE 1

PROCEDURES FOR TRANSMISSION OF INFORMATION BY MEANS OF AUDIOVISUAL TEACHING DEVICES

	Auditory Transmission	Visual Transmission
Verbal	Speech	Print
Nonverbal	Music and non-speech sounds	Pictorial

Some Questions Underlying Research

The research reviewed in this chapter represents an attempt to answer four general groups of questions. The first group raises such issues as: To what extent should pictorial material involve simplification such as is involved in the reduction of a half-tone to a line drawing? To what extent is there an age factor in the understanding of pictorial materials and do younger children require simpler representations than older childen? Do pictures provide material that is more response-related than does verbal material?

A second area concerns the matter of relationship of the audio source to the video. A vital issue is the extent to which nonredundant information can be effectively transmitted simultaneously through the two sensory channels. Another question is the advantage, if any, of transmitting redundant information through two sensory channels. A third problem in the channel-interrelation area is that of the effect of utilizing one channel to provide an informationally irrelevant background for the information provided by the other channel. Thus, music may be used as a background for pictorial information, and beautiful but irrelevant scenes may provide a backdrop for a narration. The planned use of such irrelevant materials is a matter highly related to the issue of whether learners can utilize information from more than one channel at a time or whether such transmissions may be more inhibiting than facilitating.

A third area where significant questions have been asked, particularly during the last decade is that of the importance of the learner doing more than just looking and seeing. How important is it for the learner to "participate" by making overt responses during the showing of a sound picture. Some of the interest in this problem is a belated recognition of the idea already well-incorporated into other phases of learning that the role of the learner should be an active one rather than passive. Further pressure to investigate the role of pupil participation in the use of audiovisual materials comes from those who have promoted the conceptualization of learning as a reinforcement phenomenon. While considerable research has been undertaken on this problem, the producers of equipment and teaching materials in the area have done little to develop new techniques of presentation which would facilitate participation.

A fourth area includes studies related to the design of the narration and the identification of the function which the narration serves in relation to the pictorial presentation. Such studies investigate problems related to the determination of optimum rates for the presentation of information. There are also important questions to be answered concerning the effect of increasing or reducing the redundancy of information in the narration. The effect of narrations which serve different functions in relation to the video presentation also needs to be investigated.

While considerable research has been undertaken on most of the questions which are commonly raised (or even answered) by those who write textbooks on the use of audiovisual materials, such research does not necessarily yield broad general principles of learning or of perception which can be used to guide both the production of materials and their utilization. The answering of specific questions may be useful, but it is very different from a set of general principles of learning and perception. This distinction must be kept in mind while reading the review which follows.

The following sections of this chapter will review research under the four areas discussed and provide information concerning the relationship between the characteristics of the information transmission rather than with learner characteristics. In many ways this is a limiting factor on the value of what can be achieved through this approach. Stimulus characteristics which are effective for the transmission of information owe their effectiveness to the organism having certain characteristics which permit the use of the information provided. A complete picture of the information transmission process must, obviously, relate stimulus characteristics to the characteristics of the learner and these in turn must be related to the learning outcomes. It is hoped that this volume as a whole will begin to establish such relationships.

PART I. PICTORIAL MEDIA AND LEARNING

Fleming (1962) has written that audiovisual communication has pictorial aspects which have defied analysis. The principles to be employed by a communicator in designing and arranging visual stimuli have not yet been identified. Yet, a review of the research literature on pictorial illustrations indicates leads along several discernible dimensions will be followed up in this section of the report. We are, therefore, concerned with principles for constructing illustrations so that they will function as effective and efficient means of communicating information, and of changing behavior. The pictorial display is considered here as only a means of distributing information with resultant learning. A major concern will be to identify significant features of pictorial presentations that lend themselves to measurement and which are related to how subjects learn.

Two different approaches have been used in experiments with visual perception of illustrations. The one examines viewer preference, and then attempts to determine the reason for that preference. The other compares learning from two kinds of stimuli, pictorial and non-pictorial.

Viewer Preference Studies

Miller (1938) studied third grade children (N=100) divided by sex and intelligence quotient. Six pictures were selected from common books used by third grade children. These pictures were analyzed for the number of their constituent items. Each child was individually tested as to the number of generalized and total items identified within each picture. His findings indicate that children see relatively few of the items which make up a picture; and that items which are seen are interpreted in isolation rather than as a part of a unified whole. He noted that the most important items, as viewed by the adult (illustrator), often escaped notice by children. Children of high intelligence identified more items in pictures than did children of low intelligence. Hence, only three of the eighteen comparisons between groups at different intelligence-quotient levels were stated to be statistically significant differences (no level indicated) between the sexes in their ability to retain generalized items in pictures. The results of this investigation, in summary, suggests that if pictures are to be an aid to the understanding of printed material which they accompany, cues will be needed to direct the attention of children of this age to important items in pictures.

Halbert (1944) experimented with three groups of rural elementary school children (no N given) divided on the basis of reading age. She prepared three versions of a children's textbook. One version included print plus picture illustrations, another print alone, the third with pictures alone. To the extent that memory for ideas is accepted as a measure of comprehension, she found that pictures appeared to contribute to the comprehension of reading materials. When attention to the pictures was directed by print, there was claimed to be a decided increase in number of relevant ideas (no level of significance indicated) retained by the subjects. The children derived more relevant ideas from reading a story in print alone than from viewing pictures alone. From the standpoint of stimulating and arousing ideas, pictures alone were found to be superior to print alone or to a combination of print and illustrations (no levels of significance were given in the study). Her major conclusion from the experiment was that a careful study should be made of the background and experiences of children before illustrative materials are prepared for them.

Rodriguez Bou (1950) made a study of illustrations for second, fourth, and sixth grade Puerto Rican school children (N=2,492). Of three illustrations presented, all depicting the same scene, the most realistic was preferred by 46 percent, the next by 32 percent, and the least realistic was preferred by 22 percent of the child subjects (no level of significance indicated.).

French (1952) studied children's preference for pictures of varied complexity. He studied groups of six and seven year old children (N=142) and eleven year old children (N=554) of varied socioeconomic levels to determine changes in response in relation to age. Using thirteen paired pictures with each pair containing a simple and a complex picture, he found a consistent increase in preference for complexity with age. From 72 percent to 83 percent of the six and seven year old children preferred the simple pictures made up of clear-cut, unbroken, unaccented line drawings as showing the outlines of flat, two-dimensional, familiar objects. On the other hand, 85 percent of the eleven year old children preferred the sketchy, irregular, complex pictures. The latter illustrations contained suggestions of the same objects rather than carefully well-defined representations. This experiment suggests that children have a consistent basis for their preferences for pictures that is related to age level. First grade children consistently preferred simple pictures. French hypothesized that such selections seem to be guided by the type of pictorial pattern that they have explored and comprehended in their own art work. Likewise, there is a gradual change in the direction of picture preference through the elementary school, with preferences of upper grade children toward a more complex organizational pictorial pattern in close agreement with tested adults. He found almost complete similarity between boys' and girls' responses except for a slight and statistically insignificant tendency (no levels indicated) for girls to prefer the more simple illustrations. This experiment would indicate that children display a progressive change from simple to complex in their preference for pictures from grade to grade in terms of preferring those pictures that are understandable to them on the basis of their own art experience. The main inference from the French (1952) studies is that children avoid complex illustrations until they are old enough to understand them.

French (1952) also experimented with elementary school teachers (N=88) and found that 89 percent of this group (no level of significance indicated) preferred complex illustrations over simple line drawings.

Very little research has been done on preference for pictures by adults. McLean and Hazard (1947) tested men and women (N=152) with 51 news pictures which they rated for their preference on a five point scale. Content seemed to be the most significant factor in their choice. Pictures which rated high were close to their own interests. Low ratings correlated with lack of interest, or vague content or action. As for the technical elements of design of news pictures, this study indicates that realistic drawings are preferred while silhouettes and stylized drawings are unpopular. No levels of significance were mentioned by the authors.

Woodburn (1947) reported on the studies of the Advertising Research Foundation's Study of newspaper reading. Such studies have investigated attention given by newspaper readers to print vs. pictorial illustrations as measured by selected surveys. The term "readership" is used to denote the number of newspaper readers who indicate their attention to either of these two sources. These studies indicate that readership is three times higher for material involving pictures than for newstory (print) alone. The characteristics of picture size, picture subject, color, and overlines were also reported to be related to readership. In discussing the characteristics of picture size, Woodburn reports that larger pictures obtained a greater readership, but not in proportion to the increase in size. For example, when the newspaper picture area was increased four times, reader response increased on the average only one-third. One column pictures, however, showed less readership than larger two or three column pictures which attracted up to 42 percent more attention. Picture subject seemed also to be related to readership. People attend to topics that interest them, and that touches upon their daily lives. Color was found to attract attention. Overlines as headings or captions to pictures attract people as directive cues. Picture pages are looked at by 76 percent more people than any other pages of the newspaper. However, no indication was mentioned as to levels of significance or number of subjects studied.

Smith (1959) has attempted to formulate a "perceptual organization theory" for the pictorial design of textbooks and audiovisual materials. The primary principle of the theory he advances is that artistic illustrations of the proper design can improve the interrelationship between verbal and artistic symbols. He further claims that by visual art the effectiveness of a textbook can sharpen the reader's interest in the events and ideas by emphasizing vital meanings, pointing up certain values, and in general reflecting the author's attitude toward his subjects. He also states that creative and artistic illustrations in books direct, strengthen, and motivate the individual to read and improve long-range memory of the contents of the book. He does not predict increase on a short-term basis nor does he claim an increase in immediate verbal comprehension by the use of artistic illustrations. He states that experimental tests have shown that immediate verbal comprehension with and without illustrations is not significantly different (no level of significance stated). His "audiovisumatic" theory states that properly designed artistic illustrations in books or other audiovisual materials serve three functions. First, they "perceptually motivate" the reader by attracting him to pick up the book, to explore it, and develop a feeling of expectancy when turning each page or viewing audiovisual materials. Second, an artistic illustration "perceptually reinforces" what is read or seen. The term reinforcement refers to situations or events in which the words are made more meaningful through illustrations. He also states the belief that art work correlated with print "symbolically enhances" and deepens the meaning of verbal information. If Smith's claim is true that well-illustrated textbooks provide better long-term retention of material, it may be a result of the mere increase of time which the reader spends on viewing and exploring the relationship between words and pictures or charts in addition to reading verbal information in print. The increase in time alone may contribute to such an effect. This claimed effect has not been subjected to experimentation. A comparison was made using Smith's (1958) well-illustrated book The Behavior of Man and an equivalent scientific textbook on human behavior which was not illustrated. The title of the non-illustrated book was not reported in the study. Over 80 percent of the students (N=150) in a psychology class at the University of Wisconsin indicated their preference for the illustrated book, but data have not been forthcoming on the long-term retention effect which illustrations are alleged to produce.

Spaulding (1956) made a study of the effectiveness of illustrations in materials supplied by UNESCO for newly literate adults in Latin America. The study used 252 full-page illustrations appearing in eleven fundamental education booklets. The educational value of these materials was compared with that of the same booklets without illustrations. Adults from rural and urban areas of Costa Rica and Mexico were used as subjects (N=102). Conclusions were based upon the results of recall and association tests given to the subjects after they had read the booklets. Half of the subjects read the text material without illustrations while the other half read the booklets which contained 252 realistic line drawings, woodcuts, and stylized illustrations. A total of 2,138 interpretations of the illustrations by the subjects were analyzed also by trained examiners. In the cases of eight of the eleven books tested, an average of 66 percent more information was recalled by those reading the booklets with illustrations as compared to those reading the same booklets without illustrations (no levels of significance given). In the remaining three of the eleven booklets, 26 percent more information was remembered by those reading the booklets without illustrations than by those reading them with illustrations. A conclusion was drawn that illustrations usually, though not always, help the reader to obtain more information. Illustrations designed to communicate specific ideas appeared to be most effective if the number of objects seen were kept to a minimum, if the number of separate actions necessary to interpret the meaning of the illustrations were kept to a minimum, and if the objects were realistically portrayed in the illustrations and not open to dual interpretation. It was found that print captions usually served to add information difficult to depict pictorially. This study found an inverse relationship between the number of cues in a picture and the abstractness of free-verbal naming responses made to it; i.e., the smaller the number of pictorial cues the greater the abstractness of verbal responses.

Brandt (1948) made a study of eye movements and the manner in which illustrations are perceived as a factor in the way they are interpreted. This study is a follow-up of Buswell's study (1935) of the behavior of subjects looking at a series of pictures. Buswell's conclusion was that there are wide individual differences in the general pattern of movements involved in looking at a picture and in the duration of fixations. Brandt, however, stated that subjects tend to look first at the upper left corner of a page of illustrations. The eyes tend to move in a clockwise rotation in making the first exploration over an illustration.

Fleming (1960) designed a study concerned with the important problem of establishing characteristics of pictures which influence the predictability of subjects' response to them. The clarity of his study suffers from the fact that there are, as yet, no well defined pictorial characteristics with which experiments can be undertaken, and the three characteristics described by Fleming suffer from some obscurity. In this study, subjects were presented with a picture and were asked first to name the picture and then to choose a name for it from a list. The characteristics of the pictures were varied along three dimensions. Here is where obscurity is introduced.

The first dimension was the extent to which the object was represented in detail or in abstractness. For example, a picture of a coat was represented in a half tone with all of the detail. It was also represented in outline form. In a third version it was represented by the diagram shown in Figure 1. This is hardly a continuum representing various degrees of compression of the visual information, for the third representation is a symbolic representation which the other two are not.

The second dimension involved the extent to which important features of the picture were replicated. Three pictures representing different points along this dimension would be the following: a picture showing two identical jars, a picture showing two jars differing in size and form, and a third picture showing a jar and a boat.

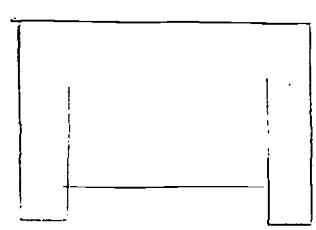

Figure 1. Abstract Representation of a Coat from Fleming (1960)

A third dimension, which might be more appropriately described as a set of dimensions, involved the use of various artistic devices for emphasizing form, object, or number of elements.

The subjects were seventh grade children (N=37) who responded orally to the pictures. The responses were classified by judges according to their abstractness.

The relationships between picture dimensions and responses were found to be as follows: (1) The concrete-to-abstract level of verbal responses to the stimulus attributes of a single picture was found to vary inversely with the overall number of pictorial attributes that were employed in the picture. The lower the number of specifiable properties the picture contained the higher the abstractness of the responses to it ($p = .001$). (2) The concrete-to-abstract level of verbal response made to a pair of pictured objects varied inversely with the number of pictorial attributes that were common to both objects. The lower the number of common specifiable properties between two pictures the higher the abstractness of response ($p = .001$). (3) The degree of abstractness of verbal response to a pair of pictured objects was positively related to one of three classes -- object, form, or number depending on which set of relevant attributes has been made most available. This hypothesis was supported at levels of significance of .02 or greater. A summary of this controlled study indicates that verbal responses can be controlled with respect to level of abstractness by controlling dimensions of pictorial stimulus design. General conclusions drawn were: (1) Reducing the number of stimulus attributes of specifiable properties of an object exhibited by a single picture tends to increase the abstractness of verbal responses; (2) a decrease in the number of common attributes exhibited between a pair of pictured objects tends to increase the abstractness of verbal response; (3) and changes in the arrangement of pictured objects so as to emphasize object, form, and number of attributes can increase the predictability of verbal responses.

The study seems to emphasize an important point in pictorial communication which is that the range of interpretation given pictorial stimuli can be manipulated by the strategy of arranging for relevant attributes that influence what an observer attends to and responds to. Level of abstractness of verbal responses can be controlled by general design strategies and manipulation of the properties of the illustrations used.

Learning from Pictorial Material

Several studies have examined the area of learning associated with pictorial print inputs of information. Lumsdaine (1950, pp. 123-149) studied pictorial representations as contrasted with verbal symbols using pictures of objects and printed words representing objects in a rote paired-associate task. Data were derived from two groups of subjects (N=450); 150 college undergraduates and 300 seventh and eighth grade grammar school pupils. The task was that of learning paired associates which were presented visually on a screen. Four types of pairs of pictured objects on black and white 16mm movie film were used. These were presented with equal frequency and in random arrangements as picture-picture, word-picture, picture-word, and word-word. Findings for both groups of students indicated that for associative learning of verbal responses, pictures or pictorial representations of objects show significant superiority over printed words naming the object (level of significance P=.002). It was found that printed words facilitate learning more when they are placed at the response end of the pair than do pictures (p = .001). Statistical tests in the study yield levels of confidence that are significant, and the findings hold for adult college students as well as for grade school children. The same basic pattern of results was found for subjects individually tested on oral responses by the anticipation method as well as for subjects group-tested with written responses, and for a slower rate of presenting the combinations at a rate of 12 paired associates per minute as well as for a faster rate of 16 per minute. These results suggest recommendations for learning tasks involving rote association, as for example, material such as foreign language vocabulary. The latter task could probably be more efficiently learned by picture-word combination than by the usual word-word pairing.

Kopstein and Roshal (1954) have verified this superiority of pictorial stimulus over a printed stimulus in teaching Russian vocabulary. They intended to replicate previous research showing that learning of a list of paired associates is more rapid if pictures rather than words are used in the stimulus position of each pair. Two groups, consisting of (N=778) basic Air Force airmen were used as subjects, were shown 16 mm motion pictures and printed words. Word trained subjects were tested with both pictures and words. The mean number of correct pair responses were significantly greater (p = .01 level) for subjects trained with pictures and tested with pictures. The superiority of pictures was maintained for the picture-trained group when tested with words (no level of significance given). A conclusion of the study is that, "these results suggest that foreign vocabulary may be acquired more rapidly if pictures are used as cues, but that the advantage of such a procedure may be affected by the methods of testing or application" (Kopstein and Roshal, 1954, p. 408).

Kale and Grosslight (1955) investigated the learning of Russian vocabulary, and found pictures were an aid to learning. Two studies were conducted. The first investigated the problem of differences in learning nouns and verbs of a foreign vocabulary by varying their presentations. The five versions of presentation were: (1) [illegible] only of both the Russian and English words, (2) still pictures with English and Russian words in print shown simultaneously, (3) motion pictures with print captions of both English and Russian word equivalent, (4) audio pronunciation of the word in both languages with motion pictures, and (5) sound motion pictures with the English and Russian words pronounced by a narrator followed by the student pronouncing the word in Russian. Subjects (N=409) were 202 women and 207 men university students. Learning was measured by a written test of Russian words following trials. Findings indicate no significant difference with respect to mean number of nouns versus verbs learned. Silent motion pictures with print captions, version 3, showed significantly more learning ($p = .05$ level) than any of the other four versions of presentation. However, the results did not hold up with still pictures. There was a significant sex difference in favor of women ($p = .01$ level). for this type of learning. This study seems to imply that single modality visual displays, (motion pictures with caption print cues) are superior for this type of learning to print alone, still pictorial and print, or sound-motion pictures with audio presentations. The audio pronunciation of the word, followed by the student pronouncing the word, seemed to inhibit learning as measured in this study. This is certainly an odd finding which is inconsistent with the results of such other research.

A second study was designed to attempt further clarification of these two questions. Three classes of conditions were varied: (1) random order of presentation versus fixed order of presentation of material, (2) print, still pictures, and motion pictures, (3) still picture with combinations of word associated with it in print or sound, or no associated word presented. This experiment also studied retention over time and relearning by testing and repeating the presentation trials one week later following the original trials. Subjects were (N=538) two equal groups of men and women, all university students. Findings were that the picture leads to superior learning over print words (beyond the .01 level of significance). It was concluded again that pictures improved learning but it apparently made no difference whether it was a still or motion picture. The absence of the sound led to superior learning (significance level at .01). The second experiment confirmed the fact that the audio channel presented simultaneously with the video channel produced an interference effect. Sound interference operated regardless of the type of picture presentation. In the second experiment, as in the first experiment, women appeared superior to men in learning foreign vocabulary ($p = .01$ level). Random order of presentation appeared to provide a superior learning situation to a fixed order of presentation, though the results are somewhat dependent on the method of measuring learning.

Learning From Graphical Data

Charts, graphs, tables and maps are more abstract than photographs and illustrative materials, and require some amount of formal training before they can be interpreted.

Vernon (1946) investigated the ability of adults who did not have an extensive general education to understand and acquire relevant information presented graphically in the form of charts or graphs. Two classes of social problems were involved in the presentation. The information in both classes was largely unfamiliar to the subjects who saw it. It contained data bearing on vital statistics and on occupational changes during the second World War. Two types of graphical presentations were used for the data, (1) line and block graphs, and (2) pictorial charts. Subjects included three groups, (1) women college students (N=52), (2) military airmen (N=89), and (3) men from a mixed army group (N=90). The women students were tested for intelligence with the group form of the National Institute of Industrial Psychology Test, while both the airmen and army group were tested with a military written intelligence test containing both verbal and non-verbal material.

There were two methods of measuring retention. In the first method, the college women students and twelve airmen were shown each graph or chart for two minutes and were then asked to recall what they had seen. The women students were asked to recall what they remembered in writing and the airmen reported orally. Their answers were graded according to degree of understanding indicated. In method two, the remaining airmen and the army group were asked a series of questions after they had studied the same graphs and charts for the same period of time. These questions were related to specific facts appearing in the graphs and charts. Their answers were scored numerically according to their accuracy.

It was found that there was a correlation ($r = 0.587$) between scores of 36 airmen on their interpretations of graphical material and their intelligence test scores. Likewise, there was a correlation ($r = 0.668$) between the army group's graphical interpretation scores and intelligence. Those with secondary school education did significantly better, ($p = .01$ level of significance) with graphical material than those without it. Results indicate that adult subjects to whom numerical data were presented in graphical form often had considerable difficulty in understanding and retaining such data. Their ability on this task varied directly with their education and intelligence. The less educated frequently displayed confusion as to what the graphical data was intended to convey. Even the better educated, who could grasp and remember content from the graphs and charts, showed little skill in generalizing from them. The conclusion of the study was that, "the subjects of this experiment did not appear to possess the ability to understand and remember graphical data to a high degree, although those with greater intelligence and better education were superior to those with less intelligence and education" (Vernon, 1946, p. 158).

Vernon (1950) in two later studies decided to extend the inquiry to discover how much difficulty younger people have in understanding factual data presented visually in graphs, charts and tables. In the first study he tested British teenagers, 24 boys and 15 girls (N=39), ages 15 to 18. Subjects were individually shown each one of the three forms of material along with a printed statement of its meaning. Such material was unfamiliar to all subjects tested. Testing was in the form of questions concerning the content of the material, the ease or difficulty in understanding it, and the preference for one form over another. No significant difference was noted in accuracy and ease of understanding between the different forms of presentation. All subjects preferred graphs, charts came next, and then tables of figures. In all cases, it was noted that the simpler the presentation, the more likely it was to be readily understood and remembered. It was concluded that for a thorough assimilation of information by graphical material, it is necessary that a coherent and logical statement or explanation also be given in printed form. There was no sex difference in the ease and difficulty of understanding the information presented.

In a second study of teenagers, grammer school girls (N=16) were subjects, aged 15 to 17½. The content of the graphical charts presented was nearly the same as in the past experiment with written texts prepared to correspond with the information given in the charts. Subjects were divided into three groups. The first group read the text for five minutes and then studied the charts separately for five minutes, the second read the text and studied the charts simultaneously for ten minutes, and the third reversed treatment one by studying the charts for five minutes before reading the text for five more minutes. A series of questions was asked orally after each series of presentations as in the first experiment. There were no significant differences for the three procedures on the number of correct answers. The study does admit that a source of confusion was introduced by not having a complete correspondence between text and charts. There were a certain number of actual disagreements over minor details, and explanatory statements given in the text were omitted from the charts. It was observed that many of the subjects, even when given text and charts together, read through the text first, then laid it aside and studied the charts in isolation afterwards. Little ability was shown in checking the text against the graphical charts. The author concludes that subjects may have to be trained in this ability to comprehend and learn from graphical material, and states that it seems reasonable to assume that if illustrative material is introduced, it must be simple and readily comprehensible in itself, and must not offer any point of disagreement with the written text.

Vernon (1953) conducted another study using (N=160) air force cadets and (N=340) college students. He presented them with maps, charts and graphs with brief descriptions and headings. The findings indicated that those adult subjects to whom numerical data were presented had considerable difficulty in understanding and remembering the material. Their ability to do this varied with their education and intelligence. The less educated frequently became quite confused. The more intelligent and well-educated people learned from graphs and charts if these were fairly simple in style. Pictorial charts were not found to be better than graphs nor was the difference in effect statistically significant. They were preferred by the less educated persons, but again not understood. General findings were that adults show little skill in generalizing from a series of graphical presentations of factual data to produce a continuous statement or argument embracing the information graphically portrayed.

An experiment was conducted by Torkelson (1954) to assess the relative contributions of three audiovisual media as aids in teaching the nomenclature and functioning of naval ordinance equipment. Two groups of 75 NROTC university students and 148 naval training recruits were subjects. Three dimensional aids (mock-up and cutaway), black and white or colored projected transparencies, and training manual illustrations were the three media used. No significant differences among the compared media were found in terms of immediate recall. None of the three types of training aids tested was superior to any other in terms of scores on tests within a two day period following training. On delayed recall tests after five weeks following instruction, significant differences favored ($p. = .01$) the cut-away aid over the manual illustrations and over the black and white transparencies. The cut-away was not significantly superior to colored transparencies.

A detailed study of factors influencing comprehension of nine different graph designs was made by Culbertson and Powers (1959) at the University of Wisconsin. Twenty-five graphs were designed using nine different ways of depicting graphic information. Subjects were (N=100) university students and (N=250) high school students all 18 to 24 years of age. The Differential Aptitude Tests of verbal reasoning, abstract reasoning, and numerical ability and an intelligence Test (not identified in the report) were correlated with scores for general graph comprehension ability. The study indicated that the DAT and Intelligence Test scores both correlated of the order of 0.5 with graph comprehension. Fictitious data were used so that students could not answer the questions from previous knowledge. Bar graphs, both vertical and horizontal, proved easier to read than line graphs. The study showed that each graph element should be identified by a label on or near the element. Element identification through a key added to the difficulty of a graph. No one variable of graph design caused consistent differences in degree of correlation between graph comprehension ability and aptitude or intelligence.

Studies of Interaction Between Pictorial and Auditory Transmissions

A further study of channel interrelationship by Hartman (1961) seems to add confusion rather than clarification to the issues. At least, the interpretation given here to Hartman's empirical data does not agree with the interpretation which he himself has given them. His plan of experimentation was to provide a set of names given orally or in print and a set of photographs which, for certain groups, was presented simultaneously with names. The names were assigned to the photographs at random, an important point to note. Now Hartman (p. 25) describes the situation in which a name is given and is accompanied by a photograph of a person as one involving the presentation of redundant information through the two channels. The actual fact is that the assignment of names to the pictures at random ensures that the information presented verbally and pictorially is absolutely nonredundant for the receiver on the initial presentation. However, after learning, the information becomes redundant. The experiment involves then two major conditions which have escaped Hartman. One condition used by Hartman involves the presentation of completely redundant information through two channels, as in the case of a spoken name and the same printed name presented together. The other condition involves the presentation of completely nonredundant information, as when a photograph of a person is shown and a name is either spoken or printed or the same name is presented in both spoken and printed form. The data have to be examined separately for these two situations.

First, let us consider the redundant situation. This is the situation in which the same name is both spoken and printed. Retention was tested either by a test involving the spoken name or a test involving the printed name. A first point to note from the data is that of the three possibilities, print alone, audio alone, and a combination of the two, the best learning occurred through the print alone presentation even though this was not significantly better than the next best. A second point is that the print plus the audio was not significantly better than the audio alone when tested on the print channel. This appears to be attributable to the fact that the print channel produces better learning than the audio when tested on the print channel and this superiority is not eliminated by the addition of the audio. The apparent superiority of print + audio over audio can hardly be attributed to a facilitating effect produced by the use of more than one sense modality. Work conducted at the University of Utah indicates that the auditory channel often introduces an element of ambiguity which does not appear on the print channel.

The cases involving the transmission of redundant information included in the study do not support the contention that advantages in learning are provided by the simultaneous use of more than one sense modality.

In those sections of the Hartman study in which nonredundant data are presented from two sources, the learning shows a decrement as compared with a single source of information. Hartman states (p. 34) that he did not expect this to be the case but, if the study is correctly interpreted here, what is known about perception would lead one to expect such a finding. That aspect of the study which deals with nonredundant information lacks clarity of conceptualization to the extent that no conclusions can be drawn with respect to the issue of the value of multichannel inputs in contrast with single channel.

In summary, then, the Hartman study does not provide data indicating advantages in multichannel inputs of information in contrast with single channel inputs, and any claims that are made in the study to the contrary are believed to be misinterpretations of the data.

While consideration was given in the Hartman study to the cases involved in the transmission of redundant and nonredundant information by two channels, a third case also exists involving the transmission of information through one channel and a noninformational transmission through another. The effects of the latter condition have been studied extensively by physiologically-oriented Russian psychologists, the results of whose studies have been reviewed by London (1954) and are discussed in the chapter on neurophysiological research. Studies of the latter kind have generally used simple inputs such as a light of a particular color or sound of a particular frequency, but despite such simplification the results show an extraordinary lack of consistency. As far as can be determined, only a single study has been undertaken using instructional materials in which information has been transmitted through the auditory modality while an input designed to provide little or no relevant information has been provided through the visual channel. In such a study, Ketcham and Heath (circa 1962) used a black and white film on the life and work of William Wordsworth. The sound track of the film was designed to describe the life and work of the poet William Wordsworth, while the visual presentation provided English scenes of the kind which might have inspired the particular poems to which the narration referred. Some students heard the sound track alone while others both heard the narration and saw the visual part too. The subjects were later given a test which covered only the material included in the narration. The finding was that those who heard the narration only learned significantly less ($p = .01$) than those who heard the narration while viewing the scenes which added no information measured on the test.

Caution is needed in evaluating such a result. Information from other sources suggests that such a result might not be readily reproduced using other materials. A compelling visual display might well block the reception of auditory information.

Outcomes of Research on Pictorial Presentations

Pictorial material is introduced into learning situations to serve two main purposes. One function is motivational and the other is informative. In the case of children of elementary school age, the use of pictorial material appears to have arousal value. Preference studies show that the younger children prefer the simpler pictures and the older children the more complex. Children prefer realistic pictures to those that provide more abstract representations. Research with adults demonstrates a preference for reading material containing illustrations and also a preference for pictures related to their own interests. The most comprehensive attempt to formulate a theory of the function of pictorial material is found in the work of Smith (1959).

On the intellectual side there appears to be some relationship between the characteristics of the picture and the abstractness of the verbal response made to it. There seems to be fairly clear evidence that, in a paired associate task, learning is facilitated by having a picture of an object at the stimulus end of the task rather than the printed name of the object, but there is a disadvantage in having the response task involve picture recognition rather than word recogniition. In the case of learning foreign vocabulary by means of such a paired associate task, there is a disadvantage in using the audio as well as the visual channel unless, of course, the objective is to acquire correct pronunciation.

A number of studies have been conducted on the information retained from printed material designed with or without various pictorial or graphical accompaniments. The overall finding is that pictorial material does little to aid retention. The ability to understand and remember material in graphical form has been found to vary directly with education and intelligence. In those cases where pictorial material facilitates learning it has tended to be simple and straightforward in character and lacking in embellishments. In a single study it was found that a cut-away of the real object made for better long-term retention than did a black and white drawing.

The problem of the interaction of multichannel inputs is complex. The evidence reviewed indicates that when the information is redundant, nothing is gained by transmitting it simultaneously through two sense modalities.

PART II. EMBELLISHMENTS AND SIMPLIFICATIONS

Audiovisual instructional materials may vary in the complexity of the presentations used to transmit information. At the one end of the continuum are highly embellished materials and at the other are materials which have been highly simplified. For example, a skill such as that involved in learning to dismantle an automobile engine could be taught through a full-color film accompanied by a narration with a musical background or by the use of a filmstrip presenting simplified black-and-white drawings with a straightforward narration. The relationship of embellishment and simplification to learning is an important problem.

The process of embellishment may be introduced for the purpose of fulfilling a number of different functions. These need to be identified and enumerated before much further research is undertaken. It will suffice here to name a few: these include embellishments which add to the realism of the visual display as when color is used, embellishments designed to emphasize particular parts of a transmission as when humor is used, and embellishments designed to draw attention to particular parts of a display as when a particularly significant component of a machine is shown in red. Embellishments do not add information and what they add is often not even remotely relevant to the message that the audiovisual instructional device is designed to convey. Such is the case with music which often introduces instructional films.

Embellishments may be divided into two categories: (1) those designed to raise the level of arousal of the learner, and (2) those calling attention to already existing information. The first category includes inputs which supposedly enhance interest and motivate the viewer, such as cartoons, humorous narration, music or sound effects. Color is also commonly used as an embellishment to provide realism. However, none of the essential information need be transmitted by color unless a color discrimination is to be learned. Teaching the meaning of signal code flags would require color discrimination; and color inputs, in this case, would not be considered irrelevant. A scene, on the other hand, utilizing color for its aesthetic value or for realistic attractiveness may add nothing to the essential information being transmitted. Here color would perform the function of motiviating or holding the viewer's interest, or perhaps that of attracting the learner's attention or of raising his level of arousal. Music is often used for the same purpose, particularly at the beginning of a movie, where it may produce a high level of arousal.

The second category of irrelevant inputs consists of devices or techniques which might have value as nemonic aids to facilitate the establishment of associative connections. For example, in teaching the phonetic alphabet, the letter with its accompanying word could be presented on the screen while accompanied by music or a humorous comment by the narrator appropriate to the word. Music and humor here would be extraneous to transmitting the phonetic letterword combination, but might conceivably assist the viewer's memory in recalling it afterwards. On the other hand, the amusing comment or the music might have the disadvantage of distracting the viewer from the primary task of mastering the association between the letter and the sound. Can irrelevant attention-producing devices arouse the learner to become more vigilant to the learning task at hand? This is a basic question to be answered.

Among the physical properities of input events, both in pictorial and audio style, those that have been varied experimentally are color, special visual effects, special sound effects and novelty and attention directing devices. The following section reviews studies that have been conducted on each of these properties.

Color

Many studies have been undertaken to investigate the effect of color on learners. The simplest of these, and also the most commonly undertaken, involves a study of the preferences of learners for colored presentations in contrast to black and white.

Mellinger (1932) tested elementary school children (N=821) with different colored, as well as black and white illustrations in primary readers. When given a choice betwen two and three-color illustrations, the children preferred the three-color pictures because of their realism. Black and white illustrations were considered less realistic. This was a viewer-preference type of study (no levels of significance given) and no measurement of learning or retention was considered.

In another children's preference study, using primary readers, Miller (1936) measured the preference for five types of pictures of grade 1 through 3 school children (N=300). The five pictures included a black and white line drawing, a wash drawing, a color illustration using three primary colors, a picture with red predominance and one with blue predominance. He found 55 percent of the children favored the full-color illustrations over the single color pictures. The others preferred a picture with single color predominance. The red illustration was preferred to the blue one by the younger children, but the percentage of choices for either single color picture tended to decrease as mental age increased. There was no sex difference for choice of the color illustrations. Children of lower intelligence tended to choose pictures of red and blue predominance more frequently than those of higher intelligence. No levels of significance were stated in the study. The main finding emphasized that more than half of these children preferred the full-color illustration to either one containing red or blue predominance, or to the black and white pictures. The older children expressed less liking for specific colors and a more pronounced preference for the fully colored illustration as compared with black and white or partially colored pictures.

Rudisill (1951) investigated the significance which children attach to color and to other qualities which give illustrations an appearance of realism (lifelikeness). Five forms of illustrations which occur in children's books were selected for experimental testing, chosen to represent differences in amount of color and degree of realism. To insure that the form of illustration, rather than its content, should be the determining factor, the same picture subject was reproduced in these five art forms; a colored photograph, an uncolored photograph, and three forms of watercolored drawings reproducing the exact size and content of the photograph. One watercolor drawing was both realistic in form and color. Another was an outline drawing unrealistic in form but realistic in color. The third drawing was "conventionalized" in form, decorative, but unrealistic in color. Hence, fifteen different pictures were obtained by reproducing three separate pictures of children's activities in the five art forms. School children from kindergarten through sixth grade (N=924) were asked to vote upon the picture preferred when paired combinations of the pictures were presented. The findings with respect to picture preferences of elementary grade school children were as follows:

a. A majority of the children's choices in the lower grades were in favor of a colored picture rather than an uncolored one.

b. Of two pictures including the same subject matter, subjects in the higher grades preferred an uncolored picture giving an impression of reality over a colored one which did not conform to reality.

c. As with earlier studies, a greater frequency of preference for realistic representation appeared with increase in grade level. The main conclusion drawn from the study states that whether a picture is colored or uncolored is less important than realism. Older children preferred an illustration uncolored if it gave a greater impression of reality than one less realistic in color. Differences between groups were large and probably significant.

In order to obtain an estimate of the extent to which adult judgments of children's preferences corresponded with the actual judgments of the children, a group of adults was asked to rate picture pairs in terms of how they thought a six or seven year old would rate them. These adult judgments did not correspond well with the way in which the younger children actually rated them for they overemphasized the factor of realism while the younger children actually preferred the more highly colored and less realistic pictures.

Shaffer (1930) studied children between the ages of six to fourteen (n=152) by analyzing their interpretations of cartoons. According to this study, there was a tendency for greater growth in interpretive abilities beyond the age of ten. Older children seemed to gain in their capacity to identify and recognize reality. Therefore, color and attractiveness, even if unrealistic, may draw the attention of younger subjects, while older subjects prefer lifelikeness and tend to underemphasize the importance of color. According to a summary by Rodriguez Bou (1950) of five earlier studies, agreement with Rudisill was expressed in the fact that younger children prefer more brilliant colors while older children prefer softer tones which tend to be more realistic.

Reference is again made to the study done by Woodburn (1947) summarized in the pictorial perception section of this chapter. He found that color contributes to the attention given to pictures by newspaper readers. His conclusion was that color was an important factor in making a picture more satisfying and less tedious to interpret and understand. Perhaps what is implied by this statement is that colored displays are more distinctive and perhaps innately more rewarding than achromatic presentations. No levels of significance were reported for the study.

Fleming cites a study by Bousfield, et.al., (1956) in which subjects (no N indicated) were examined on recall of twenty-five color slides that could be organized by color or conceptually by meanings, i.e., classes such as birds, fruits, etc. The task of the subjects was to group what they saw and to recall, for example, either several red objects together, or several objects such as birds together. It was found that the subjects grouped their responses by conceptual meaning more frequently than by color. This was true for college and grade school subjects alike.

May, et al., (1958) report a study which experimentally compared a colored versus a rather different black and white training film covering the same topic. The black and white film was of inferior quality compared to the excellent kodachrome color version. Subjects (n=200) were fifth and ninth grade school students. The topic of the film was osmosis. An identical prefilm and a postfilm test was administered consisting of 91 multiple-choice items covering knowledge of material covered in both films along with two attitude-opinion questions. None of the differences between mean scores on the colored and black-and-white film versions approached statistical significance for either the entire group or for any grade level. The experimenters had conjectured that the color film might surpass the black and white on interest and satisfaction even if no superiority was manifested in measured content learning. Gains in rated interest of the subject matter after seeing either film were not significant at either grade level. The conclusion from the evidence of this study is that the effects of color, if any, were not large enough to produce significant differences in learning from a black and white film.

VanderMeer (1952) and (1954) reproduced the essential features of the May study by measuring the differences in learning between groups viewing a black-and-white version and groups viewing colored versions of each of five training films. Ninth and tenth grade (N=500) students were subjects. Results were based on multiple-choice tests of conceptual or factual learning, and non-verbal tests involving the identification of material shown in the films. The films used in the studies presented material related to (1) the geography and economics of the rivers of the Western United States, (2) the identification of map symbols, and (3) the identification of snakes. The same tests were given immediately before and immediately after the film showing while a delayed-recall test was given six weeks later.

In addition, a measure of the relative degree of aesthetic appeal or "liking" for each film version was obtained. Five films were shown to half of the group in color while five black and white versions of the color originals of the same five films were shown to the other half of the students at the same time. Findings indicated that, on the immediate recall verbal tests, there was only one film that yielded a significant difference in learning ($p = .05$) in favor of the group which saw the color version of that film. Although none of the differences in mean scores on immediate recall tests based on the other films was significant, three of the four favored the black and white version. On delayed recall tests, three out of the five differences were significant (two at the $p = .01$ level and one at the $p = .05$ level) in favor of the group which saw the color version of that film. On delayed recall tests, three out of the five differences were significant (two at the $p = .01$ level and one at the $p = .05$ level) in favor of the color film. Scores on the non-verbal tasks of immediate retention favored the black and white versions over the color. Two of these differences were highly significant ($p = .01$ level). There were no significant differences between color and black and white film versions as measured by non-verbal tests after six weeks following the film showings. The results do not indicate any consistent superiority for color film versions over black and white though they do suggest that color may reduce the rate of forgetting. All five color films were preferred by the viewers over black and white films but only one of these comparisons was found to be statistically significant ($p = .01$ level). There were no sex differences found in preference for color over black and white. The main implication of the study was that subjects who saw a color version of a film did not retain any more information immediately after reviewing the film than subjects who saw a black and white version of the same film, but after six weeks they had forgotten less.

A second experiment was conducted by VanderMeer (1952) using (N=199) high school students. Four color films and their black and white counterparts were selected from the five films used in the previous experiment. Similar pre- and post-film tests of learning were administered, but no delayed recall nor recognition tests were given as in the first experiment. The second experiment confirmed the results of the first; namely, that insignificant differences existed between color and black and white films in terms of immediate recall of facts learned from them. All four color films again received preference over the black and white versions. Statistically significant differences for these preferences were found in two of the comparisons (p= .10 level). There were no significant sex differences in preference for color over black and white films. Results of the two studies seem to corroborate the findings of other research that color does not appear significant as a condition facilitating factual learning, there is not much difference between male and females in overall preference for color films and that strictly on a preference scale learners generally prefer color films to black and white.

Zuckerman (1954) studied the relative effectiveness of two film media by evaluating the resemblance of item responses made to the same test questions by two groups viewing two different film treatments. One group saw a complete color, sound motion training film of the flight capabilities of a particular aircraft. Another group saw a black and white filmstrip which was comprised of 262 frames, all from scenes which were later included in the motion pictures. The filmstrip was accompanied by a taped narration. Both groups were student Air Force pilots (N=90) assigned at random to learning conditions. A chi-square test indicated no significant differences due to treatments. The post-film test included 26 multiple-choice factual learning items. The main finding was that factual learning resulting from the color film was as successfully achieved by the black and white filmstrip.

Before leaving the problem of the use of color, the point must be made that the reviewer has found no adequate analysis of functions which color might perform in the transmission of information. Research tends to make the broad comparison of color versus black and white, but no research was located on the use of color for emphasizing crucial aspects of a visual presentation. Another important use of color of which no mention can be found in the research literature is the separation of one part of a visual display from another. The latter is easily illustrated. Two messages in handwriting which have been written one on the top of the other are easily separated if they are written in different colors, but their separation is much more difficult if they are both written in the same ink. The use of color can thus facilitate the separation of signal sources much the same as differences in pitch facilitate the separation of one voice from another.

Special Optical Effects

Various experiments have been conducted with certain optical effects. Some of these experiments have studied the effectiveness of learning a perceptual-motor task by films. The film presentation can vary in the extent to which it approaches an exact representation of the task as the performer sees it.

Roshal (1949) examined three variables related to the visual information provided in learning to tie a knot. The three variables in the study were designated as motion, hands, and camera angle. The motion variable involved either continuous knot tying movements versus static pictures showing successive stages of typing the knot. The hands variable pertained to the showing of the hands of the person performing the task. One version showed the hands of the performer while another film version showed the sequence of steps of knot typing without exposing the hands. The camera angle variable involved the position of the camera which varied from the position where the actual participant would see the task to an angle from which an observer watching the task would see it. Subjects were (N=3,314) naval trainees. The effectiveness of each film version was measured in terms of the mean number of knots tied correctly by those who had observed the film. The film using a camera angle showing the task as viewed by the person actually tying the knot was more effective in teaching this task than a film where the camera photographed the performance from an observer's position. Performance by the subjects viewing all the movements, or the motion version of the film, surpassed that showing merely a series of static shots portraying successive stages of the task ($p = .05$ level). No significant effect was produced by showing the hands in the picture in contrast with not showing the hands. The presence of hands in the pictures tended to obscure some steps in the task negating any benefits which their presence might produce.

A study by Cogswell (1952) was conducted to discover whether the three-dimensional aspect of films was important for teaching a motor skill. A stereoscopic sound motion picture was shown one group and learning for this group was compared to that of two control groups exposed to the same film shown as a conventional sound motion picture. One control group saw the conventional film while wearing stereoscopic spectacles while the other group viewed it with the naked eye. The wearing of the stereoscopic spectacles was found to have no significant effect on learning. The task presented by the film was that of assembling the breech block of a 40mm anti-aircraft gun. Subjects (N=321) were army trainees. Subjects were given a screening test trial to determine ability to assemble the breech block. None chosen for the experiment was able to assemble it before the training film was shown, as determined by a test. The post-film test required the subjects to assemble the gun breech in ten minutes. Two analyses were made; one to determine the significance of the differences between the mean speed scores for the assembly of the breech block for the three learning conditions; and another to determine the significance of the differences between the percentage of subjects who succeeded in assembling the breech block correctly after each learning condition. Findings indicated that no significant differences occurred between the mean speed scores and the percentage of successes in the stereoscopic and conventional versions. Both groups did learn, but three-dimensional film effects did not improve learning over the conventional motion picture.

Mercer (1952) conducted an investigation of the effects of special forms of visual presentation and their relationship to factual learning. An analysis was made of the use by film producers of three visual effects known as "dissolve," "wipes" and "fades" in 52 military training films. The effects were alleged to be symbolic representations of time, space and thought. Two groups (N=44) of Air Force trainees were subjects in the first experiment. An experimental group was given oral definitions of the symbolic representations and were shown several examples. The control group was given no such information. Each group was shown the same film and both groups of subjects were asked to indicate each time one of the special effects appeared and the meaning to be attached to it. An analysis of variance indicated no significant differences between the previously informed and the uninformed groups. Either an acquaintance with the nature and use of these symbolic representations did not enable the trained group to interpret or recognize the effects any more accurately than the untrained group or the meaning of the effects could be inferred from the content, or the meanings were obscure. The problem was then approached concerning the influence of such visible symbols on film-mediated factual learning.

The design of the experiments which explored the latter problem was complex because of difficulties of obtaining sufficient subject time to fit an efficient procedure. The details need not be spelled out here, but it can be said that fairly large groups (N=284 and 684) of subjects were involved and the reported conclusions appear to follow from the data. First, it was found that when three versions of a film were prepared which included the effects under consideration, but to varying degrees, no significant differences were found in the learning produced in different groups exposed to the different versions. The films used covered the two topics of Hunting Animals of the Past and Oxygen Breathing Apparatus. Second, when some of the subjects were exposed earlier to a lecture of the visual effects so that they would recognize them and understand their significance, they did not learn more from the films than those who had been given no such explanation, although it was demonstrated that the lecture on visual effects did teach.

An implication for film producers here is that they should not depend upon special optical effects to produce transitions in time, locality, or thought; but should concentrate upon other appropriate cues in the picture or sound track. Optical effects as they have been used in training films do not aid factual learning nor do they produce any specific meaning to the film text. A more specific means of indicating transitions such as titles or statements in the audio commentary may be adequate, less expensive, and simple to use. An additional problem pertinent to the present discussion is the study of the influence upon learning of removing any novel visual effects and of using print titles instead where transition between sequences is needed. McIntyre (1954) conducted such a study using a film demonstrating the use of military cold-weather clothing. Titles were inserted where trick effects in photography were originally placed. The titles served to organize the film content or orient the viewer to the next film sequence. A post-film informational test was given to measure factual learning. Subjects were (N=428) Army trainees. There was a significant difference between the mean scores on this test of those trainees who saw the "titles" version and those who saw the novel, trick-photographic version ($p = .05$ level). That is, trainees learned more from print titles as transitional cues than from more complex and novel visual cues. Blank film was then inserted in the place of titles to study the effect of transition without "jump cuts" and determine whether breaks in continuity could be used without seriously hindering teaching effectiveness of the film. There was a highly significant difference in post-film mean scores ($p = .01$ level) between subjects who saw the "titles" version and those who saw the blank film version. Trainees learned more from titles than from blank film transition sequences. However, there was no significant difference in learning when the visual effects were deleted and blank film was substituted in their place. The main conclusion was that the additional cost and effort in special trick optics cannot be justified on the basis of factual learning from a film. Print titles, however, increase learning and yet serve in the interest of simplicity as transitional cues.

Simplification Procedures

Carpenter (1954) attempted to determine whether motion pictures could be as effective as simple and less expensive audiovisual aids. A comparison was made of learning factual information from an original sound motion picture with learning from two filmograph versions on the topic of riot control. The desirability of simplification was suggested because many large mob scenes included in the original sound motion picture version were considered to create confusion. A filmograph is similar to a sound film, but is produced by filming still shots of the original motion picture on 16mm film accompanied by sound on film. One filmograph version for the experiment was produced by copying frames from the base film and eliminating motion. The other used still photographs and diagrammatic representation, and substituted stock photographs in place of the original complex scenes. It also eliminated 25 percent of the scenes from the first filmograph version. Both filmograph versions retained the original sound track. Pre- and post-film tests included an objective written test on factual knowledge gained from the film and an attitude test to determine if the participant of the three versions of the film had differential effects on attitudes toward the film material. The difference between the means on the pre- and post-film tests for groups viewing all three films was highly significant ($p = .01$) indicating that learning resulted from seeing the films.

The difference in the means for the group viewing the original motion picture and the group viewing the first filmograph produced from stills of the original motion film, was small in favor of the group seeing the original motion picture ($p = .01$ level). The difference between groups seeing the two filmograph versions was not significant -- the mean scores were almost identical. There were no significant differences between any of the groups of the attitude tests for all three films. Conclusions from the study indicate that the original motion picture taught only slightly more information than either of the two still filmographs covering content. It is questionable whether the more elaborate and expensive production is justified by the mean difference in factual learning over the more simple filmographs. There was no difference in effectiveness between the two filmographs indicating that simplicity of the one was as effective as the other in teaching factual information. All three versions were equally effective in developing an attitude toward the film topic.

Howe (1961) a member of the engineering drawing department at Rensselaer Polytechnic Institute designed a study to evaluate the effectiveness of three different film methods of teaching descriptive geometry to an engineering drawing class. The films created for the project were designed to meet the overall objective of helping students see and understand spatial concepts in the study of form; to learn how to see three-dimensional objects in space and understand their spatial characteristics. Three different methods were used to teach three sections of a descriptive geometry course consisting of 12 weeks of instruction for each section. Six consecutive periods were devoted also to problem solving exercises. Subjects (N=536) were freshmen engineering students. The aim of the experiment was to compare three different methods of teaching. Treatment I included the customary text completely free of pictorial illustrations, the conventional 50-minute lecture periods without the aid of pictures, and problem solving exercises which did not have pictorial representations. Treatment II used a different text developed recently with emphasis on pictorial representations of forms in space, 50-minute lecture periods involving the same pictorial representations used in the problem solving exercises. Treatment III, used the same text as in treatment II, specially prepared films which relied heavily on animation and which were used for half the lecture period. The films were followed by an illustrated lecture for the remaining twenty minutes with the same pictorial representations as in treatment II. The evaluation instruments for the study were student performance on workbooks, problem exercises, weekly quizzes and the final examination. Findings showed that no significant differences were clearly discernible among the effects of the learning conditions. The three treatments, although greatly different in terms of audiovisual materials, were equally effective or equally ineffective.

A comparative study of the effectiveness of various audiovisual media was made by McBeath (1961). It was intended to determine whether a filmograph could be a more effective teaching tool than either the captioned filmstrip or sound filmstrip. The study attempted to verify the hypothesis that the filmograph, being more polished and using more audio and visual embellishments, could teach more effectively. The filmographs were made by photographing still pictures on motion picture film, using such techniques as camera movement, attention-directing devices, and animation. One version had print captions while one did not. Content for all film versions was sixth grade social studies. A print-captioned filmstrip (35mm) was compared with a non-captioned filmstrip with narration. The filmstrips were further compared with the filmograph which used a duplicate of the sound track. The experiment was conducted in twenty sixth-grade classrooms for ten different areas of Los Angeles Country in order to include students of varying socio-economic status. The population of (N=558) sixth grade students was divided into four groups matched according to intelligence, age, sex and socioeconomic status. The findings showed no significant difference between groups on either post-film tests or on retention tests after a three-week period. There was a sex difference between pre- and post-tests and retention tests in favor of boys ($p = .01$). Students with higher intelligence quotients performed significantly better on both immediate and later retention tests than those with lower intelligence quotients ($p = .01$). The hypothesis that the filmograph can teach better than the filmstrip was rejected.

Special Sound Effects

In approaching the problem of special sound effects in aiding or hindering the transmission of information in audiovisual materials, there is a dearth of experimental literature. The question of the contribution of music in audiovisual materials must certainly be considered here. Information can conceivably be conveyed by music.

London (1936, p. 135) states that one of the functions of music in the audio input of a motion picture is, "to establish associations of ideas and carry on developments of thought." Zuckerman (1949b) completed a rather comprehensive review of the literature on the contributions of music in instructional and informational films. He states that motion picture producers believe that they intuitively integrate music with visual images and word meanings to provide associations which may function to produce particular audience reactions. Morris (1946) considers music in motion pictures to have symbolic value. He states that the musical accompaniment provides a means for establishing associations. Music is used in an effort to establish associations of the unfamiliar with the familiar, or in the hope that learning in a framework of music will aid recall. Music may be repeated with a visual stimulus to provide variation with repetition, and finally repeated without the visual presentation to provide recall with reduced cues.

Music, on the other hand, is often used primarily in audiovisual materials with the intent of producing either arousal or emotional responses. If music makes any contribution to learning from film media, and this is an hypothesis yet to be tested, then the problem becomes one of establishing what is suitable and appropriate in terms of the effects that music has on the audience. Music is included in films partly because of a tradition established by its use as an accompaniment to pictures. Often, it is provided without any specific purpose.

Evidence pertaining to the problem of the value of music in this context is peculiarly lacking despite the fact that it would be relatively easy to obtain. A little evidence is provided in studies by Neu (1950) and (1951), but in these studies the effect of music is inseparable from that of other irrelevant inputs from the sound track. Neu produced five versions of a film dealing with the use of machine shop instruments. Version 1 gave a straightforward presentation of the subject matter. Version 2 included additional relevant visual material. Version 3 had additional irrelevant visual material. Version 4 had relevant auditory material added such as the noises of a machine shop, and Version 5 had irrelevant auditory material. Music was included as two of the irrelevant auditory additions in the fifth version while other sound effects in the same version included an auto horn, a squeak of a door, and other sounds unrelated to the learning task. The subjects for the study were 2,031 army recruits divided into six groups. Five of the groups were shown a version of the film and the sixth functioning as a control group was not shown any version.

On objective post-film tests both verbal and pictorial testing situations were utilized. For all film groups an increase in learning resulted from viewing one or another version. The film groups mean scores were between one and two standard deviations higher than the mean score of a comparable control group that saw no film. However, the evidence indicated the irrelevant sound devices which included music detracted from the teaching effectiveness of the film. Experimentation here suggests that music does not add to the communicative effectiveness of an informational film. In addition, relevant sound devices such as the naming of a tool, the sound made by the use of a tool, and so forth, also made no significant contribution to the learning of the trainees.

Novelty and Other Attention Directing Devices

Devices or methods of directing attention to the relevant or critical information as contrasted to irrelevant information may be necessary. Such devices may consist of music, slow or fast motion, humor, or unusual sounds, the use of selected camera angles, etc. Relevant devices include any emphasis technique that is related to the specific information to be transmitted. For example, the close-up of a part of some structure being considered brings attention to that part. Any emphasis technique that calls attention to the screen of film process, but otherwise is unrelated to the film content or transmitted information, is called an irrelevant device. In general, it is assumed that relevant devices may facilitate learning while irrelevant devices may act as distractors or inhibit the transfer of information. On the other hand, it might be argued that some relevant devices may actually add information.

Neu's research study (1951) should again be mentioned here because his versions of the training film on introductory machine shop measuring instruments also included relevant and irrelevant transmissions other than music.

Three hypotheses were tested: (1) that film mediated learning is facilitated by relevant attention-gaining devices and inhibited by irrelevant devices, (2) learning is equally facilitated by visual and sound attention-gaining devices of the same relevance, and (3) recall of these transmissions is independent of learning of film content. It will be recalled that five versions of the same film were prepared and shown to five groups of Army and Navy trainees (N=2,631). One version contained no attention-gaining devices, but presented a clear straightforward treatment of the content. Other versions each included 26 visual relevant and irrelevant, and audio relevant and irrelevant devices placed at the same points in the film. Post-film tests included recall of factual information and recall of attention-gaining devices. Findings show no evidence that the insertion of relevant attention-gaining devices added to the teaching effectiveness of the film. In fact, for the Army population, the no-device version yielded the highest scores which were significantly better ($p = 0.01$) than those produced by the other versions. There was some evidence that the irrelevant-sound attention-gaining devices actually detracted from teaching effectiveness. For all groups, the sound irrelevant version yielded the lowest scores. The implications of the study are that when the transmission of information is the principal aim, film subject matter should be designed in a simple, straight-forward way avoiding the use of attention-gaining devices or irrelevant material.

VanderMeer (1953) compared the effectiveness of two films which employed radically different attention-gaining devices for teaching personal hygiene information by means of rewritten lyrics of familiar folk tunes. Subjects of the study were (N=176) Army recruits. The relative effectiveness of the two films was measured by pre- and post-film observations of changed behavior and paper and pencil achievement tests. Records of personnel inspections revealed no significant changes attributable to either film. Post-film written tests were administered to determine differences in attitudes toward personal hygiene. Of the five factors of personal hygience tested, one factor showed no significant differences, two factors significantly favored one film ($p = .001$) and two factors significantly favored the other film ($p = .001$). Final conclusions were that neither film changed the observed behavior of the men to any significant degree. The two films were equally successful in effecting the change of five personal hygience factors as measured by written tests. On written attitude tests regarding like or dis-like for each film, the straight-forward version obtained the higher rating as an instructional device.

McIntyre (1954) studied the effects of introducing humor in a training film and attempted to determine any difference in teaching value of such an approach as compared with an approach involving print titles indicating content. In addition, another film containing the same content presented it in a straight-forward manner without humor or print titles. The film demonstrated the use of military cold-weather clothing. Humor in the one version included both audio and visual effects such as humorous comments, trick photography, speeded motion, reverse motion, and juxtaposition of scenes. Subjects were (N=426) Army trainees. Findings showed that subjects learned significantly more ($p=.05$) when the humor was deleted and the print titles were substituted giving cues concerning the main topics to be covered. There was no significant difference in learning between the humorous and the conventional, straightforward film versions. Final conclusions were that the additional time and cost to produce a novel type film could not be justified in terms of any increased learning which might result.

Summary

One of the commonest embellishments of audiovisual teaching devices is color and, hence, studies of the effect which this characteristic has on the learner is a matter of considerable importance. Studies of preference show that when colored and uncolored versions of the same picture are shown to the younger children in the elementary grades, there is a marked preference for the colored version. The younger children are differentiated from the older children by the fact that they also prefer an unrealistic colored picture to realistic black-and-white pictures while the choice of the older children is the reverse. As age advances there is an increasing preference for realism. Younger children also prefer more brilliant colors, but the older children show an increasing preference for soft tones. Children of high school age and young adults prefer color films to black and white.

The fact that color adds to the attractiveness of a training device does not necessarily mean that it improves learning. Research points to the conclusion that black and white is as effective as color for instructional purposes except when the learning involves an actual color discrimination. Furthermore, learners prefer colored versions despite the fact that the addition of color does not generally contribute to learning. A single finding that a colored film produced more effective learning in terms of delayed recall would need to be reproduced before much weight could be attached to it.

The Roshal (1949) studies of knot typing are instructive in that they indicate the difficulty of predicting what are and what are not important elements in demonstrating a skill. This is reflected in the finding that the presence of hands are not important for demonstrating knot tying but may interfere with learning. The findings suggest that demonstrations should include only the basic elements of what is to be demonstrated.

Other studies have shown that special effects used by film producers to represent lapses in time and other events were not effective in conveying the intended meanings, at least not to Air Force trainees. Print titles seem to be more effective for these kinds of purposes. Much the same has been found to be true in the case of the use of special sound effects which appear to provide much more of a challenge to the film producer than an aid to the learner. Much the same can be said of humor and of other special means used for the purpose of retaining the attention of the learner.

Consistent with the fact that embellishments do not facilitate learning is the finding in one study that oversimplification can have a deleterious effect. The making of a filmograph from a film may reduce the information transmitted to the point of reducing learning, but this would not necessarily happen for it is easy to conceive of a case in which an overelaborate film version would be improved by being reduced to a filmograph.

Finally, the research leaves the overall impression that procedures which elaborate the process of transmitting information, either by embellishment or by other devices, do not facilitate reception perhaps because the human receiver does not have the capacity for utilizing this added information. This impression is consistent with the material discussed later.

PART III. AUDIO READABILITY, DENSITY OF INFORMATION AND RATE OF PRESENTATION

Listening Comprehension

Most of the questions concerning the design of the narration which one would like to see answered have not been answered at this time though research on listening comprehension has had a history of a quarter of a century. Well designed studies in this area go back to one by Goldstein (1940) though there had been many earlier studies which compared visual and auditory modes of presentation--studies which will receive passing reference in a later chapter. The typical comparison made between the effectiveness of reading versus listening in these earlier studies turns out to be a rather trivial one in that experience factors appear to be the major determinant of the skill manifested. The more experience at reading which the person has had, the more likely he is to gain more information from reading than from listening. The study of Goldstein was the first to point out what was really happening in this respect. In addition, Goldstein was the first research worker in the area to use materials and equipment capable of exercising some control over both the difficulty level of the material and the speed of presentation.

The Goldstein study provides many interesting findings. The data showed that comprehension declined as speed of speech was increased from about 100 words per minute to 325. Goldstein points out that the amount learned per unit of time does not necessarily decline, but does not provide data on the amount of learning per unit of time for each rate. The latter is a very interesting matter to investigate and is under inquiry at the University of Utah at the present time. Another very striking finding is that listening comprehension is described as "holding its own" (p. 61) with reading comprehension at the speed of 325 words a minute, despite the fact that none of the subjects had probably ever heard speech at such a rate.

In addition, Goldstein found that subjects were more variable in reading comprehension than in listening comprehension, perhaps because there are greater individual differences in experience with reading than there are in listening. Everyone obtains daily practice with listening.

The high standards of scientific research set by Goldstein were matched by few of the studies which followed. The trend during the two decades that followed was to place emphasis on the development of tests of reading comprehension and to utilize these in relation to educational counseling and training procedures. Few of the studies were concerned with the problem of determining the optimum rate of presentation of material. One study by Diehl, et al., (1959) used speaking speeds from 125 to 200 words per minute. They concluded that the optimum rate of presentation was of the order of 160 words per minute. A very similar conclusion was reported by Goodman-Malamuth (1957). These studies, like much of the other work in the area, make the mistake of determining listening efficiency in terms of the amount of learning produced at different speeds with the amount of material read held as a constant. What should be done is to determine the amount learned per unit of time spent on learning. Thus a listener might learn less when material was read at 250 words per minute than at 125 words per minute, but one should take into account the fact that the one rate occupies half the learning time provided by the other. It is conceivable that two presentations at 250 words per minute (which occupy the same time as one presentation at 125 words per minute) might produce more learning than that produced by the slower rate.

The area of listening comprehension has become one to be investigated largely by speech experts. For this reason one finds studies of such problems as that of determining the effect of being able to view the speaker on the comprehension of speech--a type of research which has implications for the audiovisual field. O'Neill (1952) undertook a rather thorough investigation of visual factors in speech comprehension. What he did was to vary the signal-to-noise ration in a situation in which the listener could see the speaker and determined the extent to which viewing the speaker facilitated comprehension. However, the published report of the study does not make it clear whether one group did not see the speaker so that a base line could be established from which the effect of viewing the speaker could be measured. The study claims to have established that there is a marked visual contribution in the case of certain vowels and consonants--specifically o, i, s and f.

Goldstein (1940) found that the difficulty level of the material presented audially had an influence on listening comprehension. This is a problem which has been investigated in subsequent studies.

Chall and Dial (1948) experimented with eighteen recorded radio newscasts. These were heard by college freshmen (N=124) followed by an objective test on the newscast content. Each newscast was measured for readability by the Dale-Chall and Flesch formulas. Correlations between these two readability scores and number of questions correct on the objective test were 0.74 and 0.72 respectfully. Such results suggest that comprehension and information transmission by audio inputs might be predicted by readability formulas. These newscasts, however, not only varied in verbal difficulty but also in content. It is probable that some content is harder to understand regardless of the difficulty level of the language used.

Young (1950) used different versions of an account of UNESCO activities having the same content but with four levels of difficulty. These levels of difficulty were determined by the Dale-Chall formula, and the versions varied in readability from the fifth to sixth grade level for the easiest to the thirteenth to sixteenth grade level for the most difficulty. These recordings were played to high school students (N=620) of above average intelligence. Findings on a post-treatment test of factual items contained within the verbal UNESCO accounts indicated that scores were nearly the same (no significant difference) for groups who heard the easiest as compared with those who heard the most difficult versions. No pre-treatment test was administered so that the change in learning about UNESCO from the recordings was not measured. If it can be assumed that the groups were initially equal in their knowledge of UNESCO before hearing the recordings, then varying the level of verbal difficulty of presented information produced no measurable difference in comprehension or learning.

The results of the latter study are inconsistent both with other empirical findings as well as with theoretical expectations derived from what is known about the structure of abilities. The comprehensive review by Keller (1960) of research undertaken during the previous ten years suggests that listening comprehension, as an ability, fits within the structure of other verbal abilities, though there are a few studies which provide evidence to the contrary. On such a basis one might infer that difficulty level would be a major factor in determining comprehension, as it is in reading.

Other studies of listening comprehension have been undertaken within the framework of the sound motion picture. In such research an attempt has generally been made to vary the narrative while keeping the video presentation constant. Park (1944) first analyzed the sound commentary of eight science and social studies films. A complete word count and difficulty level determination was made of the commentaries tabulated by means of the Thorndike list of 20,000 words. It was found that at least half of the different words used in the films fell within the first 1,000 word level, and 85 percent within the 6,000 word level list. He also compared the reading level of the film commentaries to that of science textbooks and comic books by measuring the factor of average sentence length. In the films analyzed, he found the average number of sentences was 77 for each film, and the average number of words in each sentence was 17. This compared favorably with sentence length of textbook materials for the same grade levels. The vocabulary level of the films seemed comparable to those of textbooks and comic books. Park reported another study (1945) of the same eight educational sound motion pictures dealing with social studies and science topics shown to elementary and secondary school students (N=842)[1] Park reported that pre- and post-film tests indicated that most gain in knowledge of film content occurred with those films having commentaries of shortest average sentence length but he gave no data to support his position. The simpler the vocabulary of the sound track, the greater were alleged to be the gains in knowledge of content. His conclusion was that long sentences in the commentary reduced comprehension. He also pointed out that the technical or more difficult words used in the commentary could not be used to teach the content in one film showing.[2] No attempt was made to measure other differences between the films, such as pictorial content, other than average sentence length and vocabulary difficulty.

In an earlier study by Einbecker (1933) the effects of sound motion pictures were compared with that of silent or sound film with print captions, or oral comments by the teacher with silent film either with or without captions. Ninth grade science classes and eleventh and twelfth grade physics classes were used in the experiment (N=329). All the films were originally sound motion pictures on topics in general science. Post-film tests were designed to measure factual learning from the presentations using diagrams and completion items. One group was shown the picture without sound track, captions, or teacher's comments. A second group was shown the same picture with regular sound accompaniment. A third and fourth with teacher's comments either with or without print captions. A fifth group was shown the silent film with print captions. Teacher comments explained technical points in the picture, elaborated on major ideas being presented pictorially, and directed attention to features of the pictures thought significant. The principal difference between the sound track and the teacher accompaniments was that the teacher avoided comments which were not illustrated in the film and explained details of the picture not covered in the sound track. There were "significant" differences on test scores between the silent picture alone, and the silent picture with teacher comments or with sound track (no levels of significance given). However, there were no significant differences between results of the presentation of the sound motion picture and the silent picture with oral comments by the teacher. The main findings indicate that verbal accompaniments increased learning by film over silent presentations, but it seemed immaterial whether it was from the sound track or the teacher. So far as this study was concerned, oral comments given by the teacher were, under the circumstances, at least as effective as the narration of a sound track accompanying a film.

Many of the early studies which have been reviewed up to this point suffer from flaws which were not recognized by the research workers. For

[1]Word difficulty and sentence length were again checked as in the first study.

[2]In an attempt to discover the relationship of vocabulary difficulties to the understanding of the content of films, the scores of pupils on pre-film vocabulary tests were correlated with the scores on the post-film content test. The correlations equaled or exceeded .50, but probably represent an artifact in that knowledge tests typically show a substantial correlation with vocabulary tests.

example, in the Chall and Dial (1948) study there is the serious possibility that the results may have been contaminated by the fact that the easier newscasts may have pertained to simpler subject matter. This, in turn, may have resulted in lower readability scores. Park's study (1944) also suffered from a similar potential weakness. The problem with both of these studies is that they include too many potential sources of variance. The study by Einbecker (1933) does not provide any results which can be generalized to other situations. One could probably design a film in which the sound track might not only add nothing to the pupil's learning but might actually interfere with the learning. In addition, an inferior and muffled sound track might communicate less information than a teacher with good enunciation. Not all of the early studies exemplied gross flaws in design--and the study by Goldstein (1940) stands out as a shining exception--but the majority did. Some of the more recent studies show greater sophistication in this respect.

Allen (1952) reported a study in which he investigated the effect of grade level of commentary on learning of factual material. Four commentaries for each of two educational films were studied. The four commentary versions of each film contained essentially the same information but differed in their scores on the Flesch (1946) reading ease and human interest formulas. Each film had four commentaries prepared, two for school textbook level. The other, referred to as easy, was made from the difficult version by shortening the sentences and simplifying vocabulary. Content of both verions, as far as factual information communicated, remained the same. On readability formulas, the difficult version was at the ninth to tenth grade level while the easy version measured at the fourth grade level or below. Seventh and eighth grade students (N=113) participated as subjects. Gains on a test served as the means of measurement. Final results showed that differences in learning between the pre-film test and the post-film test were significantly in favor of the easy version ($P = 0.01$). Those who saw and heard the easy commentary gained about thirty-three per cent more information than those who heard the difficult commentary along with the same motion picture. The study showed that verbal simplification procedures applied to film commentaries can sometimes increase factual learning. Apparently shortening sentences and substituting short words for longer ones may facilitate learning verbally.

Fletcher (1955) attempted to study the results of reducing two film commentaries by two methods; (1) judgment of script writers, and (2) an analysis of past learning from the films. One version of the film commentary was reduced eight per cent in length by script writers and another 24 per cent as a result of using the learning analysis technique. Naval recruits (N=150) were divided into three groups which were presented with the original version of the film and commentary, the shorter version by script writers, and the very shortened version from the learning analysis technique. At the completion of the film treatments, all groups were administered a 50 multiple-choice question test on factual knowledge of the films. A control group was also given the test to provide an indication of the level of knowledge existing without the film experience. Learning scores of each experimental group differed significantly (.01 level of confidence) from the control group. No significant differences were found between groups exposed to the full commentary, the shorter version by script writers, and the very shortened version based upon learning analysis. The major finding of the study was that cutting out material in the film commentary had no measurable effect upon learning from the sound motion picture. Apparently the packing together of facts by eliminating non-factual material in the commentary did not reduce learning.

Ash and Jaspen (1953) studied the effects of repeated presentations of a training film of a gun assembly task produced in two versions, one involving a slow rate of development and the other at a fast rate of development. The original film was designed to teach a motor skill involving the assembly of a gun. The slow version presented in four and one-half minutes a step by step account of the task. The fast version presented only the essential aspects of the demonstration and had a running time of three minutes. For the study of the effects of repetition, the film was shown either once, twice, or three times in succession to the same group. Learning was measured by the ability of the subjects to assemble the gun immediately following the showings of the film. Subjects were (N=1,100) naval cadets unfamiliar with the gun assembly who could not perform the task without instruction. The principal findings indicated that the slow film was appreciably better than the fast film. Repeating the slow demonstration film twice improved learning significantly (.01 level of confidence). For the fast film, two presentations were only slightly better than one; it required three presentations to yield significant learning (.01 level of confidence). Two presentations with the fast rate were only slightly (not significantly) better than one showing of the slow rate film. The study emphasizes the interaction effects of repetition and rate of development. Two showings of the slow film yielded a significant increase in learning over one showing, but two showings of a fast development film did not produce significant increases over one showing. This suggests that repetition alone cannot entirely compensate for a fast rate of development in a film. Unfortunately, the report of the study did not reveal the rate of development in words per minute of the commentary in either the fast or the slow versions.

Perhaps the most comprehensive study to date on sound track variables was conducted by Zuckerman (1949a). Essentially three conditions were involved; namely, level of verbalization which included number and kinds of words used in the film commentary per minute, the personal reference or mood of the commentary, and the timing of sound to picture. These conditions will be designated here as level of verbalization, personal reference, and phase relationships. The task chosen to be taught by a set of three motion pictures was the skill of knot tying taken from Roshal's study (1949). The experimental films were black and white, each accompanied by one of seven commentary scripts which included various combinations of the conditions varied in the experiment. A silent version was also prepared. Three verbal density levels were used, a low rate (71 to 102 words per minute), medium rate (111 to 141 words per minute), and a high rate (155 to 185 words per minute). Two forms of personal reference in the commentary were used, either the imperative or passive mood. There were also two phases of relating the commentary to the picture by either leading the visual image or lagging behind it. The seven versions which included commentary did not include all possible combinations of the experimental conditions. Subjects were (N=1,787) naval training cadets.

It was determined before the experiment that none of the subjects were able to tie the knots. Scoring of learning from these films was determined in terms of correct and incorrect knots tied following the film showings. A control group was shown the film without sound track and was then tested. The findings were as follows: The amount of verbalization had a significant effect (.01 level of confidence) on the number of knots which were tied correctly. The control group viewing the film without sound produced the lowest scores on the task: The medium level of verbalization of 111 to 141 words per minute was significantly more productive of knots tied correctly than the low or high levels (significant at the .01 level of confidence). The study raises the possibility that when a narration is used in relation to a visual presentation, lower speeds may provide optimum learning. The high level of verbalization commentary showed scores equal to the low verbalization groups. There were no significant differences between the versions involving variations in personal reference. There were no significant differences obtained between phase relationships of sound to picture. The leading commentary version which began a description of the motion approximately two seconds before the corresponding picture appeared on the screen was productive of a higher total of correctly tied knots than the lagging commentary version, but when scores for individual knots were examined only one was found statistically significant at the 0.05 level. In general, the conclusions from this extensive study may be summarized as follows: In teaching a motor skill task such as knot tying by sound motion pictures, some verbal description of the acts involved in knot tying assisted the learners, but a very detailed, redundant, commentary actually interfered with, and reduced learning. Directive statements used with this military population influenced learning more than did the passive type statements in the commentary.

Nelson and VanderMeer (1955) also recognized the fact that in most sound-motion training films a large part of the factual information to be transmitted is carried by the sound track. In their study, the sound track of an animated color training film on basic meteorology was varied by improving language intelligibility, increasing number of personal pronouns, shortening sentences, using simpler words, and reducing definitions, explanations, and repetitive concepts. Four versions of sound tracks were used with the same motion picture, and all versions had the same running time of 14 minutes. Two testing tasks followed all film showings: One was a 64-item multiple-choice factual test, the other was a diagram test consisting of simple line drawings with associated multiple-choice questions concerning interpretations of the drawings. Subjects were (N=291) Air Force Reserve Officer Candidates at Pennsylvania State University. The different film versions were shown to classes selected at random and were followed immediately by a verbal test and then a diagram test. A control group took the tests without seeing the films. Results were based upon comparisons of the relative effectiveness of the four different commentaries with the film, and the effect of the complete sound motion films in comparison with the commentary alone. Results showed that all groups viewing the film versions learned more than the control group which did not see the film (p=0.01). The differences among the various commentary versions, however, were small and not statistically significant. On the comparison of the sound motion picture films to sound track alone, one commentary accompanied by its pictures was superior on all tests to the same commentary alone (at the .01 level of significance). This commentary version contained simpler language, shorter sentences, lower frequency of difficult words, and a relatively large number of transitional words and phrases between concepts. The authors state that the contribution to learning of the addition of the pictorial elements of this film is only about twenty per cent on the average (percentage gain attributable to addition of pictorial element) above that resulting from exposure to the sound track alone. A summary of the study points out the fact that the film with any one of the modified commentaries was consistently superior to the no film group. The best commentary was the one which had the shortest sentences, and the most personal pronouns. This is consistent with the suggestion arising from the work of both Flesch and Zuckerman that personalization of commentary may aid comprehension. This study confirms others in showing that in present-day instructional movies the sound track contributes a greater share of the transmitted information than does the visual. It may be that a commentary may vary around the optimum without greatly reducing learning.

The study also suffers from the limitation that it does not provide a basis for generalizing to other film materials, a limitation which it shares with many other studies in the area. The basic deficiency lies in the fact that the study does not concern itself with a sample of a well-defined universe of events. One can hardly consider the particular training film used to be a random sample, or any other kind of sample, of a well-defined universe of training films. Hence, there is no universe to which the findings can be generalized, if any generalization is at all possible. This in turn arises another problem concerning research methods in the area. Suppose that the universe from which the sample of stimulus events were derived consisted of all training films produced in America. Results which could be generalized to this universe of films would probably not be particularly useful. A change in the policy of a few film producers might change very rapidly the characteristics of the training films available. If this happened, the results of previous research could no longer be generalized to available films.

Vincent, Ash, and Greenhill (1949) designed a study to investigate the relationship of length and fact frequency in the commentary of a sound motion picture on teaching effectiveness. A factual motion picture on the formulation and characteristics of frontal weather was used. Two variables were studied. Four versions of the commentary were prepared with the same pictorial presentations. These included; the long-heavy version containing 224 verbal facts in a film running 29 minutes, the long-light version required the same running time but only 114 facts were presented in the commentary. The short-heavy version had 112 facts in a running time of 14 minutes, and the short-light version had 56 facts also presented in 14 minutes. Redundant or irrelevant information was included as filler material in the films containing less factual information but the same running time. These four experimental versions were presented to different groups of subjects. Some were high school seniors (N=434), other college students enrolled in a basic course of meteorology (N=324), and still others were Air Force basic trainees (N=513). Each experimental version was shown to a section of each group of the experimental population. The reading level of all scripts was at the seventh and eighth grade level of difficulty as determined by the Dale-Chall formula. A factual multiple-choice test containing one hundred and thirty-six 4-choice items was used for immediate recall of information immediately after film showings. A delayed-recall test was given to the high school subjects four weeks following film presentation, to the college students one week following films, and the Air Force subjects were again tested seven weeks after the films were shown. A control group took the test without seeing the films. Findings were as follows: 1) For all three populations, and for both immediate and delayed recall tests, every experimental group had a significantly higher mean than the control group (significant at the .01 level of confidence). 2) Learning occurred with all film groups. Significant forgetting took place in that delayed-recall test mean scores were significantly lower (.01 level) than immediate recall scores. 3) The "best" commentary version among the four varied from group to group. For the high school sample, the short-heavy version (112 facts presented in 14 minutes) seemed to be the most effective; for the Air Force and college samples, the long-light version (112 facts presented in 20 minutes) was better. However, none of the differences on total score of immediate recall between versions was significant. On the delayed recall tests, all differences among the versions were much smaller and not significant. It is clear from the data that packing more factual information into the film commentary yields no more learning. The long-heavy commentary produced no more than the shorter or lighter narrations. Neither length of the film commentary nor the number of facts presented verbally seemed to affect learning. In no case did the long-heavy version group learn significantly more than the short-heavy or long-light group, nor did these latter learn significantly more than the short-light group. Further analysis of the test performance suggested that the commentary content was rather difficult for the populations even though the reading level of all versions was at the seventh or eighth grade. In addition, the experimenters indicated that the groups were not very well motivated or very interested in the subject.

Jaspen (1950) also studied the effect of varying the number of words used in the audio narration of a sound-motion film expressed in average number of words per running minute of film. The film was designed to teach the perceptual-motor task of assembling a gun. The study also experimented with audience participation so that rate of commentary was varied to permit participation. Subjects were Naval trainees (N=1,818) and the post-film performance task consisted of the assembly of the gun breech block. Measurement of criterion performance was the time to assemble the block. The first time the study was conducted only two rates of commentary were used. High rate narrations at 146 and 136 words per minute of film running time were compared with two low rate narrations of 83 and 73 words per minute. Results on the first experiment revealed no consistent difference in effectiveness between the high and low rates of commentary presentations. A second study was then conducted which utilized four rates of commentary at 142 words per minute (high), at 97 words per minute (medium), at 74 words per minute (low), and a very low rate version at 45 words per minute of running film time. This second experiment showed significant differences in effectiveness between the medium and very low rates of presentation (significant at the .01 level of confidence) but not between the medium and high, or medium and low rate commentaries. Jaspen points out that there seemed to be a curvilinear relationship between the effectiveness of the film as a learning device and rate of commentary, with the apex of learning at the medium rate of verbalization (about 100 words per minute running time of film).

Summary

The purpose of this section has been to present the studies and evidence on the effects of variations in narration on comprehension. All of the studies indicate that verbal simplification procedures applied to film commentaries increase their teaching effectiveness. Comprehension and information transmission of audio inputs can be predicted by readability formulas used to measure their difficulty.

Almost all studies indicate that some verbalization is better than none, but that there is an optimum amount. Most of the film studies have measured verbal responses of subjects on objective tests of verbal, factual information. It seems reasonable to expect that verbalization is better than no verbalization when verbal information is being presented and later tested, but the conclusion has also been validated for the learning of motor tasks such as knot tying and breech block assembly. There also appears to be an optimum rate of transmitting verbal information. Slow speeds are generally favorable, but they can be too slow.

This section was concerned with the factors which make the narration an effective transmitter of information. Research on this problem has sometimes involved narrations given alone while at other times it has involved the use of a narration combined with a video presentation.

The listening comprehension studies suggest that, <u>if time is not a factor</u>, listening comprehension is likely to be most effective at speeds of around 160 words a minute. This generalization is probably true for only relatively simple material. The intellectual level of the subjects must also be taken into account. An interesting finding is that when a narration is accompanied by video that the optimum rate of the narration appears to be lower. Such a finding fits well the model of information transmission which postulates that the rate at which information can be transmitted effectively to the human receiver is limited and cannot be increased by using more than one sensory channel or more than one source of communication.

Studies of commentaries as they are presented in actual training films show that they can be made to transmit more information by simplification. Readability formulas can be applied to the commentaries to measure their difficulty, and the measures thus derived are related to measures of learning for subjects exposed to the narratives.

The studies of audiovisual presentations show that some relevant commentary is generally better than none, but that there is probably an optimum amount. A particularly interesting finding is that the learning of some motor skills may be facilitated through the use of an appropriate commentary. Facilitation is not confined to those instances where verbal learning measured by a verbal test.

The researches reviewed in this section seem to be limited by the fact that they used training films already in use. The films incorporated in research cannot be considered to have been sampled from a universe of films in an identifiable way and, hence, there are questions concerning the generalizability of the results. The situation is somewhat comparable to undertaking research on teaching effectiveness but limiting the research to the study of the effects of a particular teacher.

PART IV. AUDIENCE PARTICIPATION AND PRACTICE

Another variable related to learning through audiovisual materials is the degree of activity elicited in the audience by the material presented. The term "participation" has been extensively employed in film research to indicate a group of techniques which provide for overt student activity during the showing of a film.

Controversy in film research exists as to whether participation techniques are effective by raising level of motivation or by providing opportunity to practice the responses to be learned. The practice concept is apparently dominant. This concept involves the familiar learning principle which states that individuals learn what they do.

Most of the audiovisual activities requiring some kind of overt audience activity are provided for by some person or device, i. e., answering questions, discussion, or a test. These are all selected and manipulated by the teacher. Little has been done on audiovisual source-controlled audience participation techniques. Only recently have a few film producers introduced audience activities by inserting questions within the film, providing blank spaces between film sequences with suggestions for student activity, or some variants of these built into the timed context of the film which require activity during the film showing. Such programmed inputs need to be studied.

Allen (1957) states that during the past decade no single condition of film use has been studied as intensively as that of "participation", and none other has elicited such general confirmation as a means of facilitating learning from audiovisual materials.

Teacher-Mediated Participation Techniques

A review of research related to the value of student participation during film use was published by Allen (1957) and provides the organization of the materials presented in this section. There is inevitably extensive overlap between this review and the previous one since the studies involved are essentially the same. The materials are presented here rather than just referring to the previous review in order to provide a degree of completeness to the chapter. In accordance with the precedence established by Allen, the studies are organized into the following categories: (1) verbalization of response; (2) perceptual-motor response; (3) knowledge of results; (4) internalized practice; and (5) note-taking.

1. Verbalization of Response

Hall (1936) studied a procedure for varying the presentation of three films on geology for general science high school students (N=139). His experimental conditions included (1) audience participation consisting of the announcement preceding the film that a test would be given and then a written test was given after the film presentation with the students checking one another's answers before handing them back, (2) no test announced or given, and (3) audience participation involving the announcement before the film that test questions would be projected simultaneously by slides below the film, and the students were then instructed to write their answers as quickly as possible. It is implied that in the third learning condition that the tests were scored and handed back, but the point is not clearly made.

A written pre-test was given to all groups exposed to the three procedures two days before and a delayed retention test was given two weeks after the film showings. Results indicated that the use of conditions one and three -- written tests following or during the film -- produced significantly ($p=.01$ level) more retention on the tests two weeks later than did condition 2. There was slight superiority in retention between the group that participated in the test immediately following the film and the group which participated in the test during the showing in favor of the latter (approximately at the five per cent level of significance).

The interpretation of the results of the Hall study should be made with considerable caution. The report of the study does not indicate whether the test items used for practice as a part of the learning procedure were the same as those used in the delayed test of retention. If the latter had been the case, then the learning produced through practice on the items is hardly surprising. Practice in answering test questions, even without knowledge of results, may produce facilitation when the same test is repeated.

Hovland et al. (1949) experimented with four conditions of presenting a sound filmstrip on the teaching of the phonetic alphabet. Subjects were (N=742) male Army recruits. One presentation was made with a standard filmstrip viewing the phonetic word in print while its corresponding letter was pronounced by the narrator. A second filmstrip presented the phonetic word in print but the audience had to pronounce the corresponding letter. A third condition used the standard filmstrip with narration as in the first condition but with the instructor announcing a test before the film. A fourth condition used the second film version (filmstrip with audience verbalization of letter response), with the announcement made prior to presentation that a test was to be given. In other words, one condition of presentation included inactivity by audience either with or without the announcement of a test. Another film condition included active verbalization of the response to be learned either with or without the test announcement. Both oral and written tests were used for recall of learned material.

Results favored the active participation group which recalled 68 per cent of the phonetic words compared to 48 per cent recall by those not participating. The difference between these two groups was significant (.01 level of confidence). A further comparison was made between the recall of easy and difficult phonetic symbols, and it was found again that the participation condition was more effective for difficult material. Participation without the announcement of a test produced as much increment in recall as the test announcement alone. The effects of the four conditions of presentation were analyzed in relation to the intelligence level of the subjects and findings indicated that participation favored tho less intelligent (p=.05). A general summary of the study concluded that active participation by verbalizing the response to be learned was most effective with the less intelligent subjects, and with the learning of more difficult material.

Gladstone and Lumsdaine (1950) reproduced the Hovland (1949) experiment with certain modifications. The procedure involved the use of 35mm slides accompanied by a recorded sound track. Subjects were derived from one platoon of army recruits (N=975). The non-participation procedure for learning consisted of presenting letter-word equivalents on slides and the narrator reading the sound equivalents to the audience. The active audience participation procedure presented the letters without the word equivalents, and the accompanying narration instructed the audience to call out the corresponding words aloud. Results confirmed the previous study in showing a decided superiority for the active participation groups over the passive groups (p=.01).

Michael and Maccoby (1953) investigated three aspects of audience participation. These were verbal testing, knowledge of correct responses, and a combination of overt-covert participation. The first factor only will be discussed here with the other two being reviewed elsewhere in this chapter. Subjects were high school juniors and seniors (N=1,029) and the film was an edited color version of civilian defense against atomic attack. Participation involved three periods during the film and one participation period at the end. During these periods subjects were orally administered questions covering some factual material presented in the preceding section of the film. The questions were answered in writing. Such participation material covered only part of the film content. In addition, the announcement that a test was to be given at the end of the film was made to half of the group while no such announcement was made to the other half. The test items that were practiced by the participation group were included in the criterion test administered after the learning session, but the criterion test also included an equal number of unpracticed items. The participation procedures used in this study produced a statistically significant gain (p=.02 level) in factual learning over a control group which viewed the film with no participation. The improvement in learning, however, occurred only for those items that were actually practiced during the participation sessions. The items not practiced did not appear to be learned any better than would occur by simply viewing the film. There was no significant difference in scores on test items between the test-announced groups and the no-test-announced groups.

Slattery (1953) compared the effectiveness in teaching information about social studies by three methods of presentation. One method used involved a sound motion picture, a second involved a filmstrip with students reading aloud the print content on each frame, while the third method used only the filmstrip with no verbalization or participation. Subjects were (N=422) fifth grade school students. The procedure was to pre-test the students, present the audiovisual materials on the next day, and then to re-test them immediately. No retention tests were conducted. Findings showed that filmstrips presented both with and without participation were significantly superior to the motion picture in this particular case (no significant level given). This supports the thesis that simple audiovisual materials are as effective or even more effective in producing learning than sophisticated and complex productions. The filmstrip with audience participation involving the verbalizing of the print content was slightly superior numerically, but not statistically, to the one without overt verbalization.

Kendler et al. (1953) investigated the interaction effect of film repetition and audience participation on learning involving a training film on map signs. Subjects were four classes of high school students (no N given) divided into seven treatment sections. One section was shown only the introductory part of the film. The remaining six sections were shown the introductory part plus either one, two or three consecutive repetitions of the film. Three of the six sections exposed to repeated presentations also participated by calling out the names of the map signs as they appeared on the screen. All subjects were tested on the learning of the presented map signs immediately following the film presentations and also four weeks later. Increasing the number of presentations produced higher scores on post-film and retention tests, with increments becoming smaller as reviews increased. The only statistically significant difference, however, was between no additional presentations and one additional presentation. The difference between one and three presentations was statistically significant on the post-film test immediately following the film but not on the delayed tests. Overt oral audience participation produced increases on both immediate and delayed tests, but the increase was significant only for the immediate post-test. In general, the main conclusion was that one repetition of the film increased learning, but that additional repetitions became progressively less effective. Overt participation during a presentation increased learning. The increments attributable to repetition and to audience participation tended to decrease on the delayed measure of retention.

The Kale and Grosslight studies (1955) which investigated a number of variables related to the learning of Russian vocabulary was reviewed under the pictorial perception section of this chapter. These rather comprehensive experiments also included an audience participation factor. They compared five methods of teaching lists of verbs and nouns, which included the use of words only, still pictures, silent and sound motion pictures, and a sound motion picture with audience participation. The participation version contained a provision for the audience to repeat each Russian word aloud after the word had been presented by the narrator. Subjects were (N=409) men and women psychology students. The results, as stated previously, indicated that the showing of a picture representing a

Russian word aided in the learning of that word. Motion pictures plus print titles were significantly more effective than titles alone. The criterion of performance was the ability to reproduce foreign words in writing. It was found that audio inputs actually interferred with this type of learning. The pronunciation of the words by a narrator seemed to inhibit learning as measured by written responses of recall material. The pronunciation of the words by the learner also seemed to inhibit learning. The conclusion is not necessarily in conflict with the accepted idea that verbalization of responses usually aids learning. In this experiment the kind of participation studied had to do with the pronunciation of the words, and the subjects were not tested for this. Participation relevant to the criterion, i.e., writing the Russian words, was not a variable in the study.

2. Perceptual-Motor Responses

Roshal's study (1949), reviewed in an earlier section, also experimented with an audience participation variable. Eight versions of a film were designed to teach (N=3,314) naval recruits how to tie knots. The participation versions of the film required the learners to tie the knots simultaneously during the film demonstration. After the film demonstration on each knot sequence, the film was stopped for two minutes and the subjects were tested by tying the knot. The results provided no significant differences between the number of knots tied correctly during the film and the number tied correctly during the test period following the film showings. Also, the number of knots tied was inversely related to the degree of difficulty of the task. While all subjects attempted to participate, a proportion never succeeded in tying knots during the film showing. The difference in criterion scores between those attempting to participate by tying knots during the film presentation and those not asked to thus participate was negligible and not statistically significant. Roshal attributed the inconclusive results of participation to the possibility that insufficient time was allowed during the film showings for effective participation. He concluded that in order to study the effectiveness of participation, films must be produced so as to make participation possible, and that this variable is more difficult to control for complicated tasks. His final summary stated that the demonstrations herein did not clearly indicate that practicing the task while watching the film facilitates learning. He recommended further research necessary in order to draw a definite conclusion concerning participation.

Jaspen (1950) investigated the problem of having the audience perform a perceptual motor task while it was shown on a screen but varied the rate of development of the film demonstration in order to provide more time for audience participation. The performance task involved assembling the breech blocks of a 40mm anti-aircraft gun, and the subjects were (N=1,818) naval trainees. He tested for the ability to assemble the gun breech after each one of the following learning conditions: (a) A slow rate of film presentation with and without participation. Participation involved the attempt to assemble the breech block while the film was being shown; (b) A fast rate of film presentation with and without participation. Audience participation was found to be a very effective procedure to use when the rate of development of the film was slow enough to permit adequate participation. A statistically significant difference ($p=.01$ level) was found in the slow version with participation as compared to the slow version without participation in favor of the former. For the fast version, the difference was in the other direction, though not at a significant level. In summary, the findings of the study suggest that audience participation is an effective procedure in teaching a perceptual motor task if the rate of presentation of the film demonstrating the task is slow enough to permit the learners to view the film while simultaneously practicing that which is being shown.

Ash and Jaspen (1953) experimented further with the films previously developed by Jaspen in teaching the assembly of the 40mm breech block of a gun. The study included the effects of concurrent participation with films that were either fast or slow in rate of development. He also varied the number of times the films were presented. Subjects were ($N=1,100$) naval trainees. Two scores were analyzed: first, a pass or fail score on the task accomplishment, and second, a time or speed score in seconds for the task performance if it was accomplished and passed successfully. The study confirmed the earlier findings of Jaspen that audience participation produced a greater number of pass scores with a film that had a slow rate of development ($p=.01$ level of significance). The positive contribution of participation in the case of the slow development film was even more apparent in the speed score data ($p=.001$ level). From the data on the relationship of participation to repetition, no significant difference was found in pass-fail scores between one showing and two showings. The speed scores, however, show a highly significant ($p=.001$ level) difference between one and two repetitions of the films. In other words, two showings of the slow development film yielded a significant increase in learning over one showing. Two showings of a fast development film did not yield significant increases over one showing. Participation does increase learning provided the rate of development of the film is slow enough to allow the learner to participate without missing important information from the screen.

The effectiveness of using continuous film loops interspersed with practice and coaching of the learner was studied by Harby (1952b). Four college physical education classes ($N=100$) were used as subjects in teaching tumbling skills. Two conditions of massed demonstration vs. demonstrations interspersed with practice, and film vs. live instructor presentations were studied using four procedures; (1) three massed live demonstrations (consecutively repeated showings) followed by active practice, (2) three massed film demonstrations also followed by active practice, (3) three live demonstrations interspersed with practice and also followed by active practice, and (4) three film demonstrations interspersed with active practice. The technique of interspersed practice was slightly superior to the massed technique, but not significantly so. The film demonstration proved as effective as live demonstrations. A second study on the effect of coaching during practice utilized four film demonstration procedures. These were (a) movie demonstrations interspersed with practice but with no coaching, (b) the same with coaching provided by a skilled instructor pointing out errors to each student during practice, (c) a continuous-run film demonstration with students free to watch or practice as they pleased and no coaching, and (d) the same as (c) but with coaching. The film demonstration interspersed with practice yielded higher average criterion scores than the procedure involving free practice while the film was shown continuously, but the difference was not statistically significant. Coaching was significantly superior ($p=.05$ level) to no coaching. The general findings of the study led to the conclusion that in the teaching of such athletic skills, a film demonstration is as effective as a live instructor's demonstration. Demonstrations interspersed with practice are not significantly superior to massed demonstrations. Coaching during practice makes a significant contribution to the learning of these skills.

Murnin, et al., (1954) studied the effect of certain kinds of practice on the learning of electrical principles. He compared the effect of using a wiring mockup board upon which the students manipulated actual electrical components with a chart diagram from which the students practiced on paper the drawing of an electrical schematic. Naval trainees (N=262) used as subjects were taught by lecture and demonstrations. Groups were tested by means of paper and pencil tests on their ability to solve electric circuit problems. Results showed that there was no significant differences in scores on the tests resulting from the two methods of practice. The conclusions appeared fairly evident that within the limitations of this design, drawing electrical circuit diagrams by pencil and paper elicited as much learning of electrical principles as manipulating actual electrical components on a wiring board. It was concluded by the experimenters that the ability to work out solutions to circuit problems may be a function of classroom instruction and not of how such principles were practiced. If the wiring board and diagram methods of practice can be considered to be applications of the participation principle, they were found to be little more effective than non-participation.

Rimland (1955), using the knot-tying films developed for the Roshal (1949) study, investigated several ways of employing repetition in perceptual-motor learning by films. The term repetition used in the study meant two presentations of the same film. The participation conditions studied were those of a) inserting a brief practice session between the two film demonstrations and b) practicing the task during the film demonstration. The test population consisted of (N=2,680) naval recruits. Permitting subjects to practice a perceptual-motor task overtly between film presentations did not, in this experiment, prove to be an aid in learning. Subjects who saw two films without intervening practice were able to perform the task as well as those who practiced the task between the two films. Permitting subjects to practice while viewing a film was not an effective aid to learning. This was found to be true whether the practice occurred during the first or second showing of the film. This finding is in agreement with Roshal's (1949) and Jaspen's (1950) studies in which it was found that concurrent practice was effective only when the film developed slowly enough that participation did not interfere with the subject's ability to observe the film demonstration while performing the task. In the Rimland study even though two showings of the film did not result in more learning than one, it should be remembered that the task dealt with the teaching of relatively simple perceptual-motor skills of knot tying. It is conceivable that as the skills to be taught become more complex, some repetitive representations of certain phases of the task may be needed in order to add additional cues, a few at a time, to permit an understanding of the task. Further studies of the effect of repetition of a film on learning, but at different rates of presentation and on more complex tasks, are needed.

3. Knowledge of Results

Gibson (1947) studied the learning of aircraft identification by slide pictures using two methods of presentation. The first, which he called the "unreinforced method" presented twenty slides of foreign aircraft each for five seconds, with the aircraft name announced by the narrator before each slide and repeated while it appeared on the screen. This presentation method was repeated three times. A second method of presentation called the "reinforced" method repeated the "unreinforced method" for the first showing, but on the following two showings the exposure time was cut by half after each subject identified each aircraft on an answer sheet and then received knowledge of results through verification of responses as correct or incorrect. The test of learning was sheer recognition and recall of aircraft names. Subjects (N=280) were Air Force trainees. Gains for the "reinforced method" were significantly greater (p=.01 level) than for the other method. Gibson concluded the experiment showed clearly the importance of overt response followed by knowledge of results.

In the Michael and Maccoby study (1953) reported under the category of verbalization of response it was mentioned that one of the aspects of audience participation studied was feedback, or knowledge of correct answers. The topic of the film was civilian defense against atomic attack. Half of the experimental classes of high school students (N=1029) were provided with knowledge of the correctness of each response immediately after they had had an opportunity to answer each question during the film participation but the other half received no feedback. Results showed a statistically significant (p=.01 level) gain on the post-film test for the groups receiving knowledge of correct responses during participation. These differences held equally for both high and low intelligence groups. The main conclusion was the proposition that superior learning will occur when the learner is given the opportunity to rectify an error after knowing that an error has been made, the nature of the error, and what the correct response should have been. The author's summary stated that regardless of the other variables implied in the study, the most important factor influencing the amount of learning in this experiment was the provision of knowledge of the correct response during the participation.

The Harby (1952b) study, previously reviewed, throws some light on the value of participation involving knowledge of results. One of the effective conditions for teaching tumbling skills to college students was coaching during practice. Coaching during interspersed, continuous, or free-choice film presentations with practice resulted in significantly greater learning taking place (p=.05 level) than when the film was just watched. The coaching conditions consisted of pointing out errors to individual students by a skilled instructor.

Stein (1952) conducted a study to determine the effects of testing the audience on film content before the film showing either with or without knowledge of results. Previous studies have shown that film learning increases when the audience is given an orientation to the subject matter to be learned or is shown the film twice. The question posed here was whether film learning will increase if the audience is told what they are expected to learn by providing the same test before and after the film and by providing an item by item knowledge of results on the pre-test. The effect of arranging the pre- and post-film test items in the same order that the item content appeared in the film vs. a randomized order was also studied. The film, Weather and Measuring Instruments, was presented to (N=1,700) naval seamen. Three pre-film tests using three variations of knowledge of results plus a post-film test were utilized. The three procedures with the pre-film test included no knowledge of results, partial knowledge by a device indicating either right or wrong answers and a complete knowledge of results by providing the correct answer to a missed item on the test. A delayed recall post-film test was also administered one week later. Results indicated that the experimental treatment with complete knowledge of results was superior both to the other experimental treatments ($p=.001$ level) and to a control group not receiving the pre-film tests ($p=.001$ level). When the groups were divided into the upper and lower 30 per cent of AGCT scores (intelligence test scores), both the upper and lower 30 per cent of the group receiving the experimental treatment with complete knowledge of results maintained their superiority over the other experimental groups and the control group. In other words, the more intelligent and less intelligent subjects were both helped by the complete knowledge of results on the pre-film test. The same superiority in scores ($p=.001$ level) on the retention tests also appeared for the group receiving complete knowledge of results on the pre-film tests. Another conclusion of the study was that the effectiveness of a pre-film test depends on giving the learners items in the order in which the related information appears in the film. The findings are not surprising for the pre-test with knowledge of results provided an additional learning situation. The findings can hardly be attributed to the superiority of the film orientation provided.

Levine (1953) studied the effect of participation with knowledge of results in relation to motivation. An attempt was made to produce high motivation in half of the subjects by instructions given prior to the film showing. Half the subjects also had active review sessions interspersed during the film. These sessions involved not only review but also the study of ten of the thirty-five questions used in the post-film test. The other half of the subjects saw the film without the review sessions. Subjects were (N=939) Air Force trainees. The topic of the film was World Maps. Results showed that, as in previous experiments, larger gains occurred on items practiced with knowledge of results than on non-practiced test items under conditions of both high and low motivation. Significant gains occurred also on non-practiced items in the active participation group working under both low and high motivation conditions. No statistical significance levels were given in the study.

4. Internalized Practice

Harby (1952a) compared mental practice, defined as the symbolic or covert practice of a perceptual-motor skill, with overt observable practice in teaching shooting the basketball free-throw. Subjects (N=250) were college physical education men students. Seven groups were given separate treatments as follows:

I. Control Group	1. Pre-test (20 free-throws) 2. Post-test (20 free-throws) twenty-one days later. No other practice or training in between.
II. Physical Practice Group	1. Pre-test (20 free-throws) 2. One-minute demonstration by an instructor followed by 20 free-throws per day for twenty daily class periods. 3. Post-test (20 free-throws)
III. Mental Practice Group A	1. Pre-test (20 free-throws) 2. Short film shown six times (15 minutes) each day while subjects "mentally practiced", for seven daily class periods. 3. Post-test after seventh day (20 free-throws).
IV. Mental Practice Group B	1. Pre-test (20 free-throws) 2. Short film shown six times (15 minutes) each day while subjects "mentally practiced", for fourteen daily class periods. 3. Post-test (20 free-throws) after fourteenth day.
V. Mental Practice Group C	1. Pre-test (20 free-throws) 2. Short film shown six times (15 minutes) each day while subjects "mentally practiced" over a total of twenty daily class periods. 3. Post-test (20 free-throws) after twentieth day.
VI. Mental Plus Physical Practice Group A	1. Pre-test (20 free-throws) 2. Short film demonstration (shown once each period) followed by 20 free-throws each day for twenty daily class periods (prior to the

film showing, students were exhorted to mentally practice).

3. Post-test (20 free-throws) after the twentieth day.

VII. Mental Plus Physical Practice Group B (This group consisted of eight men who had already been members of Mental Practice Group B)

1. Pre-test (20 free-throws)
2. Short film shown six times (15 minutes) each day while subjects mentally practiced for fourteen daily class periods.
3. Post-test (20 free-throws).
4. Seven additional days of physical practice (instructor's demonstration followed by 20 free-throws, daily).
5. Post-test (20 free-throws).

A comparison between pre- and post-tests showed that twenty periods of physical practice (treatment 2) yielded the most significant gains among all groups (p=.01 level). Fourteen periods of mental practice (treatment 4) involving thinking about the movements of the skill, yielded the only other significant gain between pre- and post-tests among all groups (p=.05 level). Mental practice using films was the most effective treatment among the mental practice groups (p=.05 level) when carried on for fourteen class periods. The group which was instructed to think about the task or mentally practice it for fourteen class periods and then physically practice it for seven additional periods (treatment 7) made the greatest gains in learning. However, it is difficult to draw any conclusions because of the small number of subjects in this group (N=8).

Previous experimenters, Vandell, et al., (1943) have reported difficulty in keeping learners at mental practice for periods longer than five minutes at a time. The use of films during mental practice in the Harby experiment seems to have extended the period during which learners can or will practice mentally. The conclusions suggest that groups of learners who follow a procedure of mental practice together with demonstration films can achieve by this means a significant gain in their learning of a physical skill. It is furthermore suggested that covert or implicit practice of a perceptual-motor skill should be supplemented by some amount of reinforcing or confirming experiences afforded by actual overt practice with knowledge of results.

The Michael and Maccoby study (1953), previously discussed, also investigated the variable of mental practice. One group participated overtly by writing answers to questions that were asked as the film was stopped periodically. Another group participated covertly; that is, they were asked to think the answers to the questions. When tested, the mental practice group was found to have learned the factual content of the film as well as did the group that wrote the answers during overt participation. There were no statistical differences between the amount learned by overt practice and that learned by covert practice. However, the improvements of either overt or covert participation procedures over the non-participation control groups were significant at the .01 level of confidence.

Patterson conducted an exploratory study (1953) in teaching education students a perceptual-motor task by the traditional instruction method and compared it to a film demonstration with interspersed mental practice. The task was the threading and operation of a motion picture projector. One group received three hours of individualized instruction and practice on the task. The other experimental group received several showings of a film demonstrating the task, and was asked to practice mentally the steps of the task during and between the showings, but the group never actually received overt practice on the task. Results showed that the mental practice group learned the task as well as the actual practice group as measured by a performance test. However, the actual practice group took a shorter time to perform this skill in the performance test situation.

5. <u>Participation by Notetaking</u>

One of the earliest studies involving the taking of notes during a film or filmstrip was undertaken by Vernon (1946). Unfortunately, for the present purposes, the learning conditions involving notetaking were not of central importance to the purposes of the study and no straightforward comparison can be made between the showing of a film or filmstrip with and without notetaking. The only comparison which can be made in the Vernon study is between spending an extra hour on a filmstrip with notetaking and spending an hour on practical instruction without notetaking. The comparison is not a particularly illuminating one because of the number of different factors involved. In any case, no clear advantage could be found for the one procedure over the other. Vernon comments that the procedure of notetaking hardly appeared to be worthwhile, particularly under the circumstances of the study where problems of illumination made it a difficult task.

Ash and Carlton (1951) investigated the extent to which notetaking during film showings might affect learning. Freshmen students in a liberal arts college (N=216) were studied during the showing of two films. The first groups were simply shown the films followed directly by administration of a test. The other groups were shown the films and told to take notes during the viewing procedure. In one group the notes were collected immediately following the film and the students were then given the test. In the other group the students were allowed to review their notes for 10 minutes before the notes were collected and the test was given. The post-film test items covered factual content of the films and were of the multiple-choice variety. A control group was administered the test before seeing the films to determine what students knew about the topic before receiving instruction. The results indicate that the group not taking notes during the film earned a significantly ($p=.01$) higher scores than the group taking notes. Although the group spending an extra 10 minutes devoted to review of their notes produced a slight increase in learning over the other notetaking group, the advantage was not a statistically significant one. The final conclusion of the study stated that notetaking actually may have interferred with learning from the films. Subjects apparently cannot attend to both the film and notetaking at the same time. Review of the notes aided somewhat in the recall of points written down, but it did not compensate for the interference caused by the notetaking act itself. It is concluded that from the only two studies located on notetaking, the two reviewed here, that the findings have not established notetaking as an effective adjunct to learning by film.

Film-mediated Participation Techniques

A report by May in the exploratory study of the Yale Motion Picture Research Project (1947) was one of the first to investigate motivation and participation in film-mediated procedures by inserting questions within the film. Motivational questions were defined as those which attempted to increase the students' interest and arouse curiosity concerning the materials presented. Participation questions included those which were programmed within the film to require students to respond by practicing or rehearsing the facts to be learned just after they were presented in the film. Subjects were (N=150) high school students. The subject chosen for the film was the heart and circulation of the blood, a widely taught topic at the high school level encompassing a considerable variety of factual material. The five methods of presentation used in the study were: (1) film shown once without questions, (2) film shown with motivating questions in the form of print titles preceding each unit of the film, (3) the film version with participation questions on the screen in print which subjects answered on worksheets after each unit, the correct answer then being shown in print on the screen, (4) film with both types of questions, motivational and participation, appearing in print on the screen, and (5) the film shown twice without questions. A forty-item multiple-choice factual examination measured the students' knowledge of the subject matter taught. Results were interpreted as follows: the addition of participation questions within the film, as in presentation (3), produced a gain of four per cent between pre- and post-film scores on the test over and above the gain of group (1) which was exposed to the factual film only. The level of significance of the difference was not given. The effect of adding motivating questions which directed attention to relevant information was compared with only the factual film and again showed an average gain between pre- and post-test scores of 2.3 per cent (no level of significance reported). The same comparison was made between presentations (4) containing both motivating and participating questions and the presentation involving the film only. A gain of 5.8 per cent was observed, (no level of significance given). When the learning from the participation version was compared with that from showing the film twice, it was found that a 54 per cent increase in time required for participation resulted in a 49 per cent gain in correct answers, but the double-showing required a 100 per cent increase in time and resulted in only a 46 per cent gain in learning. This study is one of the few which takes into account the time spent. The results of the study are not easily interpreted since there is no indication of the overlap between the questions used for instructional purposes and those used in the criterion test.

Kurtz et al., (1950) experimented with six methods of teaching a body of factual knowledge by films. Two different films were used one dealing with the care and use of hand tools and the other with snakes. Six versions of each film were prepared as follows: (1) original film as a control version, (2) a repetition version consisting of two prints of the original film spliced together and shown in continuous succession, (3) a single print of each film with a series of multiple-choice questions inserted every half minute, (4) a single print of each film with print statements inserted every half minute which were reiterations of factual points made in the film, (5) the same as version the third but with only every alternate question inserted, and (6) the same version as the fourth but with only every alternate statement inserted. The total population for the study included (N=3,039) high school students. In the question versions the choices were shown in print on the screen and the students were required to answer them on an answer sheet. After a short interval, the correct answer was given in print on the screen and the film continued on to the next point. The research report states that the test items used during the showing of the film were very simple and were not used in the criterion test administered after the learning sessions had been completed. The statements in treatments (4) and (6) were intended to supplement the information which immediately preceded them in the film and were inserted at the same places in the film as were the questions in the question version. Results were derived from a 71-item multiple-choice post-film test. All differences, between mean scores on this test were small and no levels of signigicance were given for the differences between versions but the following two relatively consistent relationships existed: (1) The repetition version, showing the film twice, was better than the questions version, alternate questions version, and alternate statements version; (2) The statement version was consistently better than the alternate statements version, which included only half of the statements, but not better than the repetition version. A sex difference was also noted for both films -- the scores of the girls were lower than the scores of the boys. No mention was made, however, of the time involved for two showings of the film as compared with the time involved when questions or statements were inserted. It is very evident that the time of exposure to the film content may result in more learning if two showings require more time than the insertion of questions or statements.

Hirsch (1952) used the Classroom Communicator equipment developed for the Instructional Film Research Program at Pennsylvania State College to study the effect of knowledge of test results upon the learning of meaningful material. The Classroom Communicator is a piece of electronic equipment designed to enable immediate and continuous communication between the instructor and any student in the class to inform the student whether or not his choice is the correct response or what the correct response should have been. Six technical navy training films were used ranging from simple to difficult material and varying in content. A pre-test was administered to determine initial knowledge of the subjects on the films. Each film was shown twice to two of the experimental groups. A delayed-recall test administered three weeks following the showing of the film consisted of 120 multiple-choice questions. For all groups of subjects except the control group the same test items were also administered after the first showing and a number of different conditions of knowledge of results were introduced.

Six methods of presentation were used as follows: (1) control with no knowledge of results, only the films were shown; (2) knowledge only that answer to a test question was "right" or "wrong"; (3) same as the second method but with the correct answer shown all students by means of proper choice number on each multiple-choice question, (4) same as the second method but with the filmstrip question repeated on screen with all choices except the correct one deleted. This was done to determine the difference between associating with the question a number of a correct response (method 3) and the correct answer itself; (5) the same as the fourth method but with the film shown again following the instructional test; (6) the same as the fifth method without any knowledge of results -- in other words, just the showing of the films, the test without knowledge of results followed by a second showing of the film.

The problem was that of determining which of these six methods produced the greatest learning as measured three weeks later. Subjects were (N=138) Naval ROTC cadets.

The following are the results of the experiment: (a) the groups appeared to have been homogeneous with respect to knowledge of subject matter at the start of the experiment as determined by an analysis of variance from the pre-film test; (b) all methods were superior to the first method in which the film was only shown once with no test and no knowledge of results, these differences were statistically significant beyond the .05 level; (c) the second showing of the film following knowledge of results (method 5) resulted in the greatest retention of information on the retention-recall test three weeks later, significant at the p=.01 level over all methods except the fourth method. In summary, knowledge of test results aided retention. When, in addition to knowledge of results, the film is also repeated a second time, additional learning took place. The sheer time of exposure to film content may account for the findings of this study. Here again one may wonder whether anything more was achieved than training on the test items included in the criteria measure.

Kantor (1960) attempted to determine experimentally whether questions inserted in a sound motion picture can significantly raise the teaching effectiveness of factual information when such questions are inserted both visually and aurally. The subjects were (N=617) seventh grade pupils of three junior high schools from widely different socioeconomic levels of Los Angeles. Scores from the California Test of Mental Maturity and the occupation of pupils' parents were also available for the study. Three versions (two experimental and one control) of a factual film, The Sunfish, by Encyclopedia Britanica Films, Inc. were used. In one experimental version of the film the print questions were inserted before the content concerned. In the other experimental version identical questions were inserted after the content. The control version had no questions inserted. The narration of both experimental versions was recorded to insert the questions at their respective places so that this same voice would be heard throughout. The control version was also rerecorded using the same voice but without inserted questions. In both experimental versions the questions appeared on the screen at the same time as they were announced in the narration. Unfortunately, the experiment included no version in which only the audio or only the video was used for asking questions. A film pre-test was administered one week before the experiment, subjects were shown the film followed by a post test, and five weeks later a delayed retention test was given. No significant differences were found between versions. Since this result is inconsistent with those previously reported, one may speculate that it may be a result of the fact that only eight questions were used. Findings also showed that boys did better than girls on the pre-test. Pupils with high language scores on the California test did significantly better on each of the film versions than those with low language scores (no level of significance given). In each film version, pupils from high socio-economic status families did significantly better than those from low socio-economic status families. The latter differences were significant at the p=.01 level. Gains in film learning, as measured by post-test over pre-test scores, were highly significant in all cases (p=.01 level). The same relative gain was found for the delayed test five weeks later, with a slight loss (p=.01 level).

Summary

Verbalization of response and the furnishing of knowledge of results appear to be the most effective participation techniques. Notetaking was shown to be of doubtful value, and the film-mediated processes such as insertion of questions within a film still require further investigation to prove their effectiveness. Of course, the answer has still never been found whether increased learning during participation is due to actual practice, increased time exposure to film content, or increased motivation resulting from the involvement in the activity. Several studies have directed attention to this question with no conclusive answer. Michael concluded that increase in learning was due primarily to practice effects. The Yale study found that material directly practiced during participation was learned to a much greater degree than that not covered in the participation questions. These findings supported Michael's study. Hovland, Lumsdaine, and Sheffield suggest that both practice and motivation factors may add to the learning effects from films. They consider that the response to be learned should be actively practiced during the film and that such participation may further motivate the learner. Findings show that active participation is most effective when the material to be learned is relatively difficult. The studies also show that rate of presentation of the material is important. The most effective learning was found to occur at a slow speed of presentation particularly when participation was required. The film must be designed to provide time for overt or covert activity to take place while still permitting the subject to follow the development of the film presentation. The problem of the relative effectiveness of participation vs. repetitive showings of the film seems to be one of time. No time comparisons were sufficiently analyzed to answer this important question. As a final conclusion, participation during a film will result, under most conditions of instruction, in increased learning. Overt verbalization of responses practiced by the learner during the film result in increased learning. Furnishing knowledge of results as a part of the participation process also has positive effects upon learning. These findings seem to have some consistency from study to study.

The studies reviewed in this section provide findings which suggest that the use of techniques which relate activity to the presentation of a film is a matter of considerable complexity. Two different conditions have been involved in these studies with different results. First there is the condition in which some form of activity is required at the same time as a continuous flow of information is provided by the instructional device. In the second condition, the flow of information is halted while the learner is asked to engage in some kind of activity, either overt or covert, related to the presentation.

Studies carried out under the first of the two conditions include those in which some manipulative skill has been learned such as knot tying or the assembly of the breech block. The general findings of these studies are that learners experience considerable difficulty in following a continuous demonstration and, at the same time, undertaking the task themselves. Such simultaneous performance can be undertaken effectively only when the pace of the presentation is reduced below that which would ordinarily be selected by a teacher. This finding suggests the possibility that inputs and outputs cannot be easily undertaken simultaneously, if they can be undertaken at all. Another interpretation is that the outputs involved in practicing a skill require the learner to utilize the sensory inputs generated by the task itself. The combined inputs from the instructional device and the task itself may overload the information processing capacity of the system. Notetaking is a special case in which the introduction of an activity fails to improve learning. Here again the activity has a certain incompatibility with the monitoring of a continuous flow of information.

The second condition appears to be one which adds to the effectiveness of learning. Examples of so-called "participation" under this condition are found in studies in which a film or film strip is stopped at various places and the learner is then given questions to answer questions, or where the learner is asked to pronounce a particular word shown on a screen. A point to be noticed is that these situations do not require the learner to monitor a continuous flow of information while performing a task. The display remains stationary while the learner pronounces the word. Under this kind of condition, the learner benefits from such participation.

A particularly interesting finding is that participation does not have to be overt. What some investigators have called mental practice has shown itself to be as effective as overt activity even when psycho-motor skills are being learned.

Somewhat puzzling is the fact that multiple showings of a film have been found to be about as effective as a single showing involving some kind of participation. One possible factor producing this effect is that the time involved in a single showing plus participation may be equal to that of two showings. Time may well be the critical factor and not participation or nonparticipation.

CONCLUSIONS FROM RESEARCH ON SOUND MOTION PICTURES AND RELATED DEVICES

Each section of this chapter has been followed by a summary and there is no point in repeating the summaries at this time. However, there appear to be certain conclusions which cut across more than one section and which need to be highlighted at this time. These conclusions fit well with information derived from research on perception and learning presented in later chapters.

First, the evidence points to the conclusion that simplification results in improved learning. This seems to be generally true regardless of the nature of the presentation -- whether it is pictorial or verbal. This raises interesting problems, for the simplification of pictorial content will generally result in a less realistic presentation than a presentation which is close to the life situation. The argument which is commonly given in favor of audiovisual materials is that they provide a degree of realism which other procedures do not. The realism provided may not be entirely an advantage and may interfere with the transmittal of information. The problem of simplifying realistic situations, so that the situations retain information essential for permitting the learner to respond effectively at some later time to other realistic situations, is an important one.

The fact that the verbal content of a presentation becomes more useful for learning purposes as it is simplified and as it is transmitted at rates slower than the moderately fast rates of ordinary speech, suggests that the rate of assimilation of material is an important factor to take into account in the design of audiovisual materials. The data suggest that the information processing system of the human learner is a limited capacity system and that this capacity limitation may not have been properly considered in the design of such devices. This point may be related to the previous point. It may well be that simplicity of presentation is necessary for effective learning because the learner has a limited capacity to utilize information. A source of information has generally a vastly greater capacity for transmitting information than the human learner has for receiving.

One property of audiovisual materials appears to have largely escaped notice, namely, that the video portion typically represents the environment as it is encountered while the audio is strictly symbolic (except perhaps in the case of music). Thus one channel presents a sequence of objects while the other presents a sequence of symbols. The relationship between the two channels could be reversed; the sound channel might present a series of objects or events (such as the sound of footsteps) and the visual channel might present symbols for them (such as the written words "sounds of footsteps"). One reason why the latter situation is not generally used is that auditory events which are nonverbal have an ambiguity which visual events do not have to the same extent. Producers of radio drama of the pretelevision era were acutely aware of this fact and when, in a radio play, thunder sounded, one of the actors would always have to say something such as "Listen to the thunder." In this way the auditory event was clearly labeled. It seems that the ambiguity of nonverbal auditory events has resulted in the custom of the auditory channel being limited in use in motion pictures to symbolic materials while the visual is generally used for nonsymbolic events.

Now various relationships can exist between the symbolic and the nonsymbolic, but nowhere in the literature on audiovisual materials can one find a place where these have been specified. If they were specified, then research could be conducted on the learning which they involve and the conditions which best facilitate learning. Few studies deal with the learning of symbol-object relationships. Kale and Grosslight (1955) investigated the learning of Russian vocabulary, and with the interesting finding that it makes a difference whether the sequence object-symbol or the sequence symbol-object is used. As other such relationships are made explicit, they will become amenable to study.

The studies that have been reviewed make various assumptions about learning. The typical audiovisual study of the past has made the assumption that learning is essentially a perceptual process -- the film is shown and the viewer somehow absorbs some of the information provided. Scepticism with respect to this conceptualization of learning appears in the more recent research which has stressed "participation" in addition to passive viewing and listening. Experimentation with respect to the value of responding in contrast to viewing has been severely hampered by the fact that most devices for the presentation of audiovisual information have not been designed with a response-reinforcement model of learning in mind but rather they are based upon a perceptual model. The research reviewed points to the interesting conclusion that overt responding on the part of the person exposed to a sound-motion picture sometimes facilitates and sometimes interferes with learning. The data suggest that if the responding coincides with the reception of information it is harmful, but if it does not then it has a facilitating effect. What this means is that viewer participation generally requires a slowing up of the presentation of information.

A very puzzling finding is that the repetition of the showing of a film may make the same contribution to learning as the participation activities which have been used. This is hardly to be expected in terms of what has been written about learning for it leads to the conclusion that time of exposure to the perceptual experience is the crucial factor.

The pages that follow are concerned with a review of knowledge concerning the information transmission process, placing emphasis on those aspects which have implications for the design of audiovisual materials. Most of this knowledge is consistent with that which has been gleaned from research with audiovisual materials, but it provides information about many more learning factors than have been or could be studied in audiovisual research using materials similar to those used in the classroom. The language of communication theory which has value in discussing much of the research reported in subsequent chapters, is outlined in an appendix.

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CHAPTER 3

THE RELATIVE EFFICIENCY OF AUDITORY AND VISUAL TRANSMISSIONS OF INFORMATION AND SOME STUDIES OF MULTI-MODALITY TRANSMISSION

THE RELATIVE EFFICIENCY OF AUDITORY AND VISUAL CHANNELS FOR TRANSMITTING CODED INFORMATION

One cannot reasonably ask the general question whether the eye or the ear is more efficient for the transmission of information, for clearly some information is more efficiently transmitted by one sensory channel than by another. If a person needed to know about the appearance or physical characteristics of an unfamiliar animal he would do much better to examine the animal visually than to have a description related by another observer. Such visual observation would be best until he asked about the vocal noises emitted by the animal, in which case he would do better to hear the actual sound of the animal than to obtain visual information about the vocal mechanism. Where direct information is needed about the world, the sensory modality should be used which can best transmit directly the particular physical information involved.

The problem of the relative efficiency of the auditory and visual channels becomes a meaningful one when the same information can be coded in two different ways, one of which is appropriate for transmission through the ear and one of which can be transmitted through the eye. This is a problem which has been more often recognized as an important one in the design of aircraft cockpits than in the design of audiovisual devices. For example, a warning signal for a pilot may be provided either by the flashing of a light or by the sounding of an alarm. The problem in such a case is to determine which one of the two warning signals is the most efficient. A special case of this class of problem is found in the use of language which can be transmitted through both visual and auditory channels and this special case has important implications for education.

A summary has been made by Henneman and Long (1954) of the information available concerning the relative efficiency of the visual and auditory senses as channels for data presentation. While this report is several years old, it is still an excellent summary of current knowledge concerning the problem. The summary begins by pointing out that when coded information is used, there are difficulties in making a comparison of visual and auditory presentations. For example, the same information may be coded so that it involves a color discrimination in the visual modality and a pitch discrimination in the auditory modality. This raises the question whether pitch and color discriminations are comparable. Perhaps the visual sense would be more effective if the same information were coded so that it involved a brightness discrimination, in which case a brightness discrimination would be compared with a pitch discrimination. Again, when verbal material is transmitted either through the auditory or the visual channel, the auditory channel involves the perception of a modulated sound wave while the visual channel involves form perception and the stimulus has primarily spatial characteristics. Here again one does not know whether this comparison is an optimum one. There is the possibility that if printing involved the use of differences in shading and hue in addition to the spatial qualities of ordinary type that the transmission of information would be much better than it is at present.

Henneman and Long also point out that the relative efficiency of inputs through different modalities depends upon other conditions such as the utilization to be made of the information and the other activities in which the receiver is engaged at the particular time. For example, if the task of a pilot required him at a particular time to be scanning the space in front of him looking for the lights at the approach to the runway, inputs of information from the control tower should not provide visual displays which he can only observe by redirecting his vision from the direction of the windshield to the direction of the instrument panel.

The criterion of the effectiveness of a particular transmission through a particular sensory modality has to be the effect which the transmission has on behavior. This, in itself, produces difficulties in the assessment of the effect of inputs. While auditory inputs can be paralleled by audible outputs there is not the same parallelism between visual inputs and the corresponding outputs. Nevertheless, the parallelism between input and output in the case of auditory communication has an illusory simplicity, for all outputs have to be coded into muscular activity before they can produce speech or any other transmission of information. The output which follows in some way from a visual input may involve just as long and complicated a coding system and chain of events as one which arises from an auditory input. There is, of course, some evidence provided by direct studies of audiovisual devices that the most sensitive test of learning is provided when the output of the receiver is in the same form or in a closely similar form to the transmission which has been received.

A Comparison of the Efficiency of the Auditory and Visual Modalities

Henneman and Long have made a thorough search of the literature which deals with the relative efficiency of the auditory and visual modalities. The literature which they have searched consists of studies which have made comparisons with respect to specific aspects of the two sensory modalities and do not cover studies of the relative efficiency of the modalities when complex tasks are involved. The comparisons in these studies fall into the following categories:

The selection and blocking of stimuli. The fact that only the eye and not the ear has any directional orientation in man has the important consequence that the eye can be moved to receive or block stimuli while the ear cannot. Certain auditory stimuli, such as high pitched sounds, also have the capacity of forcing themselves on the perceptual system so that they cannot be ignored. Thus, in the design of a sound movie, a television program, or a television commercial, circumstances can be arranged so that the receiver can hardly escape from receiving the auditory message, but much less can be done to ensure that the video portion will be received. The receiver's gaze may simply be directed in the wrong direction. For this reason, the pilots of aircraft prefer to have auditory transmissions of information rather than visual.

Dimensions for coding. Despite the fact that conditions for the transmission of information have to be much more carefully arranged to obtain the attention of viewers than to obtain the attention of hearers, much more has been done and probably can be done to devise ways of coding visual transmissions than to code auditory transmissions. While auditory information is rarely coded in forms other than speech, Morse code, warning signals such as automobile horns, and perhaps one should include music, the coding of visual information includes a vast range of laboratory instruments as well as graphs, pictures, and other displays commonly found in books.

An important difference is also immediately apparent in the presentation of information through the two different sensory modalities. Visual information requires little more than paper and ink for storage and presentation, but the storage and subsequent presentation of auditory information requires rather complicated mechanical or electrical equipment.

The reason for the poverty of coding procedures in the auditory modality as compared with the visual, stems also from the fact that the latter modality provides a much greater number of dimensions in terms of which information may be coded. For all practical purposes, auditory information is coded in terms of frequency, intensity, and the time distribution of signals, (location is hardly a satisfactory coding device in the case of sounds); the visual modality provides at least six dimensions which are satisfactory for coding information and others which are less satisfactory. Henneman and Long (1954) point out that visual information can be satisfactorily coded with respect to two spatial dimensions, intensity, wave length, time, and distance from the observer. The same writers also point out that tradition may also play a part in the fact that the visual sense has been much better exploited than the auditory for the transmission of information and that this factor may be as important as the number of available dimensions in terms of which information may be coded.

Henneman and Long also point out that, in the case of both senses, much greater sensitivity is shown in the making of differential judgments than absolute judgments and that the transmission of information should be undertaken in such a way that it involves differential judgments rather than the absolute. For example, a pupil in elementary school can learn rather easily to identify the higher of two notes. This task is simple compared with that of learning to identify a note when it is played. Where absolute judgments are involved there appears to be an upper limit set on the amount of information which can be used and this limit is set by central rather than by peripheral factors. Henneman and Long summarize current knowledge in the following words (p. 11):

> "The major conclusion from the above research is that there seems to be some maximum amount of information that can be obtained from the absolute judgments of a single stimulus dimension, this being 2 or 3.32 bits and equivalent to the use of 4 to 10 categories. This indication of a general information-handling capacity for all senses suggests the operation of a brain mechanism at work rather than sense organ processes as the principal determiner of rate of information assimilation."

Comparison of eye and ear. The capacity of the eye to make use of spatial discriminations is far greater than that of the ear. Charts and diagrams as well as many common instruments, including the clock, take advantage of the capacity of the eye to make use of spatial characteristics. The capacity of the ear to make use of spatial relations is so limited that the properties of auditory space are rarely used for the transmission of information. The spatial quality of visual presentation makes it possible for the operator to perform certain operations such as the simultaneous comparison of two objects or sets of data or other displays. In the case of hearing, there is a tendency for one transmission to mask another simultaneous transmission; but this masking effect does not have to occur in the case of vision for the displays can be spatially separated and still remain within the field of vision. There is even some possibility of superimposing visual messages without interference as it does with the use of overlays and with color coding (or other coding) of different overlays or different parts of particular overlays.

While data can be presented to the eye either simultaneously or sequentially, data transmitted to the ear must generally be presented sequentially. While the ear does have some capacity for separating simultaneously presented messages, the difficulty of undertaking this task is such that simultaneous presentation of two messages is rarely found except in the case of music. The issue of the relative efficiency of the two senses for the making of temporal discriminations has been studied but the outcomes of the research are equivocal. Henneman and Long cite a study which shows that auditory morse code can be received more rapidly than visual morse code (but this may be a practice effect). However, other studies are also cited which point to the conclusion that both vision and hearing are about equal for the detection of discrete stimuli.

The fact that information is transmitted through the use of speech at a rate which rarely exceeds 200 words per minute, while reading is commonly undertaken at twice this rate, has sometimes been cited as evidence that vision permits a more rapid transmission of information than does hearing. However, recent work indicates that the rate of speech is set by the speech mechanism itself and that under some conditions speech may be transmitted at much higher speeds than those that are customary.

Henneman and Long (p. 12-13) offer four main conclusions in taking an overview of the literature which are as follows: "(1) the efficiency of the visual sense for temporal discrimination is much greater than formerly thought; (2) whether there is any actual difference between the two senses in this regard seems to depend upon specific experimental conditions; (3) with adequate training it would seem possible that either sense might be employed for the intake of information requiring fine discrimination of temporal intervals; (4) the visual sense probably affords more redundancy than audition because of the greater overall sensitivity to spatially and temporally distributed stimuli combined."

Henneman and Long use the term referability to indicate the extent to which an informational display presents data for a relatively long duration so that the receiver can refer back to it and use it by repeated reference to guide his external or internal behavior. Very few auditory messages are referable in this sense though apparatus can be rigged so that a receiver can obtain repetition of any particular communication. Many kinds of visual transmissions have the characteristics of referability though, under some circumstances, motion picture and television transmissions do not. Such lack of referability of the latter transmission is a serious weakness in their value as educational devices. In contrast, in the classroom repetitions of auditory information as well as of visual displays are easily arranged.

A comparison of the visual and the auditory transmission of information with respect to the attention factor is considered in the chapter on attention.

Information Handling Capacity

One of the problems in perceptual studies has been the difficulty of quantifying stimuli in such a way that the total effect of the stimulus is included in the measure. If one were to be presented with a picture of a cat, and his task was to categorize all cat pictures in one category and all dog pictures in another category, just which cues allow him to perceive this picture as a cat? Was it that the cat was furry? So is the dog. Was it the cat's tail? The dog has a tail as well. One can readily see that some of the cues in the picture do not add to the discriminability, but rather, since they are relevant, or irrelevant to both categories they may act as a hindrance to accurate discrimination. In the past many studies have had to ignore these effects, and concentrate all of their interest on those areas that allow discrimination. Although this has been very profitable in increasing our understanding, it is possible that in some cases the conclusions drawn have been somewhat in error because the real effects of other stimulus cues have been ignored.

One case in point would be the often made assumption when dealing with the printed word that each word presented bears no relationship with the preceding or following words. In the use of nonsense syllables, this assumption approaches the truth; and so nonsense syllables have been used often in situations where the perception of the stimuli was to be considered an independent event. With words, however, there are almost always simultaneous or successive relationships between the stimulus elements. This would also hold true for other types of stimulus materials, for example, the stimulus elements of a musical score or a series of concept formation figures.

In dealing with word sequences, the experimenter often has a problem in specifying with assurity the amount of relationship between the different stimulus elements. This relationship is measured in terms of redundancy or constraint. (Contraint is defined by Garner (1962) as ". . . the amount of interrelatedness or structure of a system of variables as measured in informational terms." p. 145).

With the aid of information theory measures, it is now possible to measure the amount of redundancy or constraint in a stimulus sequence, in some cases. Shannon (1949) has suggested a manner in which we can measure the redundancy of letter sequences. His method was to present a series of letters and spaces, and then ask the subjects to guess the next letter. As the subject guessed correctly, the letters were written down for him to see; if he guessed wrongly. Shannon used two different techniques: (1) The experimenter noted that the subject had made a wrong guess, and the experimenter told the subject what the right response was, or (2) the experimenter did not note the errors made, but rather, he noted how many guesses the subject made before guessing the right response. After Shannon had gathered these data, he made a numerical assessment of the redundancy. To do this, he compared the actual guesses needed or the mistakes made with the number that would be expected if each event could be considered independent.

Miller (1957) and Aborn and Rubenstein (1952) among others have used nonsense syllables and have constructed rules of order and relationships among these nonsense syllables so as to vary amount of information that was represented by the presentation of these syllables. As one increases the rules governing the possible next choices in any sequence, one also decreases the amount of information represented by the presentation of the next stimulus. By varying the rules governing the next choices, these experimenters were able to control the information input of their stimulus arrays. As constraint increased, the mistakes in reception and recall of the stimuli decreased. (Miller refers to what is designated as constraint in this chapter as 'belongingness' or 'cliché-edness').

Miller, Heise, and Lichten (1951) showed that the amount of information represented by a nonsense syllable also affected the recognition threshold. They also used words in sentences and digits. Their results show that when the stimulus materials became more redundant, and/or more constrained, the recognition threshold was lowered.

Haslered and Clark (1957) looked at the area of redintegrative perception using words as their stimuli. They found that their subjects could identify significantly more words ($p < .001$) when the subjects could define the words than when they could not define words. They further showed that, when the alternatives were reduced by the experimenter, more words in both categories, defined and undefined, were correctly identified, (no level of significance given). "In contrast to the results on the tachistoscopic test of recognition were those on 'aided recognition'. Generally, the stimulus-word was chosen 85-90 per cent of the time correctly from among the five alternatives, but, as shown by a p greater than 0.1, the difference between words that could and could not be defined is now insignificant" (p. 99).

Are there stimulus dimensions other than the effects of constraint that we can measure by use of information measures? Attneave (1955, 1957), using information measures to study the affects of symmetry and information on pattern-memory and to study the determinants of the judged complexity of shapes, has shown the information theory approach to be of great use in this type of work. In commenting on his 1955 study of symmetry, information and memory for patterns, Attneave says, "The usefulness of concepts derived from information theory in the quantitative investigation of a concept as vague as that of the 'good figure' has been demonstrated by the experiments reported here" (p. 221-222). In the later study, Attneave identified some of the physical determinants of the complexity of a shape, i.e., "(a) the number of independent turns (angles or curves) in the contour, (b) symmetry (symmetrical shapes were judged more complex than asymmetrical with number of independent turns constant, but less complex with total numbers of turns constant), and (c) the arithmetic mean of algebraic differences, in degrees, between successive turns in the contour" (p. 226). The reader is referred to these two articles for additional information.

Rappaport (1957) conducted a series of four experiments to study the role of redundancy in the discrimination of visual forms. He varied both the amount and the source of redundancy and found that there was no essential difference in the times used in sorting the figures used with the two different sources of redundancy in a noise-free situation. He interpreted this as being due, in part, to the non-utilization of redundant features of a stimulus by S when external noise was absent. He further suggested that ". . . in certain situations there may exist a balance of effects between the beneficial characteristics of various types of redundancy and the detrimental features that arise when redundancy is introduced in too great amounts or in an ineffective way" (p. 9).

Bruner, Wallach, and Galanter (1959) designed a study aimed at getting at the identification of recurrent regularity in stimuli. They stated at the outset that these regularities can be masked by the addition of irrelevant factors (noise), or that ". . . the regularity itself may be of such a complexity that it exceeds the memory span that an observer brings to the task" (p. 200). As more irrelevant information was added to the stimulus, the task of identifying regularities was made more difficult. In this experiment the recurrent regularity was in the pattern of occurrence of a series in which only one of the two lights used was lighted in each trial. The basic pattern was left-left-right. The noise was the randomization of the occurrence of the lights on one or more trials. Other methods were used to study other effects such as the effects of high or low error-costs. The main finding in this study was when there was little or no noise, and if the pattern were of a complexity that was within the limits placed by the process of immediate recall, then the elements of regularity were immediately recognized.

This type of study is not far removed, if at all, from the concept formation type of study. When the regularities in stimuli are used to categorize them, we have a concept formation study. Bourne and others, in a series of experiments (cited in the chapter on concept learning), studied concept formation as a function of variables suggested by information theory. As they increased irrelevant information, the reinforcement of irrelevant information, and intradimensional variability, they found corresponding decreases in performance. As increase in the number of relevant dimensions resulted in an exponential performance-decrement.

Hope is held out for the future use of information theory measures in problems similar to those mentioned above. However, we must not forget that there are some drawbacks to these measures. Information theory is not a panacea that can be applied to all and every field of psychology and give meaningful results. Many of the other measures available to psychologists are more appropriate and more meaningful in many area of psychological research. The use of information theory measures should be based upon a logical rationale.

It has become increasingly obvious that men have trouble understanding each other. The problem lies not only in trying to understand the motivations, aspirations, thoughts, and actions that are not overtly or specifically expressed, but also in trying to understand the meanings implied in man's overt attempts to communicate with other men. Are there limits to the amount of information that a man can utilize in a given length of time? How can one increase the likelihood of his communication being properly received and understood? What can man look for as the ultimate rate of communication with other men?

Although these questions are large in scope and can only be handled briefly here, there are data which shed some light on these problems.

The concept of channel capacity derived for the description of physical systems can also be applied to human beings. In humans channel capacity generally refers to the amount of information that the human can process as determined by the physiological and psychological limits inherent in him or the situation. Sometimes it is used to refer to the capacity of a particular nerve to transmit information. The channel capacity of a nerve, such as the optic or auditory nerves, is generally much greater than the central capacity for processing information.

The concept of channel capacity has been used with a number of distinct meanings. In the research covered in this chapter the term channel capacity is used to refer to the ability of the human to utilize information. In the chapter that follows, channel capacity is used in accordance with current practices in physiology and refers to the capacity of the afferent nerves to transmit information to the higher centers where the information is utilized. It is unfortunate that no uniform usage has emerged and that the different meanings refer to very different phenomena. An additional confusion is also caused by the fact that the term channel capacity sometimes refers to the amount of information that can be taken in on an instantaneous presentation and sometimes it refers to the rate at which information can be transmitted and utilized. The former is measured in bits and the latter in terms of bits per second.

Miller (1956) reviews several researches on channel concepts in his paper: "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information".

The methodology used in most of the investigations reported by Miller was that of setting as the task for subjects the categorization of stimuli varying along one dimension. The dimension varied had direct relationship with one or another sense modality; i.e., loudness-hearing, brightness-sight. Although many different degrees of stimulus intensity were used, the subjects categorized all of these different intensities into relatively few categories. The log to the base two of the number of these categories then yielded a number in bits that can be referred to as a "channel capacity". Pollack (1952) found a channel capacity of 2.5 bits for absolute judgments of pitch. Garner (1953) found a channel capacity for absolute judgments of loudness at 2.3 bits. Beebe-Center, Rogers, and O'Connell (1955) found a channel capacity of 1.9 bits for taste intensities. Hake and Garner (1951) found a channel capacity of 3.25 bits for judgments of visual position. Ericksen and Hake (1955); Ericksen (1954); and Pollack (1952, 1953a, 1953b) conducted related studies with other stimuli varying along one dimension and found the same general result, i.e. that there seems to be a channel capacity in the human, as measured by this technique, of from 1.6 to 3.9 bits with a mean at 2.6 bits and a standard deviation of 0.6 bits.

There is a surprising amount of agreement between the channel capacities of the different dimensions of the various sense modalities as measured in this way. One should keep in mind, however, that the differences in the channel capacities of the different dimensions are real and, in fact, there is considerable variation, although not as much as one might at first suspect.

Other experiments have used two dimensions varying at the same time. In examining everyday experiences with communication, one will see that one is able to make absolute judgments about more than just seven different objects, discriminating between them with assurity. One reason for this ability that might seem to be at odds with the channel capacities derived by the method described above is that one may be reacting to more than just one dimension of the object. There are many different dimensions along which an object (stimulus) could vary. Does one obtain an additive effect when two or more dimensions are varied simultaneously in the same stimulus?

The results of Klemmer and Frick (1953), Pollack (1953a, 1953b), Halsey and Chapanis (1951) and others have shown that the adding of another dimension does indeed increase the channel capacity, but not as much as had been thought possible by virtue of the channel capacities of the two different dimensions as measured by the previously outlined method. For example, when Pollack asked listeners to judge both the loudness and the pitch of pure tones -- loudness has a channel capacity of 2.3 bits and pitch a channel capacity of 2.5 bits -- one could expect a channel capacity for the combined effects of these two dimensions to be 4.8 bits. The experimental results show a channel capacity of 3.1 bits instead. All of the above mentioned experiments and others of the same type show that the addition of dimensions that vary does augment the channel capacity for making absolute judgments, but not to as high a degree as one might be led to expect judging from the capacities of the individual channels alone. However, Miller (1956) points out that studies of a dimensional stimuli are a far cry from the complex stimuli of the real world faced everyday. Only a single study by Pollack and Ficks (1954) has attempted to deal with very complex variables. They used six different acoustic variables that they could change:

frequency, intensity, rate of interruption, on-time fraction, total duration, and spatial location. Each one of these six variables could assume any one of five different values, so altogether there were 5^6, or 15,625 different tones that they could present. Under these conditions, the transmitted information was 7.2 bits, which means that there were 150 different categories that could be absolutely identified without error.

To generalize then, we might sum up the studies briefly reported by saying that the addition of stimulus dimensions results in an addition to the limiting channel capacity, but not to the same degree as the channel capacity of that one dimension figured without the effects of the other dimensions. As more dimensions are added, there is a decreasing increment in the channel capacity of the multidimensional system. People are less accurate in any one dimension if they must judge more than one attribute at the same time.

The data suggest that the amount of information which can be taken in on a single presentation of a display is probably quite limited -- perhaps of the order of 10 bits. However, since most displays that are introduced in educational settings are shown to the learner for extended periods, typically involving many minutes, the limitation is not as great as it may seem. The main point to be emphasized here is the fact, which comes clearly from the data that man has a very limited capacity for processing information about the outside world, and hence, the design of audiovisual teaching materials requires that they concentrate on essential information.

What does this mean to communication? All of the ramifications would be difficult to list, but some of the more obvious ones are: (1) we do not use all of the information impinging upon our nervous system in making judgments, (2) as one increases the number of dimensions that vary, there is an increase in the amount of information being communicated[1] but this increase is not in proportion to the corresponding increase in the amount of information represented by the variability of the stimulus, and (3) the addition of new sources of information actually has the effect of reducing the amount of information from any one given source that is being utilized.

In the study of the limits of the information handling capacity of the human organism, attempts have been made to determine the capacity of the nerves related to different sense modes for the transmission of information. In doing this, different research workers have arrived at different estimates of channel capacity. This is a problem which will be explored later in the chapter related to physiological problems of information transmission.

Finally, mention must be made of a single study in which an attempt has been made to estimate capacity to process information in terms of bits per second -- a somewhat different problem from that which has been considered up to this point. Quastler and Wulff (1955) report a maximum

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[1]"Communicated" as used here refers to the amount of the transmitted information that is actually received and used.

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rate of information transfer when the information is encoded in language of about 25 bit/sec.. This value is based upon the characteristic limitations inherent in language such as: (1) constraint, (2) time necessary to say or read a word or phoneme, and (3) limitations in the alphabet of the source and the receiver -- for example, there are only a limited number of phonemes from which all the words in a language are constructed. Even considering these limitations it is generally conceded that our theoretical capacity to transmit and receive language-encoded messages is greater than we use.

Because man's ability to receive information is apparently limited, it becomes necessary for the educator to choose very carefully the information that he wishes to communicate to his students. The indiscriminate flooding of any sensory channel with information would probably result in conditions that would hamper the learning of the desired materials, rather than facilitate this learning. To further insure the learning of the desired materials, the manner of their presentation is also important.

Information Theory and Problems of Memory

It is a well-known fact that meaningful verbal material is easier to memorize than nonsense material. One explanation of this phenomenon is that meaningful material permits more positive transfer from previous learning. Just what has been transferred from the learner's previous experience may be specified in many ways. Miller and Selfridge (1950) studied this question by generating statistical approximations to English. By thus controlling the amount of information in the stimulus and by comparing the amount of information retained by the subjects using immediate recall as the measure thereof, they came to the conclusion that the subjects' familiarity with the rules which govern the sequential properties of meaningful passages is probably much more important in facilitating recall than is the subjects' understanding of the passage.

Aborn and Rubenstein (1952) used nonsense syllables that were arranged into sequences according to rules that varied from random assignment to schemes with a high degree of constraint, that is, with many rules governing the choice of the next stimulus element. Using information terms, the sequences varied from those in which there was no redundancy (the nonsense syllables were randomly assigned) to those in which there was a high degree of redundancy (where there was a great deal of organization). Their results confirmed and extended the results of Miller and Selfridge. Aborn and Rubenstein found:

1. When there was a lower average rate of information (more redundancy, more constraint) more syllables were correctly recalled than when there was a higher average rate of information per syllable. That is, when there were fewer possible choices for the next syllable in a series, there were more correct guesses.

2. Between the limits 2 and 1.5 bits per syllable, the amount of information learned by the subjects was constant. The ratio between the amount of information learned between these limits, 2 and 1.5 bits per

syllable and the amount of information in the stimulus was constant.

3. As the degree of organization of the stimuli was increased beyond 1.5 bits per syllable, that is, as the amount of information represented by a stimulus presentation became less than 1.5 bits, the amount of learning decreased at a disproportionate rate, so that the ratio between the amount of information learned and the amount of information in the stimulus array decreased.

4. There is some degree of predictability of a given subject's behavior with respect to the amount of material of a given degree of organization he will learn. This predictability is contingent upon (1) the degree of organization of the material to be learned-beyond a certain degree of organization there is no real amount of predictability possible, (the degree of predictability was not specified by Aborn and Rubenstein although one would surmise that it would bear some relationship to the 1.5 bits per syllable that has been mentioned in other contexts). (2) the average rate of information in the given stimulus array, and (3) the subject's level of ability as measured in a passage having a different average rate of information.

The second paper by Rubenstein and Aborn (1954) reports an experiment in which they sought the solution to the problem raised by the findings that there was an actual decrease of information recalled in passages of highest organization. By studying the relationship between the degree of organization in the passages and the length of study time allowed the subjects, and by training the subjects more extensively, Rubenstein and Aborn came to the following conclusions that extend the knowledge afforded by the earlier experiment:

1. "The relationship between degree of organization and amount of information recalled is independent of length of study period for shorter study periods. In the longest study periods (10 and 15 min.) there is a tendency for performance in patterns of lower organization to improve disproportionately to performance in patterns of higher organization."

2. "The amount of information recalled per unit of study time decreases as the length of study time increases. The 'loss' is percentagewise the same for all degrees of organization" (Rubenstein and Aborn, 1954, p. 152).

Other studies have affirmed the conclusions of the above mentioned studies.

Attneave (1955) used dot patterns on a matrix in a series of three experiments and obtained similar results to the above. The dot patterns were varied with respect to information context and symmetry. In all three experiments the patterns of dots were varied in such a way as to permit comparison between memory for symmetrical patterns and memory for (a) asymmetrical patterns with the same informational content -- hence fewer cells, and (b) asymmetrical patterns occupying the same number of cells, and containing more information.

In none of these experiments were symmetrical patterns easier to remember than asymmetrical patterns with the same informational content, and in two of the experiments the difference was significant. This superiority for remembering symmetrical patterns was least striking in the case of immediate reproduction. Random patterns were found to be more difficult to remember the greater their complexity.

Attneave states that, "These results are believed to constitute an important clarification of the Gestalt doctrine that 'figural goodness' is favorable to memory" (Attneave, 1955, p. 222).

Although the above is in no way meant to be an extensive review of the experiments done in this area, the studies reported do show that the mathematical theorems and/or conceptions of information theory have application to the psychology of learning. As the techniques for quantifying the information in stimuli are perfected, the use of information theory theorems in studies of memory will increase, and be extended to include the recall and/or memorization of more complex stimuli such as line figures and pictures.

One more very important point remains to be made. Within the framework of information theory there is a term that might also be used to describe an important process related to memory. That term is "coding," or to be more accurate, "recoding." An experiment was conducted by Sidney Smith related to this phenomenon and reported by him before the Eastern Psychological Association in 1954. An account of this experiment appears in Miller (1956).

The essential process involved in the Sidney Smith experiment was the recoding of information into chunks. This is the term used by Miller (1956) to differentiate between material organized by their smallest integral elements, i. e., individual letters, numerals, dit or dah in morse code, etc., and material involving groupings of these elements into larger segments, i.e., words, telephone numbers, phrases, etc. There seems to be some limitations that keep channel capacities within a rather limited range. This range is considerably below the range of individual items represented by an array of eighteen binary digits. However, Smith taught his subjects to arrange these binary digits into chunks by recoding them into decimal numbers and did observe that it became possible for his subjects to remember the whole list after thoroughly learning the code.

Miller (1956) then suggests that recoding is an extremely powerful means of increasing the amount of information that the human learner can retain. In a sense, this is done whenever the learner studies a book, but, rather than remembering the detailed information contained in the pages, retains only a knowledge of where the information can be found in the particular book. What he has done in such a case is to remember coded information which enables him to retrieve the information from the book. This is a much more efficient process than that of learning all the information contained in the book. Unfortunately, almost nothing has been done on the design of books which will improve the capacity of readers to remember where information is to be found. The ordinary haphazard process of making an index for this purpose leaves much to be desired.

Task Demands in Relation to the Sensory Modality Selected for the Transmission of Information

Studies of the relative efficiency of the visual and auditory modes for the transmission of information have been typically undertaken in research in which the problem has been to find ways of communicating efficiently with the operator of a piece of equipment. In such studies the operator most commonly mentioned is the aircraft pilot or the equipment operator. The point is stressed not only in the Henneman and Long review but also in many other studies that the efficiency of a particular modality for the transmitting of information depends upon the immediate task faced by the operator. For example, there are times when the pilot of an aircraft is fully occupied visually watching the radio compass and panel instruments, as well as locating other flying aircraft. At such times, additional information must be transmitted through the ear. When two-way communication is needed, this has to be accomplished by auditory means since two-way visual communication is a much less well developed art.

In the case of the design of multiple channel instructional communications, the problem of assessing the relative effectiveness of the auditory channel in comparison with the visual is made particularly difficult because there is no source which can be used to determine the task of the receiver of the audiovisual communication. That the task of the receiver is to receive is a truism which contributes absolutely nothing. Yet the fact is that the determination of the efficiency of a channel to use for communication is highly dependent upon the task of the receiver.

Receivers of audiovisual presentations may perform a number of operations as a result of what they see or hear. Their operations may include the following:

- Associating a spoken word with a set of visually perceived attributes;
- Learning that a set of visual phenomena represents a set of verbal propositions;
- Deducing the defining attributes of a class of events;
- Deducing the relationship between defining attributes;
- Identifying sequences of events;
- Identifying functional relationships between phenomena;
- Learning how to perform a particular skill;
- Learning to avoid dangerous phenomena;
- Engaging in aesthetic experiences (sometimes through being given cues concerning what should be appreciated);
- Understanding the essential features of propositions expressing casual relationships through viewing simplified representations of the phenomena;
- Understanding the essential features of visual displays through the use of visual coding devices such as line drawings;

Experiencing the visual and auditory environments of people in other lands, in other parts of the receiver's country, in other periods of history, etc.

The Relative Efficiency of Learning Verbal Material Through Auditory and Visual Channels

A basic problem related to the use of the auditory and visual channels is the relative efficiency of these channels for communicating material to be learned when identical information is transmitted by means of the two channels. The obvious material to use for such a study is verbal material. While other kinds of material, such as music, have comparable visual and auditory forms, there are relatively few persons who are practiced in the use of these other forms.

A major difficulty involved in the use of the two sensory modalities in the learning of verbal material is that the speed of presentation of material through these modalities is typically different. While speech will rarely run higher than 150 words per minute, material to be read is often presented at a rate far in excess of this speed. Written material presented at the introduction of movies is typically presented at least at this speed and often at a much more rapid rate. While it has been demonstrated that the intelligibility of speech is related to the rate at which it is spoken, the difficulty of receiving and interpreting the higher rates of transmission may be a result of lack of experience. If the human speech mechanism had a facility for operating at say 300 words per minute, a high degree of intelligibility at that speed might well have been achieved.

Many studies have been undertaken in which verbal material has been presented through the eye alone, the ear alone, and through both senses. These studies, which generally involve simple materials presented at a single specified rate, have been reviewed by Day and Beach (1950). The latter review covers research of questionable quality, and the fact is that most of the studies which have been undertaken appeared in the early part of the century and very few have been undertaken since 1940. The recent and related studies of Broadbent, Triesman, Cherry, and others represent such a different technique and approach that they will be reviewed separately in a later chapter. In a sense, the latter studies have superceded those considered by Day and Beach.

In the studies which come within this review, the learning of four different kinds of materials are considered. These are nonsense syllables, digits, discrete words, and meaningful prose. The latter has sometimes been featured in studies of the effects of advertising comparing auditory and visual methods of presenting the same material. Despite the fact that the studies cover a great diversity of materials, subjects, and learning and retention conditions, Day and Beach consider that a number of generalizations emerge from them although many are based on very small samples and do not include tests of significance. These generalizations are reproduced in the following paragraphs in quotation marks together with comments (Day and Beach, p. 8-9). The comments were not in the Day and Beach report and are attributable entirely to the writers of this report:

A. "Meaningful, familiar material is more efficiently presented aurally, whereas meaningless and unfamiliar material is more efficiently presented visually." A number of different factors could be involved in this. When nonsense syllables are transmitted to a receiver, accurate transmission is more likely to occur with visual presentation since auditory presentations may involve some ambiguity. For example, the syllable BER is clear and unambiguous as written, but as spoken it would be mistaken for BUR or BIR. For this reason alone meaningless material would be better transmitted by the visual channel. The results from which this generalization is based are also contaminated with an age factor and at lower age levels one might expect the difference to disappear.

B. "The greater the intelligence level of the receiver, the greater is the relative advantage of a visual presentation." This effect may be due to the fact that those who obtain the highest scores on such receiving tasks tend to be the best readers.

C. "The greater the reading ability of the individual, the relatively more effective is a visual presentation." This is inevitably so since the visual presentations in the studies reviewed were all verbal.

D. "The relative efficiency of a visual presentation increases with age from a definite inferiority at the age of six to a possible superiority at the age of sixteen." This effect may reflect the increase in speed of reading which occurs with age. It suggests the importance of the learning factor in determining the relative efficiency of one channel over another in the transmission of information.

E. "Usually difficult material is more effectively received with a visual presentation. whereas particularly easy material is better understood with an auditory presentation. The relative effectiveness of the visual presentation increases with increasing difficulty of the material." This could be a result of the fact that visually presented material can be easily examined and re-examined and much complex material may require more than a single presentation for comprehension. This interpretation is related to conclusion J which gives it support.

F. "When comprehension is tested by an immediate recall of the material a visual presentation is favored; if the test of comprehension is made after a considerable interval of delay, an auditory presentation is favored." This conclusion lacks strength both in the amount of data cited to support it and in the fact that it does not fit any particular set of expectations.

G. "The relative efficiency of a visual presentation diminishes as the interval of delayed recall increases." Here again the relationship to delayed recall is a puzzling one and most of the data which supports this conclusion are the same as those which support the previous conclusion.

H. "One of the most significant advantages of the visual type presentation system is the relatively greater referability, or opportunity for reviewing the material, that it affords. It has been found that the less the referability afforded by a visual presentation system, the less is its advantages over an auditory presentation." This conclusion appears to provide an explanation of some of the preceding conclusions.

I. "Such organized and related material as prose or factual information is better understood with an auditory presentation; material such as code that is comparatively discrete and unrelated is more effectively received with a visual presentation." The factor of referability may well be operating in this case also.

J. "The comprehension of material can be tested either by the ease with which the material is learned or by the amount which is retained after a period of time. As a rule, measures of learning tend to favor a visual presentation while measures of retention are higher after an auditory presentation." The reason for this is thoroughly obscure.

The type of research considered in the Day and Beach review has been a vanishing activity among psychologists, perhaps because of the attempt during the late nineteen fifties to concentrate on research on complex materials such as sound movies and educational television broadcasts. An exception to this is the work of Mowbray which is reviewed in a later section of this chapter. Such materials do not lend themselves well to the study of the relative efficiency of two sensory modalities for the transmission of information. Almost nothing could be found in more recent literature which followed up systematically the knowledge already gained from the studies reviewed by Day and Beach.

A second important factor which appears to emerge from the review is that the experience factor plays a very important role in determining the extent to which one sensory modality is superior over another. While there appears to emerge from many of these studies the conclusion that with younger subjects the visual modality is inferior to the auditory, this may be a product of the fact that the visual tasks involved in the studies have been typically verbal and required reading. Whether the same difference would occur with nonverbal visual representations is an open question.

Studies of the Simultaneous Transmission of Auditory and Visual Information

The Day and Beach review also covers studies in which redundant information has been transmitted simultaneously through the eye and the ear and in which the data derived from the procedure have been compared with data derived from presentations involving a single sense mode. The results of such studies are of crucial importance to the design of audio-visual materials. The conclusions drawn by the authors of these various studies support the position that a simultaneous presentation of the same information through both the auditory and the visual channels results in

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more effective learning than the transmission of the same information through either channel alone. All of the studies which are cited to support this conclusion deal with very simple materials such as digits, words, or nonsense syllables. It seems that the problem has not been studied with meaningful prose and neither has it been studied with different representations of the same object in the two sensory modalities as when the word square is said and an outline of a square is projected onto a screen. The conclusion drawn from these studies is surprising but it is not supported by a single study which utilizes a test of significance. The studies on which the conclusion is based are summarized in Table 2.

Some further comments must be made about the entire series of studies since they are cited in almost every textbook on audiovisual education to support the educational procedure advocated by these texts. Despite the fact that they are widely quoted and form a cornerstone for the audio-visual field, they are so ill-designed by modern standards that they are of only historical significance. The absence of any tests of significance is just one of the serious flaws that runs throughout the entire series. In addition, the studies show a complete absence of control over such factors as the time of exposure of the material to be learned and the selection of materials. A careful first-hand examination of the studies leads one to the conclusion that they do not provide any information relevant to the problem which they were designed to solve. The conclusions may be true, but one cannot arrive at such an evaluation from an examination of the data they provide.

In addition, the conclusions drawn from the studies on the simultaneous transmission of auditory and visual information are so contrary to what would be expected in terms of modern perceptual theory and modern perceptual research, that serious consideration must be given to the possibility that the outcomes were mere artifacts resulting from poor experimental procedures. There is also the possibility that if tests of significance had been applied to the data that very different conclusions would have been drawn.

SOME RESEARCH CONDUCTED AT UTAH AS A RESULT OF THE REVIEW OF THE LITERATURE

Since the studies which have been considered in the previous section form the basis for much that is advocated in books on the use of audio-visual materials, those engaged in the project of which this volume is a product considered it a matter of substantial importance to undertake similar studies with the incorporation of proper controls and appropriate tests of significance. The experiments which follow were conducted by Van Mondfrans and Travers (1964).

In the review of the early studies in this area by Day and Beach (1950), several factors were identified as important for the design of an experiment in this area. These factors were: (a) the meaningfulness of the stimulus material -- the more meaningful material favors the audio channel, (b) I.Q. -- a higher I.Q. favors the visual channel; (c) reading

TABLE 2

EARLY STUDIES COMPARING THE AUDIO, VISUAL, AND AUDIOVISUAL MODES

Name	Date	Subjects	Material	Results
Elliott	1936	Adults	Advertising Names and Copy	AV>V, AV>A, A>V*
Koch	1930	14 College Women	Nonsense syllables	AV > to all, V>A
O'Brien	1921	7 Graduate Students	Meaningful Nonsense	V>A>AV AV>V>A
Henmon	1912	6 Advanced Psychology students	Nouns, 2 digit no's, nonsense syllables	A>V, AV>V, AV>A** A≥V, AV≥V, AV>A
von Sybel	1909	17 Students	Nonsense syllables	AV>V with long exposure time V>AV with short exposure time AV>A, V>A
Schuyten	1906	Subjects aged 11 to 14 1/2 large N	Digits	A>AV A>V
Kemsies	1900 -01	German students 15 1/2 and 12 1/2 yr. olds N=29, N=30	Latin and German vocabulary words	A>AV>V before practice effects added A>V>AV after
Smedley	1900 -01	All elementary and secondary school children in Chicago	4 to 8 digit numbers	AV>A,** AV>V** V>A above 8 yr. old A>V below 8 yr. old
Quantz	1897	50 University Juniors and Seniors	Common words Prose Competing prose Passages	AV>A, V A>V**
Munsterberg and Bigham	1894	5 subjects	Numbers and colors	AV>V>A

* A>V means that audio was superior to visual
** Very slight differences

ability -- high reading ability favors the visual channel; (d) age -- as age increases the relative effectiveness of the visual channel increases; (e) the method of testing used to determine the amount of learning that has gone on -- visual testing favors the visual channel, audio testing favors the audio channel, etc.; (f) the interval between the learning task and the testing -- a shorter period favors the visual channel, whereas a longer period favors the audio channel. (g) referability -- visual displays have greater referability than auditory inputs; this might account for some of the advantage of the visual channel in some of the earlier studies; (h) organized material (redundant) vs. non-organized (non-redundant) material -- the more highly organized material favors the audio channel; (i) and the criteria used to determine when the task had been completed; immediate memory favors the visual channel, and the amount retained over time favors the audio mode. It was therefore decided to conduct an experiment in which the audio, the visual and the audiovisual modes of presentation were compared, controlling more of the factors that had made the earlier studies difficult to interpret and using tests of significance. The experiment was designed to provide as much data as possible that would be useful in interpreting the earlier studies and in drawing conclusions about the efficiency of these three modes of presentation in the learning of various types of material.

The Problem

In the first study there were three different levels of meaningfulness and redundancy in content; (1) nonsense syllables, (2) common words, and (3) common words with constraint. The words with constraint were lists of words in which an association value other than zero exists between words near to one another in the list. While it is true that earlier studies have varied the amount of meaningfulness of the stimulus material and studied the relative effectiveness of the different modes of presentation, their purpose was not the study of the interaction between the mode of presentation and the level of meaningfulness and redundancy in the stimulus. This will be the specific area under investigation in this study, although the data allow other comparisons as well.

The levels of meaningfulness or redundancy in the stimulus materials were controlled by selection. The nonsense syllables were all selected from a list compiled by Glaze (Underwood and Schulz, 1960). They all had meaningful ratings between .50 and .60 on Glaze's scale. They were also selected so that all were pronounceable. The words were taken from the Lorge-Thorndike list of the 501 to 1,000 most common words, with the restriction that they all had to be 6 or 7 letters long. The words with constraint were selected from the same list as the words, but were ordered in an (adverb or adjective) noun-verb-noun sequence such that the four words in each group could conceivably be found in the same order in an English sentence (16 sentences) with only the addition of some connectives needed to make a sensible sentence. There were three lists of each of these materials. The lists were of essentially the same difficulty. These selection techniques also controlled the level of organization of the stimulus material.

The factors of I.Q and reading ability were not controlled, but were taken care of by the random assignment of subjects to the various learning conditions of the experiment, i.e., the nonsense syllables, words or words with constraint.

All of the subjects were college students enrolled at the time of the experiment in a beginning Educational Psychology class required of all secondary education teaching majors. They were all between 19 and 36 years of age. The data of earlier studies had indicated that these age limits would be well within a range where they would be of no advantage to the audio presentation due to age alone.

The method of testing the learning that had taken place in this experiment was that of immediate recall. The subjects were to write down the stimulus elements that they could remember immediately after a stimulus array had been presented. It is recognized that this method of testing could give a slight advantage to the visual mode of presentation since the criterion test involves the making of a visible representation rather than an auditory representation. The incorporation of different methods for measuring learning, with both visible and audible products, would have added too much complexity to this initial study. However, in evaluating the results of this experiment the reader must view the apparent relative efficiency of the visual mode of presentation as possibly being inflated.

Previous attempts to control the referability of the audio input and make it more nearly comparable to the visual display in duration have used such devices as repeating it several times. Neither of these devices proved to be desirable, so another device was used in this experiment to ascertain the effects of referability. The time of exposure of each visual stimulus element was held constant at either 4 or 2 seconds. In the analysis one could determine whether the greater amount of referability of the visual display under the four second conditions would cause more learning compared with the visual at two seconds.

Procedure

Each subject was assigned to a learning condition (nonsense syllables, words, or words with constraint), a treatment order (for example, A, V, AV or V, AV, A), an order of lists (for example list one, list three, list two), and an exposure time (two or four seconds). The assignment of subjects was done with counterbalancing so that there were no order effects, other than the effects of practice. For example, not only did the three treatments occur the same number of times in the first, second or third position, but each was followed by or preceded by the other two the same number of times. Nevertheless, the subjects could be expected to do better on the third series of trials than they had on the first since they had to some extent, learned to learn.

The audio presentation was effected by a tape recording. The visual presentation was via a filmstrip projected on a screen. The synchronized audiovisual presentation was produced by combining the other two and is synchronizing them so that the aduio input occurred simultaneously with the onset of the visual display. Each subject participated in only one learning condition, nonsense syllables, etc., but in all three treatments under that condition, one list was presented to him auditorily, another list visually and the third list audiovisually.

There were 72 subjects in all with 36 participating in the experiment with a two second exposure rate and 36 at the four second exposure rate. The stimulus elements were presented one after another at either the two second exposure rate or the four second rate until all sixteen elements in that list had been presented. The subject then was allowed $1\frac{1}{2}$ minutes to write down as many of the stimulus elements as he could remember. This was repeated until the subject had been able to write down correctly all sixteen of the stimulus elements for two consecutive trials or until ten trials had been given. Then, another list was presented the subject using another method of presentation, until the subject had been given all three lists and all three treatments.

The subjects' scores were error scores; that is, how many out of the sixteen stimulus elements were not remembered? A Latin square design was used in the analysis of the data.

Results

The results of this experiment which are important for answering the question at hand are those concerning the relative efficiency of the audio, visual and audiovisual modes of presentation and the interaction between the level of meaningfulness or redundancy of the stimulus material and the mode of presentation. The main effect of treatment (A, V, or AV) was found to be significant (p less than .001). When this effect was broken apart, using a Scheffe test, it was found that the audio mode of presentation was significantly less effective than the visual and the audiovisual modes (p less than .001). The audiovisual and the visual modes of presentation were about equally effective. The reason for the finding that the audio mode of presentation was less efficient is clear when the interaction of treatment (A, V, or AV) and the level of meaningfulness or redundancy in the stimulus material is considered. These two factors produced a significant interaction (p less than .001). However, when a Scheffe test was applied, it was evident that the main part of the interaction effect was between nonsense syllables and the audio mode of presentation. The audio mode of presentation was very inefficient in learning the nonsense syllables, but the visual and the audiovisual modes of presentation on the other hand were not found to be different from each other in any of the three learning conditions. The audio mode was found to be about equally effective in the two learning conditions using meaningful materials as stimuli. Only when the stimulus material was such that an audio presentation was highly ambiguous did any real differences in the relative efficiency of the three modes of presentation appear. It was therefore concluded that there were no real differences in the relative efficiencies of the three modes of presentation except when the stimulus material was of a highly ambiguous or non-organized nature or when some other factor such as age, or reading ability was operating.

A Further Experiment

The study previously summarized provided a condition which gave some advantage to the audiovisual presentation. Exposure time for the visual display was either four seconds or two seconds. This would make it possible for the subject to hear the audio message and then look at the same message visually transmitted. This could provide the same effect as an extra learning trial. However, if the presentation method had permitted the learner to have in this way an extra learning trial on each presentation involving both sensory modalities, then the result would have been shown in a marked advantage for the audiovisual method of transmission of information. In actual fact, no such advantage appeared. Whether training in alternation from the audio to the video and back again would produce the effect of an extra learning trial is an interesting question.

Since the time factor of presentation involving redundant materials through two sensory modalities would appear to be important the hypothesis seemed plausible that if the time of presentation were reduced further, then the transmission of information through two sensory modalities would have a deleterious effect. There is certainly much information that suggests that the nervous system under such conditions might show the effects of overloading and jamming. The Broadbent model (1958) discussed in Chapter 5 would also suggest that a further reduction in the time of exposure might produce jamming and a reduction in the effectiveness in the learning conditions. It was decided, therefore, to conduct an experiment using a one second exposure time, but retaining all of the other conditions of the previous experiment.

The problem of this second experiment was, then, to determine whether a jamming or inhibitory effect would occur through overloading when two sensory channels were used when the exposure time of simultaneously-presented redundant stimulus inputs was very short.

The Procedure

The procedure was exactly the same as in the previous experiment except the times of exposure were one second and .6-second . The same three treatments were used (A,V, and AV). The subjects were all students enrolled at the time of the experiment in an elementary class of Educational Psychology. There were seventy-two subjects in all, thirty-six participating in each exposure time.

Results

The data for each type of stimulus material was analyzed separately. Both stimulus exposure times were included under the analysis of the data from each stimulus material.

In the nonsense syllables analysis the main effects of time (p less than .05) and treatment (p less than .001) were significant. More was learned by subjects at the 1-second exposure than at the .6 second exposure. When the treatment effect was broken down, it was found that the audio presentation was significantly inferior to both the audiovisual and visual. The audiovisual presentation was slightly inferior to the visual, although the difference was not significant.

It is interesting to note that although the order effect was not significant, the first series of trials was found to produce less errors than the second, and the second less errors than the third.

In the words analysis there were no significant effects. However, there was a slight tendency for the audiovisual mode of presentation to be inferior to the other two.

When the data from the words with constraint condition were analyzed, the significant effects were time (p less than .05), the time by sequence interaction (p less than .05), and the order effect (p less than .001). The time and order effects were as expected with more being learned at the one-second exposure time than the .6 second exposure time, and more errors in the first series of trials than the second, and more in the second than in the third.

Once again the effects of treatment were not significant. This substantiates the conclusions drawn from the other data. It was found that there was a slight superiority of the visual mode of presentation over the audio mode, although this difference was very slight. There was a larger inferiority of the audiovisual mode compared to the other two. This difference was not quite significant at the .05 level at the .6-second exposure rate, but at the 1-second exposure rate the difference between the visual mode and the audiovisual mode was found to be significant at the .05 level.

Conclusions Drawn from the Study

The study is consistent with the doubts expressed about the validity of the long line of ill-designed studies which have supposedly supported the conclusion that the transmission of redundant information through two sense modalities results in the transmission of more information than when only one sense modality is used. The conclusions of the von Mondfrans and Travers study are at least consistent with the models of information transmission derived from physiology and psychology which will be reviewed in the next two chapters.

Wrong conclusions are very easily drawn from the type of data presented in the von Mondfrans and Travers study. For example, the data clearly show that the audiovisual and the visual presentations produce approximately the same amount of learning, but the auditory transmissions tend to be inferior particularly with unfamiliar materials such as nonsense syllables. Now these same data might have been analyzed in a different way. Some well-intentioned student might have compared the amount of learning in the audiovisual situation with the average of the learning under the auditory and the visual conditions. Now, if this were done, the audiovisual form of presentation would have had an apparent advantage for, despite the fact that the audiovisual and the visual presentations produced approximately the same results, the auditory presentation was less effective. This comparison of the audiovisual with the average of the single sense modality presentation would, then, clearly lead to a false conclusion. This kind of false conclusion is clearly evident in a number of contemporary studies of audiovisual problems.

Our conclusions are not in accord with the position taken in most current texts in the audiovisual area; but, in terms of available knowledge, our position is believed to be sound.

Other Recent Studies of Multimodality Transmissions of Nonredundant Information

Relatively little interest has been shown in recent decades in the effect of the transmission of redundant information through more than one sense modality. However, a series of studies by Mowbray (1952, 1953, and 1954) provide information about a related problem, namely, the effect of transmitting nonredundant information through two sense modalities simultaneously. There is plausibility to the idea that, if different information is transmitted to two sense modalities, more may be learned than if information is transmitted through one sensory mode.

Mowbray does not seem to have been concerned with the problem of determining whether more information can be transmitted through two senses than through one, but his studies provide some incidental data related to this problem. His stated purpose was that of testing the relative efficiency of audition and vision under conditions involving the simultaneous transmission of information.

In Mowbray's 1952 study subjects were given presentations of the alphabet with certain letters left out or presentations of the first twenty numbers with certain numbers left out. These materials were presented either through the auditory <u>or</u> the visual mode or the presentation was through both modes at once. In the latter case, the alphabet was transmitted to the one sense modality and the number series to the other. The task of the subject was to detect the missing digits or the missing letters of the alphabet. The duration of both the auditory and the visual stimuli lasted six seconds. The per cent of correct identifications of missing digits or numerals is shown in Table 3. .

When two modalities are used, there is no particular fall off of one modality at the expense of the other. Mowbray further reports that if easy material is transmitted to one channel and difficult material to another, it is the easy message on which there is the greatest increase in errors, a finding which parallels closely the outcomes of research on vigilance tasks.

TABLE 3

PER CENT CORRECT DETECTIONS FOR TEN SUBJECTS AND FOR ALL NONSIMULTANEOUS AND SIMULTANEOUS CONDITIONS

Modality	Nonsimultaneous		Simultaneous	
	Alphabet	Numerals	Alphabet	Numerals
Visual	51.6	70.0	31.6	43.0
Auditory	54.0	71.1	31.8	39.1

(From Mowbray, 1952, Table 3, p. 299.)

An important point to note is that in this experiment the auditory material was presented as a sequence, while the visual material was presented in its entirety at one time. In order for there to be comparable conditions between the methods of presentation, the visual presentations should also have been presented as a sequence. This brings out the central difficulty involved in the comparison of auditory and visual channels of communication. The auditory functions as a single channel system in which one part of a message must be transmitted before the transmission of the next part can begin. On the other hand, visual presentations can transmit large quantities of information at a given instant.

A second difference between the visual and auditory channels is in the speed with which information can be transmitted. Spoken messages are rarely transmitted at a rate above 150 words per minute, though a few speakers may rattle off their communications at the rapid pace of 200 to 250 words per minute. The latter speeds are very rarely encountered. On the other hand, visual presentations of the same material often transmit the same information at rates of 300 or more words per minute. While the practical limit in the case of oral transmission is set by the transmitter, the practical limit in the case of visual transmission is set by the receiver.

From the data of this first study, there is no straightforward means of comparing information transmitted in the bimodality procedure with the single modality procedure. Scaling problems do not permit us to add together the scores from the auditory and the visual transmissions in the simultaneous transmission and compare the amount learned with the amount when a single transmission is used. The numerical sum of the scores for the auditory and visual information combined for the simultaneous condition is slightly greater than the information gained from a single transmission, but the small difference may well be an artifact. A much more definitive answer to this question can be found in the data provided by Mowbray's second study (1953).

In his second study (1953), different information was also transmitted through the visual and auditory channels, and through both channels simultaneously. The information was verbal and consisted of prose passages involving three different levels of reading difficulty as determined by the Flesch formula. The material was transmitted either through a tape recorder or through a visual display in which the reading speed of the subject was paced so that it was undertaken at the same speed as the auditory display, or both presentations were made simultaneously. Subjects were tested for their knowledge of a passage with a true-false type of test administered immediately following the presentation. As an additional control, some of the subjects were asked to answer the true-false questions without having the benefit of either hearing or seeing the passages. The scores of the latter subjects did not differ significantly from what could have been expected on the basis of chance. The main results of the study are presented in Table 4. .

TABLE 4

PERCENTAGE OF CORRECT RESPONSES ON TESTS OF RETENTION FOR PROSE PASSAGES PRESENTED VISUALLY, AURALLY, OR SIMULTANEOUSLY VISUALLY AND AURALLY

Difficulty of Prose Passage	Control Group		Experimental Group	
	Visual	Auditory	Visual	Auditory
Difficult	60.8	63.3	58.2	56.5
Medium	67.4	67.3	58.1	56.1
Easy	74.0	73.1	63.4	59.5

From Mowbray, 1953, p. 367.

The results indicate that there is less retention for any particular passage in the simultaneous presentation situation than in the single passage presentation. Significantly more (p=.001) was retained in the case of the single presentation than in the double presentation. Significantly more deterioration (p=.001) occurred with the auditory material than with the visual, and the easier material suffered relatively the most from simultaneous presentation.

Just what to make of these findings is difficult to say. The report does not provide an estimate of the total amount learned when two channels are simultaneously involved as compared with the total learning when one channel is involved. While the scores for learning on each one of the two channels presented simultaneously are lower than the corresponding single presentation condition scores, there is still the possibility that the total learned when only one sense modality is involved is less than when two modalities are involved. One approach to the testing of the latter hypothesis involves the argument given below:

1. In Table 4 a score of 50 represents a chance score, since the test was a true-false test and, by chance, a subject might expect to have 50 per cent of his answers correct by guessing.

2. The amount of learning can be considered to be related to the extent to which a score is above the 50 per cent mark. Thus a score of 60.8 could be considered to be 10.8 points above a chance score. The score given in Table 4 can be converted into deviations from 50, and these are shown in Table 5 .

3. The visual learning plus the auditory learning have been added together in a final column of Table 5 . The mean of the entries in this final column is a measure of the total learning across passages for the three levels of difficulty. This value is numerically identical to that obtained from the auditory condition alone, and only very slightly greater than that obtained from the visual condition alone. The data suggest that the total learning through the two simultaneous inputs involving different materials is no more than the total learning involving a single prose passage using a single sense modality.

4. The above argument involves a number of assumptions about the equality of the units involved in measurement.

TABLE 5

DATA FROM TABLE 4 (MOWBRAY 1953)

CONVERTED INTO DEVIATIONS FROM 50

Difficulty of Prose Passage	Control Group		Experimental Group		Experimental Group
	Visual	Auditory	Visual	Auditory	Visual and Auditory
Difficult	10.8	13.3	8.2	6.5	14.7
Medium	17.4	17.3	8.1	6.1	14.2
Easy	24.0	23.1	13.6	9.5	22.9
	Mean = 17.4	Mean = 17.9			Mean = 17.9

The experiment by Mowbray, although designed to study the problem of the division of attention, throws only indirect light on the problem. His passages were long, attention to the auditory and the visual presentations could be alternated, redundancy within any one presentation was large, and there are other factors too which produce difficulties in understanding the results. In a later experiment, Mowbray (1954) attempted to remedy some of these deficiencies.

In his 1954 experiment, Mowbray used as a task the filling in of names on maps from instructions given both through the eye and ear. However, the messages transmitted through the two channels simultaneously were different items of information referring to different items on the map. The information was transmitted in four-word messages and the auditory messages were synchronized word for word with visual messages. In the analysis of his data, Mowbray showed that only on very rare occasions did a person utilize both items of information but generally only used one source of information. In only about ten per cent of the presentations were both sources of information used.

The conclusion to be drawn from the Mowbray data is that the amount of information derived from nonredundant transmissions of information through more than one sense modality is probably equal to the amount of information which can be transmitted in a comparable time through one modality. One would expect this conclusion to hold only when the transmission rates are relatively high and comparable to typical narration rates. The conclusions drawn from the Mowbray data fit well the conclusion drawn from the Von Mondfrans and Travers (1964) study that there is little to be gained by transmitting information through more than one sense modality -- at least not with the rates of information transmission used in the research. The two sets of data together suggest that the factor that limits the amount of information that can be transmitted resides in the higher information processing centers in the central nervous system. This conclusion finds substantial support in the chapters that follow.

Summary and Conclusions

Since many of the studies reviewed in this chapter have formed a foundation for current theory of the use of audiovisual materials, an evaluation of these studies is a matter of focal interest to the audiovisual field.

The studies on the relative advantages of visual and auditory transmissions of information indicate that each sense modality provides certain advantages. The visual mode has a larger number of codeable dimensions, which are well exploited in teaching aids, and also provides a less ambiguous transmission of information than the auditory. On the other hand, the reception of visual information requires that the receiver make the proper muscular and orienting responses prior to the intake of information. Auditory information is more likely to be received when it is transmitted from a source without warning than is the visual.

While the studies which are typically quoted in books on audiovisual teaching materials appear to support the position that transmission of the same information through more than one sense modality results in more learning than when only one sense modality is involved, none of these studies involved tests of significance to evaluate the validity of their conclusion and the procedures involved generally showed a grossly inadequate control of the experimental conditions. Studies undertaken at the University of Utah do not support the conclusions of the earlier research workers but are on more solid ground because of the modern laboratory methods and designs which have been used. Our conclusion has to be that there is no evidence to support the position of writers on audiovisual materials that the transmission of redundant information through more than one sense modality produces superior learning.

Studies have been undertaken that involve the simultaneous transmission of nonredundant information through both the auditory and visual modalities. A re-examination of some of the data from these studies leads to the conclusion that the information received when two sense modalities are used is equal to the amount received when only one sense modality and one transmission of information is involved. The transmission of two separate messages through two senses resulted in less of each message being received than when only one of the messages was transmitted.

The data examined in this chapter leads to the conclusion that the amount of information transmitted has nothing to do with the number of sense modalities involved, so long as the information can be transmitted through each of the senses involved. The data suggest that the amount of information which can be received is limited by the capacity of the central nervous system to handle information and not by the capacity of the sense organs.

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CHAPTER 4

THE MECHANICS OF THE TRANSMISSION OF INFORMATION IN THE CENTRAL NERVOUS SYSTEM

A review of research, relevant to the design of audiovisual learning materials, cannot neglect knowledge which has been accumulated concerning the nature of the nervous system as a transmitter of information. Neurophysiology has been a rapidly developing field which has accumulated much knowledge in recent years concerning the transmission of information. The processes involved in peripheral transmission have been much more amenable to study than have been the cortical processes related to the utilization and storage of information about which relatively little is known at the physiological level.

A review of such literature is relevant to our purpose in that it provides important cues concerning the nature of the nervous system as a transmitter of information and, hence, of the conditions under which information can be effectively transmitted. It also provides important information about the limitations of the system as a transmitter and suggests reasons why informational inputs often never reach the higher centers of the nervous system where they can be utilized.

One cannot draw a hard and fast line between psychological and physiological data for the two overlap. For example, the characteristics of the stimuli which impinge on the receptors are of interest both to psychologists and physiologists. Many studies of the reception of information from the environment could be equally well reported in psychological or physiological journals. In addition, the two disciplines show a healthy cross-fertilization of ideas with a resulting sharing of terms and concepts. For this reason; some of the research discussed in this chapter is not primarily the work of physiologists but covers work which would be primarily the product of psychologists. It is presented here because it has relevance to the other material discussed.

Research on the physiology of the nervous system, insofar as it is directed towards the development of an understanding of the system as a transmitter of information, has been influenced extensively by developments in electrical engineering as well as by developments in psychology. Electrical engineering has been the main branch of empirical science concerned with the design of systems for the transmission and storage of information and has developed a set of concepts useful in thinking about such systems. Shannon's well-known work at the Bell Telephone Laboratories is classic, but electrical engineers have also explored a whole range of problems related to information transmission including that of coding, decoding, compression and storage. Physiologists have freely borrowed the concepts that have been thus developed. An example is the work of Walter Rosenblith whose symposium on Sensory Communication (1961) represents an outstanding contribution to the area.

The role of psychologists has been less that of providing constructs and more that of providing information about sensory phenomena. The model of the functioning of the nervous system which the physiologist develops must be consistent with behavior as well as consistent with events at the molecular level. Psychological data forms an essential backdrop for neurophysiological model building.

Coding at the Receptor Level

An understanding of the information transmission process in the human organism requires knowledge of the ways in which the information received is coded at the receptors. Except for the chemical senses, information is received by the receptors in the form of energy changes or continuous levels of energy impact. It is well known that each receptor is constructed to be particularly sensitive to certain energy changes rather than to others, the receptors on the retina being particularly responsive to changes involving light energy, touch receptors in the skin to mild mechanical impact and so forth. All the information which the organism receives about its environment, either internal or external, comes through energy impact at the receptor level or chemical interaction in the case of smell and taste. The information reaching the receptors is changed in form there before it is transmitted to the higher centers of the brain. This change in the form of information is referred to as coding. Coding involves a change in the nature of the energy transmitting the signal as when information conveyed by light is changed at the retina to an electrochemical activity in the optic nerve. A code which transmits all of the input message is said to be reversible, that is to say, the information provided by the output message can be used to reconstruct completely the input message. The receptors do not seem to be constructed to provide a completely reversible code. Some understanding of the coding process at the receptor level is important for understanding the problems of transmitting information to the human organism.

In applying this conception of information transmission, the receptors are considered as transducers, that is to say, devices for transforming energy from one form into another form. These transducers, through this process of energy transformation, code the information received by the organism.

Many forms of energy change can be observed when a message is followed from the receptor organ to a nerve and thence to the cortex of the human brain. The energy changes involved are difficult to trace beyond the surface of the receptor. A detailed account of the transmission of the message within the organism cannot be given with the same clarity with which one can describe the transduction of telephone messages through complicated electronic amplification equipment. The reason for this is that there are technical difficulties involved in the exploration of biological transduction and the tracing of impulses involves following them through minute and intricately interwoven structures which cannot be mapped out at this time. There is also the additional complication produced by the fact that the structures are, undoubtedly, not uniform within any one species. What is known about the transduction process and the coding which it involves can be discussed at this time only in the most general terms.

The coding of information by the nervous system can be explored from two different approaches. On the one hand, the physiologist explores receptor activity and studies the relationship between information inputs and outputs of receptors, and by this means discovers what characteristics of inputs are coded by the receptor and transmitted as outputs. On the other hand, the psychologist attempts to discover what aspects of the information available to the organism can form the basis for discrimination learning and from such data he can make inferences about the coding capacity of the receptor and nervous system. For example, psychological data make it clear that the nervous system has very limited capacity for coding information related to the location of sounds, but is well equipped for coding information related to pitch. Such psychological studies provide evidence concerning the capacity of various sense modalities to transmit various kinds of information.

Physiological Information Concerning Coding at the Receptor Level

While it is common knowledge that the impact of appropriate energy, force, or chemical solution on a receptor nerve results in the transmission of a nerve impulse along an afferent fiber, the process involves much more than a simple coding of the energy impinging on the receptor into a set of nerve impulses. Several other effects appear to be involved which have considerable consequence.

First, there is some evidence that the actual sensitivity of a receptor may be reduced or inhibited by central processes. The evidence for this has been reviewed by Livingstone (1958, 1959, 1962). That central neural processes can influence the transduction of information at the receptor level is a relatively new concept having important implications for all educational processes involving the transmission of information to human receivers.

Granit (1955), for example, reports that stimulating the midbrain integumentum induced a lasting augmentation of the frequency of firing of individual ganglion cells in the retina both in the case of spontaneous firing and in the case of response to a flash illumination. The importance of such findings rests in the fact that it opens up the possibility that perceptual distortion can occur at all levels of the nervous system down to the receptor level itself.

Second, the firing of one receptor may influence the rate of firing of other receptors within the same modality. To further illustrate this phenomenon, we may cite experiments reported in a study by Hartline and Ratliff (1956). The study undertook the simultaneous measurement of the frequency of the discharge of nerve impulses from two ommatidia units enabling the exact description of their interaction. The inhibition that is exerted mutually among the receptor units in the lateral eye of Limulus was analyzed by recording oscilliographically the discharge of nerve impulses in single optic nerve fibers. The discharges from two ommatidia were recorded at the same time by connecting the bundles containing their optic fibers to separate amplifiers and recording systems. Ommatidia were chosen that were relatively close together in the eye. These were illuminated independently by separate optical systems. The frequency of the maintained discharge of impulses from each of two ommatidia illuminated steadily is lower than when each is illuminated by itself. When only two ommatidia are illuminated, the magnitude of the inhibition of each one depends only on the degree of activity of the other. The activity of each in turn, is the resultant of the direct excitation from light and the inhibition exerted on it by the other.

This appears to be an important process related to the transmission of information. It needs to be explored and the conditions of the cortex most favorable for receptor transmission need to be identified -- A statement which is undoubtedly a naive oversimplification of the problem.

A third process complicates enormously the study of sensory coding. Recently, using micro-electrode techniques, it has been shown that a part of all sensory transducers spontaneously fire, even when deprived of their usual stimulation. This can be shown, e.g., by recording optic nerve impulses from a single nerve fiber while an animal such as a cat is in complete darkness. The impulses recorded in this instance arise from some sort of instability of the receptor organs rather than from actual stimuli. Receptors fire at intervals, even when not exposed to external energy sources, and thus the response to external stimulation produces a neural discharge rate which is superimposed upon the base rate of firing. It appears that the nervous system keeps at least some of its receptor elements in readiness for firing and at such a sensitivity level that "physiological" noise is sufficient to arouse spontaneous impulses. In fact, the spontaneous firing may be a necessary and integral part of the input conditions involved in sensory perception, transduction, and transmission. This is the theory of Kuffler, et al., (1957) who maintain that the spontaneous firing is modulated by the incoming signal and is thus a necessary part of the process.

This maintained activity or spontaneous firing, has been observed in several sense organs of vertebrates and invertebrates (Tasaki and Davis, 1955). Such spontaneous discharges are of special interest in the retina because of its similarity in neuronal organization to the higher nervous centers in which continuous activity is well known. The presence of maintained activity is also related to the problem of transmission of sensory information. It implies that visual stimuli are transmitted by modulation of ever present background discharges. The occurrence of a background discharge with a random component, or "noise", is essential evidence in support of the view that sensory thresholds should be regarded as signal/noise discrimination problems.

A study by Kuffler et. al., (1957) carefully controlled experimental interference factors as the statistical properties of maintained discharge were analyzed, along with the changes in maintained impulse frequency with different levels of steady illumination and in the absence of light. The preparation involved a decerebrate cat with the III, IV, V and VI cranial nerves crushed or cut to prevent movement of eye and facial muscles. Nerve or ganglion cell potentials were recorded by microelectrodes and the nerve impulses were periodically counted via electronic counters. Continuous maintained discharges were seen in all ganglion cells during steady illumination of their receptive fields, as well as in complete darkness. Possible artifacts, such as electrode pressure, abnormal circulation, anesthetic, and several other factors were excluded as the source of the maintained discharge. Visual stimuli appear to be transmitted by modulation of the ever present background activity.

Discharge frequencies were measured following changes of retinal illumination. No consistent patterns of frequency change were found. The maintained discharge frequency may be permanently increased or decreased, or may remain practically unchanged by alterning the steady level of illumination. In addition, there were often transient frequency changes during the first five to ten minutes after changing illumination, before a final steady rate was established.

Statistical analysis of the impulse intervals of the maintained discharge showed that the firing probability at any time depends on the times of occurrence of the two preceding impulses only, and in such a way as to indicate that each impulse is followed by a transient depression of excitability that outlasts the following impulse.

A fourth process involves the mechanical analysis of data which occurs in conjunction with the activity of many receptors. This is most obviously a matter of importance in the coding of auditory information but other sense modalities show similar but less well developed mechanical coding devices. Bekesy and Rosenblith (1951) and Davis (1959) have pointed out that the cochlea acts as a mechanical acoustical analyzer in which the location of maximum mechanical movement is a function of frequency. This provides a system of space coding in which the specific location of a receptor determines the message it will transmit. Oddly enough, in the case of the ear, the intensity of the physical stimulus is not generally coded in terms of frequency of neural impulse as it is in the case of some other sensory modalities, although coding of this type occurs to a limited extent. Another method of coding intensity involves the existence of a set of receptors with graded thresholds for firing. A third mechanism for coding involves the fact that while a sound of a given pitch produces maximum activity at one particular point in the basilar membrane, it is also capable of producing lesser effects at other points.

While the relationship of the inputs of information to the basilar membrane and the coded output is extremely complex there is one type of input which bears a simple relationship to the output. When frequencies below 2,000 cycles per second impinge on the basilar membrane, volleys of impulses tend to be produced in the auditory nerve. These volleys are at the same frequency as the sound which produced them.

Psychological Approaches to Problems of Sensory Coding

The discovery of the coding system of the receptors has importance for psychologists interested in the design of information transmission systems. This problem has been of particular concern to psychologists engaged in the design of aircraft, for the pilot must be provided with a flow of information both with respect to the internal operation of the aircraft and also with respect to such matters as location, altitude, course with respect to other aircraft and so forth. The information must be supplied in a form which is easily coded by the operator. That some forms of information are more readily coded by the nervous system than are others is manifestly clear. For example, the nervous system can easily determine whether a light is on the left or the right of the operator but cannot determine with any comparable accuracy whether a sound comes from a point to the left or a point to the right. It is well established that the nervous system has much greater capacity for coding information with respect to location of source in the case of vision than in the case of sound. Most of the available knowledge concerning the dimensions in terms of which messages can be coded is derived from the study of the auditory and visual modalities, though in recent times, interest has been shown in exploring the modality of touch. Since our interest in this review is mainly in the modalities of vision and hearing, the discussion will be limited to these modalities.

Henneman and Long (1954) have compared the processes of coding involved in audition and vision. They point out that there are six useful dimensions for coding in the case of vision which provide some accuracy: the two spatial coordinates, and intensity, wave length, time, and depth. Auditory coding, for all practical purposes involves only three dimensions of coding, namely, intensity, frequency, and time. A fourth dimension of auditory localization is so inefficient that it is hardly worth adding as a means of transmitting information in a civilized culture though it may have been the carrier of information with survival value in more primitive times. The greater number of available dimensions for coding probably makes vision the preferred channel of communication in so many situations. The mere number of available coding dimensions may not be the only factor operating in the preference commonly shown for visual presentations. Another factor may be that the whole technology for presenting visual information is much better developed and has had a longer history than the technology of audio presentation which had to await the electronic age for it to move much beyond the use of the human voice. Henneman and Long imply that much needs to be done to develop audio techniques for transmitting information and that prejudice in favor of the visual may be to some extent a product of an inadequate technology.

Learning may involve either the ability to make absolute judgments or relative judgments. Man is generally much better at making relative judgments and many learning situations are designed to take advantage of this fact. Thus a medical book shows side-by-side illustrations of healthy and malignant cells and a book for antiquarians shows pictures of both genuine antiques and fine reproductions of them. The ability to make discriminations along any one coded dimension depends upon the number of just-noticeable-difference units that are contained in the dimension. The evidence appears to indicate that the number of such units in the codeable dimensions discussed here is much larger than most learning tasks are likely to require. In other words, the coding system has all the capacity needed for handling situations that man is likely to encounter.

While the conclusion may be drawn that in the case of vision most of the dimensions by which information is coded have been fully exploited, the hearing channel appears to have a much greater capacity for transmitting information than communication techniques imply it to have and an advanced technology could well improve vastly the use of auditory dimensions for the transmission of information. For example, there is the possible improved use of auditory cues in learning many motor tasks. In learning to use a rifle, the marksman might well be warned by the sound of a tone that he was off target and the amount off target could be indicated by the loudness of the tone. Ordinary speeds of speech probably grossly underuse the channel and coding capacity of the human ear, and yet almost nothing is known about the capacity of humans to learn to use much higher speeds of verbal information transmission. While coding dimensions place a limitation on what can be transmitted, the human typically operates far within that limit.

Signal-Noise and Signal-Signal Separation

The familiar psychological phenomenon of perceptual processes separating the input into figure and ground, -- a phenomenon discussed in every textbook on perception, -- is discussed by physiological psychologists and engineers alike as a process of separating signal from noise. Sometimes the same problem is discussed in terms of separating one source of signals from another source of signals. The second problem is generally a much more significant one than the first. Noise is defined as a randomly occurring event. Noise in the case of auditory phenomena may be events of a single frequency occurring randomly or a set of random noises distributed over a particular range of frequencies. When the events are distributed over the entire range of audible frequencies the term "white noise" is generally applied. The concept of visual noise is less familiar to those concerned with audiovisual education. It refers again to random events consisting of light which may be within a narrow frequency range or cover a wide band. A television picture which is disturbed by white flecks is an example of a noisy visual display. In terms of the definition given here, most visual displays are not noisy but rather are they jammed with large numbers of different sources of information. The problem of the human receiver is to separate these sources of information and to attend to that which has relevance for behavior. Such a separation is obviously of vital importance in the case of vision since the input is rarely restricted to those visual phenomena about which information is to be transmitted. Consider, for example, a typical sound movie used for educational purposes. The sound is likely to be limited to a single voice transmitting relevant information; on the other hand, the visual display is very rarely limited to the relevant information at hand. If, in the movie, a scientist is demonstrating an effect, the chances are that the scientist and the laboratory will appear in the picture in addition to the effect. In such a case, the image of the scientist and the laboratory represent irrelevant sources of visual information and the effect being demonstrated represents the relevant source. The observer of the movie must discriminate and separate relevant sources from irrelevant sources. Since irrelevant sources are the overwhelmingly large part of the input of data, it is remarkable that such a separation is possible. Without such a separation, the nervous system would be flooded with irrelevant data.

There are, of course, many situations in which a similar problem exists in the auditory modality. What has been termed the "cocktail party problem" -- the separation of a voice and the message it is communicating from several simultaneous voices -- is also a problem of separating signal from signal, though the problem in this case and the mechanics involved is much better understood than it is in the case of visual presentations.

There are, of course, obvious factors which facilitate or interfere with the separation. It is easy to attend to the louder of two voices if the contrast is great, but it is not as easy to attend to the least loud. For similar reasons a whisper is difficult to separate if it is against a loud noisy background. There is not too much difficulty in accounting for the fact that a loud signal can be separated from a background of considerably less intense noise. Much more difficult to account for is the common situation in which several different voices are all making communications within close range of one another and in which a receiver is able to listen to and receive the message from only one source.

That different voices can be listened to even when there are many different persons speaking is a well known fact. Such a situation can be described as one in which there are many external channels of communication operating, each one of which is providing a high level of traffic, but a selection is made of the source to be attended to. Broadbent (1962) suggests that one basis on which voices can be discriminated even when only a phoneme is involved is the frequency with which the voices are modulated. Two distinct voices, modulated at different frequencies, will produce a response in different regions of the basilar membrane. In such a case, the two voices would be transmitted by distinct bundles of nerve fibers. However, as the modulating frequencies approach one another there will be an increasing overlap in the fibers in the basilar membrane which are involved and increasing difficulty is experienced in discriminating the one message from the other.

Despite the fact that two messages transmitted simultaneously by the same voice (as can be done when the two messages are superimposed on a tape) sound like a babel, the persevering listener can, by exercising effort, often discriminate and unscramble the two messages. The task does not seem to involve a peripheral mechanism, but rather is it an unscrambling undertaken centrally in the nervous system.

Cherry and Sayers (1956) and Sayers and Cherry (1957) provide some evidence that some of the information needed for signal separation comes from a combination of the time difference with which the signal reaches the two ears. Two signals, a wanted and an unwanted signal, are best separated by the receiver when the signals reaching the two ears arrive with the greatest time separation. The data collected by these investigators fits the observation that persons deaf in one ear have much greater difficulty in separating two sources of verbal communication than persons with binaural hearing. The mechanism appears to be similar to that which communication engineers refer to as cross correlation. However, not all of the process of signal separation occurs through the mechanism involving time differences for other important factors play a part. Cherry (1953), Cherry and Taylor (1954) and Cherry and Bowles (1960) have shown that message separation is also highly dependent upon transitional probabilities from word to word of the message. Two messages consisting of meaningless strings of words are very hard to separate, but messages that have coherence can generally be separated with the one message being fully understood and the other not recognized. The separation is, then, dependent upon knowledge previously acquired about transitional probabilities in the language in which the overlapping signals occur. One suspects that on this account young children might have much greater difficulty in separating auditory communications than would adults who have had vastly greater experience on which transitional probabilities might be based. A third mechanism suggested by Broadbent (1962) is related to the fact that speakers differ in the basic frequency which is modulated by enunciation processes. He suggests that voices and their messages can be separated through a capacity of the ear to identify basic modulation frequencies and to separate the messages which they carry from voices involving different modulation frequencies.

The mechanisms involved in the separation of signal from signal and signal from noise work sufficiently well in most human receivers that few teachers even recognize that the separation process could possibly produce problems. There are some striking cases where difficulties related to such separation play a part. For example, the typical brain damage syndrome in a child is commonly manifested by a high degree of distractability. Such a child seems unable to continue for long to receive a communication from one source. One solution to his learning problem is to limit the number of sources by having the child alone in a simple and quiet but rather drab room. Such a limitation of signal sources appears to improve the learning of such children.

Much less is known about the process involved in the signal-signal and signal-noise separation in the case of vision than in the case of hearing. In the case of vision, the process of lateral inhibition appears to provide some data reduction even at the level of the retina which may well give particular emphasis to boundaries. The directional nature of vision and the high information carrying capacity of the fovea also provides a means whereby information may be obtained from certain selected aspects of the environment to the partial exclusion of others. This does not indicate the kind of information that is used in the separation of one visual source of information from another. The cues which permit the separation of visual signal sources have not yet been identified. In addition, nothing is known about any learning that may be involved. It may well be that young children in the lower elementary grades may have more difficulty in signal-signal separation than older children which suggests that there may be advantages in providing them with a visually simpler environment. The trend in education has, of course, been the reverse. The tendency has been to fill classrooms with numerous visual sources of information as if the presence of these sources necessarily added to the informational intake. Much the same has been true in visual presentations by means of films. Displays on any particular frame of the film tend to be very complex. It is a rare producer that eliminates all but the essential visual features necessary for transmitting the information that is to be transmitted.

Information Capacity of the Sense Organs and Their Immediate Afferent Nerves

The information capacity of the sense organs is a matter of interest to those designing teaching devices. For those not familiar with the basic concepts of information theory, an appendix provides essential information for reading those sections of the report which involve the measurement of information. It is important at this point to make a distinction familiar to engineers (see Bell, 1956) between the information capacity of the sense channel, which is usually measured in binary digits per second and the information content of the signals transmitted. Consider, for example, a parallel problem in the transmission of television signals. A television channel has a capacity for transmitting information at about 5.7×10^6 bits per second, but the signal it transmits may carry only a very small amount of information as when the station identification is broadcast at times when the station is not operating. The mere fact that one sensory channel has a much larger capacity for handling information than another channel does not mean that it transmits more information.

Most of the knowledge available concerning the information handling capacity of the sense organs is derived from the study of the eye and the ear. Since these modalities are of primary importance for information transmissions in schools, a brief review of the capacities of these sense organs and the immediate afferent nerves which lead from them is appropriate.

Information capacity of the retina and optic nerve. The information handling capacity of the eye is directly related to the problem of visual acuity which is normally measured by determining the discriminations which the eye can make. For example, when the Landolt ring is used for the measurement of acuity, the task of the subject is to determine the presence or the absence of a cut (in the form of a small blank square) in the ring. The information transmitted by the retina can be measured in terms of the bits of information transmitted about the ring. The total visual pattern can be considered as a grid of such acuity squares, either black or white. Jacobson (1951a) utilizing data from a number of sources concludes that the retina functions as an information transmitting device as though it consisted of a grid of 240,000 such squares. He infers further that the number of stimuli within each square of the grid that can be discriminated per second is 18. From this he concludes that the information capacity of the eye is 18 x 240,000 bits per second which amounts to 4.32×10^6 bits per second. The argument involves many assumptions which cannot be explored or even stated here, but it may be said that the estimate is probably on the conservative side. An example of a simplifying assumption used by Jacobson is that the transmission is achromatic. Color adds a coding dimension which, in turn, might contribute to the information capacity of the visual channel as he has estimated it.

Information capacity of the ear. Jacobson (1950, 1951b) has also attempted to provide data which compares the information capacity of the eye and ear. The possible combinations of frequency and intensity of tones which lie within the range that the ear can perceive indicates that the ear could transmit up to 10,000 bits per second. The latter figure is a rough estimate and, as in the case of estimating the information transmitting capacity of the retina and optic nerve, involves a number of assumptions which cannot be fully justified.

Comparison of information carrying capacity of eye and ear. If the estimates of Jacobson can be considered to represent the general order of the information carrying capacity of the two sense modalities then, in theory, the eye may carry 430 times as much information per unit of time as the ear. A part of this difference is to be accounted for by the fact that the optic nerve has about 900,000 fibers while the auditory nerve as it leaves the cochlea has only about 30,000. In addition, Jacobson suggests that each optic fiber may carry about 5 bits of information per second while the auditory nerve fibers are limited to about 0.3 bits per second. This comparison of the two sets of fibers may, on the surface appear to account for differences in the information capacity of the two modalities but it is based upon the assumption that both nerve tracts use a binary coding system although the fact is that the auditory tract does not. The two tracts differ in the extent to which fibers function independently one from the other, the optic nerve fibers showing the greater independence.

The data which have been discussed here do not lead to the conclusion that a greater quantity of useful information can be supplied through the human eye than the human ear. It is quite conceivable that the transmission of the same verbal communication by written and spoken words may involve a much larger information capacity when it is transmitted by the eye than by the ear. One can easily understand how the image of a table requires a greater channel capacity than the word "table" for effective transmission. What is much more important is the fact that the brain is capable of utilizing at the highest levels less than one percent of the information provided by the ear and perhaps only one part in 250,000 for the eye. An understanding of what aspects of the information are utilized and how the messages communicated become compressed is of importance to the problem of designing messages in such a way that the nervous system will retain the essential information and discard the irrelevant.

Capacity of the utilization system. The distinction has already been made between the information capacity of the channel and the amount of information communicated. In the case of both the auditory and the visual channels, the amount of information which is utilized by the higher centers is vastly less than the information capacity of the channels involved. Jacobson (1951b) suggests, for example, that if a person were to receive speech at the high rate of 300 words per minute, and if both the speaker and receiver were equipped with a vocabulary of 150,000 words, then the transmission rate would be estimated to be about 90 bits of information per second. Since the redundancy of spoken English is fairly high, the transmission rate of information might be estimated at around 50 bits per second. This would require only one half of one per cent of the channel capacity of the system. If the entire redundant message were transmitted, then it would utilize only about one per cent of the capacity of the system. Jacobson makes another computation which suggests that the information transmitted by a piece of music is at the rate of about 70 bits per second. If such speech and musical transmissions represent a transmission of the maximum amount of information which the brain can utilize, then one must conclude that the brain is capable of using somewhat less than one per cent of the information that the auditory mechanism is capable of transmitting.

Miller (1956) has studied what he refers to as channel capacity for immediate memory. Miller's concept of channel capacity is not entirely clear for the concept of channel capacity ordinarily involves a time element and would be measured in terms of bits per second. The Miller paper deals only with a unit of bits, or perhaps one should say bits per transmission for he is concerned with the amount of information which can be transmitted for storage in immediate memory. The conclusion drawn in the paper under consideration is that for inputs involving absolute judgments, the channel capacity is about 2.5 bits for undimensional conditions but that some increase in capacity is apparent as the number of coded dimensions involved is increased. With six coded dimensions for the transmission of information subjects were able to utilize about 7.2 bits of information. For typical experiments on the span for immediate memory, the results of studies are somewhat ambiguous for, by recoding the information, the channel capacity can be very much increased. For example, a person may retain as many as 40 bits of binary information if the information is recoded into a decimal system. Miller points out that to remember a series of digits such as 1 0 1 0 0 0 1 0 0 1 1 1 0 1 1 1 0 would be a very difficult task. However, if the series were considered to represent a series of decimal numbers represented in a binary form then the problem becomes relatively easy. The first five of the binary digits can be represented by the decimal number 20, the second five by the number 9, the third five by 25, and the last by 6. The four numbers 20, 9, 25 and 6 can be remembered quite easily. Miller goes on to point out that the use of mnemonic devices for memorizing complex arrays of information is another illustration of the use of recoding in order to facilitate the retention of information. Additional evidence to support the Miller hypothesis has been provided by Cohen (1963) in an experimental study.

Such recoding is effective partly because it increases the amount of information carried by each item and partly because it converts information into a form through which the brain can readily handle and easily retain verbal information. It is for this reason that if one is shown a picture of the chancel of a church, one can retain the essential features of the visual display by saying to oneself, "This is Gothic architecture with fan vaulting." If the latter verbal information is retained much will be remembered about the architectural features of the church. On the other hand, if the picture is presented without the coding of the information in verbal terms, the observer may be able to retain only the very crude features of the display such as that the design involved arches. The coding of the visual display into such terms as <u>Gothic</u> and <u>fan vaulting</u> permits a reconstruction of the visual display on a future occasion.

An important relationship between the audio and the video in learning situations may be for the audio to provide a coding of the visual information. The suggestion is not that this is the only relationship between the audio and video displays but it is one important relationship.

Miller (1956) proposes that the number of "chunks" of information that can be carried when recoded is equal to the number of bits of information that can be carried prior to recoding. He suggests that recoding is a very important device used to overcome problems of channel capacity. He also points out that language represents one of the most important means of recoding information to save channel or storage capacity.

While Miller never gets to the point of discussing channel capacity in terms of bits per second, the inputs which he discusses and which lead to some kind of judgment generally involve the organism for at least a second or longer. <u>One must assume that the channel capacity is ordinarily less than</u>

that estimated by Jacobson (1951a, 1951b) -- perhaps less than a tenth of the figures which he gives. If this is the case, then the information used is probably less than one tenth of one per cent of channel capacity of the sensory input. One presumes that the information provided by the nerves leading from the sense organs is in some way scanned and that, somehow, a small portion is retained for utilization.

Coding and Compression in the Afferent System

Previous sections have already pointed out that coding occurs at the receptor system, that it is complicated, and that there is no uniform coding system across all modalities. For example, the eye uses a modified binary coding system, but the transmission of information through the ear involves a code remote from that which could be considered a binary system. Beyond the level of the receptor and throughout the entire afferent system the transfer of information involves not only additional coding but also what is referred to as the compression of information. The term compression refers to those processes in the nervous system which result in the reduction of information as well as the reduction of redundancy. Two additional processes also play a role. One of these is inhibition which can operate at all levels of the nervous system and which can result in the blocking of neural impulses at particular relay points. The other is the selection of information for further use, for it is quite clear that only a small fraction of the information entering the nervous system is either used or stored. First let us give some attention to the problem of the reduction of redundancy. A major mechanism involved in this is lateral inhibition which functions at all levels of the nervous system.

Compression of information. Just as information at the receptor itself feeds into an active system and what is transmitted beyond the receptor point is partially dependent upon the activity of the system, so too do the nerve impulses leaving the receptor enter a system which is active and which is influenced by events in other parts of it. For example, Ratliff and Miller (1958) report a study which suggests that the optic nerve does not consist of a series of "private lines" which transmit with perfect fidelity information about the distribution of radiant energy falling on the receptor mosaic. The pattern of activity in the optic nerve is not a direct copy of the pattern of radiant energy striking the retina. Excitatory and inhibitory processes appear to be operating even at this level. One of the most important of these processes is that of lateral inhibition.

The process of lateral inhibition of nerve fibers appears to take place at all levels of the nervous system. Brooks (1959) in reviewing the evidence on contrast and stability points out that inhibition of neurons by their neighbors occurs quite generally in projection systems. Hartline and Ratliff (1958) have investigated the function of inhibition in the transmission and filtering of information reaching the visual cortex and have concluded that two inhibition processes are at work. One process is the reciprocal inhibition of antagonistic neurons in the same area. The other is the lateral inhibition of synergistic neurons in adjacent regions.

There is some agreement among writers concerning the function of lateral inhibition in the handling of information. In the case of the visual transmission system, the total effect would be that of producing greater contrast between different aspects of the same input. The total effect of the process would be to reduce the redundancy in visual information so that the final impression recorded at the occipital cortex becomes more like that of a line drawing than a half tone.

At this point, information collected by Hubel (1963) is particularly pertinent. Hubel has been concerned with the transmission of visual information all the way from the retina to the cortex. In some of his work anesthetized animals have had their retinas stimulated and activity at the cortex and at the main relay point, the lateral geniculate body, have been studied. What he finds is that the cortex is particularly effective for recording visual stimuli which he describes as "slits, edges, or bars" (p.8), and that particular cells are sensitive to those slits, edges, or bars, which have particular slopes. The picture of visual information transmission and storage which derives from the work of Hubel is that of a system which reduces visual information to a representation similar to that of a line drawing and which probably stores information in that general form.

Attempts have been made to simulate this compressed process by photographic techniques of which Barlow (1961b) has provided an interesting example. In the Barlow illustration a photograph is presented of two men facing the camera and standing against a background of a building. In the processed photo which simulates the result of lateral inhibition all edges and lines of contrast are enormously accentuated so that the product resembles more a line drawing than it does a half tone. In this specially processed picture most of what would ordinarily be considered to be the essential information has been retained but minor details and redundant information have vanished. Both of the persons in the picture are clearly recognizable and so too is the style of architecture, but textural details have gone. The position that such a process may well operate is perhaps very indirectly supported by the fact that visual information can be effectively transmitted by means of line drawing. Indeed, the cartoon and the diagram are often considered to be preferred ways of transmitting certain kinds of information and perhaps they owe their efficacy not only to the fact that they eliminate both redundant and irrelevant information, but it may well be that they are presenting information in a form similar to that in which less carefully prepared information is simplified by the nervous system. This is also a problem about which some information is being acquired by electrical engineers. For example, Cherry (1962) reports an electronic procedure for separating signal from noise in the transmission of pictures by television which also results in compression. The procedure depends on the detection of picture edges and boundaries. The result of such compression resembles rather closely a line drawing in which little appears to remain except dark lines representing the detail of the picture. Such detail functions resemble the crude drawing of children which tempts one to reach the conclusion that compressed visual data of this character is stored in the nervous system and is capable of being reproduced in the drawings of children. Storage is, presumably, in some form isomorphic with the line drawing produced. At least, data are stored in the nervous system in a form which permits the generation of a line drawing, and which permits a line drawing to be more easily generated than a half tone.

Now, returning to the Cherry report, another particularly important finding must be pointed out. That finding is that the compressed drawing which emphasizes boundaries can be electronically reconstituted into a half tone representation and the representation does not differ too much from the original from which it was derived. While the reconstituted picture has been compressed in the ratio of 2/1 from the original picture. the effect is not marked because the detail detection process and the reconstitution of the half tone has the effect of filtering out visual noise.

The point which is being made here is that information can be stored in a highly compressed form and yet it can be restored to a form closely resembling the original provided that the mechanism involved is programmed to handle the data according to an appropriate set of rules. The nervous system has apparently great capacity for doing this kind of thing as is witnessed by the fact that an artist can take a simple line drawing representing a particular human face, and from it he can paint a portrait which includes a wealth of detail. The process, of course, has limitations, as is evident from the fact that a portrait artist never relies completely upon memory but demands a series of sittings. In other words, in the case of the artist, the process of coding-compressing-storing-reconstituting-reproducing results in some loss.

One presumes that lateral inhibition is not the only mechanism that results in the reduction in the redundancy. What these other mechanisms are remains a matter of speculation. Barlow (1961a) has considered this matter at considerable length but is obviously handicapped by a lack of data. While one can trace the impulses produced by a single tone throughout the afferent system from auditory receptor to the cortex, such research provides little information concerning the more elaborate problem of how complex inputs are simplified. Barlow (1961) presents a number of hypotheses concerning the compression of data, one of which is that the relay of information at each nucleus involves further compression. Barlow (1959) has also shown that a recoding process could occur at each sensory relay point which, he considers, would be a redundancy reducing code. In order to do this the relay systems would have to store information concerning the frequency of occurrence of each combination of messages arriving at the relay point. Whether such storage of information within nuclei is possible, is not known. A rather baffling problem is presented by the fact that although the sensory relays may be hypothesized to produce a reduction of redundancy, they feed into a larger number and not a smaller number of nerve fibers. The anatomical plan of the nervous system is such that afferent tracts include more fibers rather than fewer fibers as they approach the higher levels of the nervous system. Presumably, this proliferation of fibers permits the wide diffusion of sensory information, a process which is virtually the opposite of the compression of information.

Much less obscure are phenomena related to the inhibitory effects operating at relay points. These inhibitory effects involve processes other than the compression of information and the recoding of information.

Inhibition at the afferent relay points. During the last decade considerable interest has focussed on the inhibitory mechanisms which operate at the various afferent relay points. At least two kinds of phenomena occur. Particular interest became focussed on such phenomena with the discovery by Hernandez-Peon et al. (1956) that electric activity in the cochlear nucleus was influenced by inputs through other senses. In the latter study stainless steel electrodes were permanently implanted in the cochlear nucleus of a cat. This nucleus is the first relay point of the auditory nerve. After the animal had recovered from the operation, short bursts of rectangular sound waves were produced by a loudspeaker near the cat's ear yielding a click-like sound. The clicks resulted in the transmission of neural impulses down the auditory nerve which the investigators could pick up through the electrodes embedded in the cochlear nucleus. Up to this point there was nothing particularly novel about the procedure. However, the next step produced dramatic results. While the cat was being exposed to the periodic clicks, a number of highly significant stimuli for the cat were introduced one at a time. The stimuli involved (1) two mice in a closed bottle, 2) fish odors delivered through a tube, and (3) an electric shock delivered to the paw. When any one of these stimuli were introduced, a depression in the activity in the cochlear nucleus occurred. The discoverers of the phenomenon stated that they believed that they had demonstrated that central inhibitory mechanisms may play an important role in the "selective exclusion" (p. 332) of sensory information from the midbrain and higher centers.

In a later study, Hernandez-Peon et al. (1957) demonstrated a similar inhibitory effect in the optic afferent tract when the intact cat was described as "attending" to the auditory stimuli. Hernandez-Peon (1961) and his associates have reproduced the same inhibitory phenomenon also with other sensory tracts and conclude that it is a very general one. The problem has been further explored by Galambos et al. (1956) who have demonstrated that electrical stimulation of the floor of the medulla of a cat will produce a supression of auditory transmission at the level of the cochlea nucleus. The shock has to be applied at the site of the decussation of the olive-cochlear pathway for it to be effective in producing the inhibitory phenomenon.

Inhibitory and facilitative processes occur at all levels of the nervous system. Hubel et al. (1959) have reported that certain cells in the auditory cortex of cats respond only when the cat is attending to the source of the auditory stimuli. Thus it appears that the activity of the cortex is selective in relation to stimuli. Such a process would also serve the purpose of conserving the limited capacity of the cortical system to deal with those informational inputs which had the highest relevance for behavior.

One must presume that the blocking at the sensory relay points is not complete and that the signal passes in an attenuated form. Certain signals which have high value for organisms penetrate even when no attention is being paid to the sense modality through which the signal comes. A person will hear his own name even when engrossed in an activity demanding the closest attention to visual stimuli though he may not "hear" conversation going on in the same room. The Hernandez-Peon data could not really indicate the extent to which information is transmitted in an attenuated form for the recordings of activity at the level of the auditory ganglion are made against a background of high electrical noise. In the records the signal level is a little above the noise level and the noise level could well cover up the transmission of an attenuated signal.

The data on inhibition at the relay points, as well as psychological observations, suggest that the nervous system has a capability of utilizing data from only one sense modality at a time but that the data from the other modalities reaches the higher centers of the nervous system in an attenuated form. The latter information, which must surely be highly compressed, would have to be monitored so that when a signal highly relevant to the organism occurs, the inhibitions on its channel of origin are released so that the information becomes fully available. This would imply that the inhibition occurring at the relay points is selective and that the information which passes is, perhaps, to some extent already filtered for relevance.

Habituation at the Afferent Relay Points

A second well established inhibition phenomenon is that of habituation. At the behavioral level this is a familiar phenomenon illustrated by the introduction of a loudly ticking clock into a room which a person may find, at first, to be quite disturbing. Soon he habituates to the noise and becomes unaware of its occurrence. Physiologists have been able to begin exploring the neural basis of such habituation. Hernandez-Peon and Scherrer (1955) have been able to demonstrate habituation at the physiological level. The essential feature of their technique was to demonstrate that as a sound was repeated in the ear of the cat that the response in the cochlea nucleus became less and less marked. Here again, as in their studies of inhibition, the high level of noise in the record makes it difficult to determine whether the auditory signal is completely or only partially supressed. Hernandez-Peon (1961) cites a substantial research literature to support the position that this phenomenon is a very general one and characteristic of the transmission of monotonous inputs regardless of modality.

In the case of the phenomenon of habituation, the interpretation of the data involve the same problems as are involved in the case of inhibition at the same relay points. Even after habituation has occurred to a maximum extent there must surely still be an attenuated signal which passes through and reaches at least the midbrain if not the cortex. If this were not so, it would be quite impossible to account for such phenomena as a person noticing when a clock stops ticking, even though he has become completely habituated to the ticking. One becomes aware of signals to which one has become habituated once they are cut off, a fact which implies that the signals are being recorded at a fairly high level of the nervous system.

Interactions of Sensory Inputs as Studied by Psychologists

The effect of providing a stimulus to one sensory modality while another is engaged in the performance of a task is a matter which has long been of interest to psychologists. A particularly practical problem in this area is the effect of noise on visual discrimination tasks, a problem which has long been the subject of investigation by British psychologists. The meagre results produced by the latter research were perhaps the result of defining a problem of great interest with respect to the functioning of the nervous system in terms of the practical problem of the effect of noise on performance at certain industrial tasks. The broad problem of which the latter is a part is that of the effect of one sensory input on other inputs. One aspect of this problem, namely, the effect of the activity of a particular visual receptor on the functioning of other visual receptors has already been touched upon. In this section we will turn to the interaction where the receptors involve different sensory modalities.

The problem here considered is the modification of the input through one sense organ when another is stimulated. The latter input will be referred to here as the accessory stimulus, following the practice initiated by London (1954) in an article summarizing the Russian research in the area.

London points out that sensory interaction is an area of inquiry in which Russian research workers have shown a concentrated and long-term interest. The research which they have undertaken on such problems lacks many of the refinements of planning and design which are typical of American psychological research; nevertheless, the research is so extensive, covering as it does several hundred bibliographical entries that it cannot be disregarded, particularly insofar as it reflects a consistent trend in the findings.

The Russian research has been vast in its scope and covers such obscure topics as the effect of specific odors on visual acuity. London reports such confusing findings as an increase in the level of peripheral visual sensitivity as a result of sniffing spirits of hartshorn, but that some odors when they produce a strong negative reaction may produce the reverse effect. The Russian research has even explored such oddities as the effect of sensations due to bladder distension on the sensitivity of various peripheral sense organs.

Two main conclusions can be drawn from the data. First, the evidence indicates that all modalities undergo modification in sensitivity as a result of the stimulation of other modalities. Second, accessory stimuli may either facilitate or inhibit the main transmission of information.

The inhibitory or facilitative effect of accessory stimuli seems to be mediated through the reticular formation on which all sensory inputs converge and which also receives inputs from the cortical areas.

Unfortunately, much more is known about the inhibitory effects of accessory stimuli than about facilitation phenomena. Certainly accessory stimuli have indirect effects on perception through the fact that they also influence activity in the reticular formation. Presumably, even when sensory inputs from a particular modality are being inhibited, the sensory inputs still reach the reticular formation and higher centers, but in an attenuated form. Such inputs to the reticular system may be expected to have the result of raising the level of arousal, in addition to any effect that they may exert on other senses.

The psychological research which has been undertaken on sensory interaction is quite consistent with the data which the physiologists have derived from the direct study of the nervous system through the use of implants. The main difference is that the psychologists claim to have discovered some facilitation phenomena operating through sensory interaction, but physiological research has not at this time demonstrated any such phenomena, except perhaps for the case of summation phenomena.

The main implication of research on accessory stimulation for the design of audiovisual aids is a word of caution. Inputs appear to interact in many ways and with pronounced effects. Thus noninformational inputs to one sense may influence the reception and processing of informational inputs through another modality.

Storage of Information

While the topics of coding and storage are intimately related, much is known about the coding of very simple inputs but less is known about storage.

It seems clear from what we know of the nervous system that information in a highly compressed form reaches those areas of the nervous system in which most of the storage takes place. Of course, storage may occur at many levels, but most storage probably takes place in the cerebral hemispheres. The coded and compressed information reaching the cortex is probably widely distributed through a system which provides a high degree of redundancy. Storage could conceivably be localized and nonredundant or involve a diffuse system involving considerable redundancy. The latter system is consistent with evidence from the effects of brain injury which generally show that, in the case of the adult, injury to specific parts of the cortex does not result in the loss of specific information or skill, though injury to Broca's area is one of the notable exceptions to this rule. The memory model provided by the computer in which each piece of information is stored in a particular location does not provide a good model of human memory. Computers are engineer designed and, among other considerations, cost forces the elimination of redundant storage. Biological mechanisms, on the other hand, have very often had survival value because they provided redundancy of function. A familiar example of this is the existence of two kidneys, when a single kidney is more than sufficient to perform the necessary work. Perhaps one of the major difficulties in understanding the functioning of the nervous system has been the fact that it does not follow the kind of design principles used by humans in the construction of mechanisms.

A second important point to note is that the mere reception of sensory data does not generally result in effective storage. The old adage that learning has to be undertaken by doing is a statement of the fact that unless the incoming information is used in some way it is not likely to be stored. This fact has very important implications for audiovisual education. If storage occurs mainly in relation to activity, then the passive viewing of a movie is very unlikely to result in the retention of much information.

Looking back over the history of psychology one can see two different theories of retention. The classical theory of retention seen in the works of nineteenth century writers is that retention involves a weak representation of the original experiences which make it possible to conjure up images and to re-experience a ghostly representation of the original experience. Such storage involves a set of impressions of the inputs, very much after the analogy used by John Locke when he stated that sensations leave their impression on the tabula rasa which represents the mind. A long debate followed the establishment of this model by Locke concerning the extent to which retention was in terms of specific sensory impressions or whether the mind was capable of storing general ideas. The strong position taken by Bishop Berkeley that only specific sensory impressions were retained had a long influence on introspective psychology and did much to consolidate the position that storage was in terms of sensory impressions. That retention is of the inputs themselves was an attractive concept that lead to the study of retention in terms of imagery. Indeed, such a concept of retention was as obvious and evidently true to the nineteenth century psychologist as the concept of a flat earth had been true to the sixteenth century theologian.

Few of the early discussions of retention refer to it in relation to function. Much of the nineteenth century discussion of the problem was closely tied to a discussion of imagery, as if the function of retention were to provide a basis for the reinstatement of experience through imagery. Retention was measured, if it were measured at all, in terms of the subject's capacity to reproduce the material to which he had been exposed. Such was the procedure of Ebbinghaus who exposed subjects to nonsense syllables and then determined the number that they could reproduce correctly. Thus, the theory of the storage of information remained for more than two centuries.

The next major development in a theory of retention came with the publication in 1920 of an important paper by Henry Head, an English neurologist and physician, who devoted much of his life to the study of aphasia. Head pointed out, as Hume had almost two centuries earlier, that impressions received through the sense organs are surely not stored one by one but are consolidated and organized. Storage is not of a set of independent traces but of a combination of these impressions which Head referred to as a schema. Head was particularly interested in those schema that represented the individual's own body image. Schema are not only in a continuous process of modification by new incoming impressions but they also modify all sense data and provide a basis for its interpretation. Head was the first to point out that inputs are coded chronologically. One can recall that event A happened before event B and this information must be in some way coded in the nervous system.

The concept of a schema developed by Head was later picked up by Bartlett (1932) who made it known to psychologists, and popularized it in psychological literature. While it still remained a fuzzy concept at the perceptual and sensory input end, Bartlett also tied it in closely with a response component. Schema, for him, modified both the interpretation of sensory data and also responses. His position is confused by the fact that he maintains that (p. 201) schema are both organizations of "past reactions" and of "past experiences." Whether the organizations of "past reactions" are organizations of the kinesthetic and other experiences that accompany reactions or something more akin to habit hierarchies is not clear.

The work of Head, despite its popularization by Bartlett, had little impact or research although much work of an empirical nature was undertaken during the same period. The extensive nature of research undertaken during the period is shown by the fact that three reviews of empirical findings of this period cover several hundred references. Robinson (1924), McGeogh (1928) and McGoegh (1930) all reviewed research on memory, but only the last of these included a section on theories of retention. Much of this research was undertaken in the Ebbinghaus tradition and represented a follow-up of his work.

In the last few years a new trend is apparent in the approach taken to problems of retention largely through the influence of persons outside of the field of psychology who have become interested in problems of the storage of information and the various mechanical and electronic models that might be used for that purpose. The first point to note in this approach is that the basic requirement of a storage system is that it permits the storage of some kind of representation or model of the information stored. Now what is stored may not be a close representation of the information transmitted to it. For example, a computer may have the capacity of producing the logarithm of any number to any base, but to do this it will not have to have stored the logarithms of all numbers to all bases for this would be an impossible requirement. What is stored in the computer for this purpose is a subroutine which permits the calculation of any number to any base. The latter is a much more economical system of storage than the storage of tables of logarithms. What is stored may be only very indirectly related to the inputs and the outputs.

In the case of the storage of information in human receivers, the information stored must be a model of those aspects of the environment which have relevance for the behavior of the individual. The inputs are represented by information about the environment and the outputs by responses and, somewhere along the line, aspects of the environment must have representation in a form which permits them to influence responses.

A major function of the higher centers of the nervous system is to store a model of the external environment which can function as a guide to behavior. The information provided by this model is coded and compressed, though probably involving certain kinds of redundancy. The latter statements do not imply that the internal representation physically resembles the external world. The model of the environment which comes to be built into the nervous system has no more direct resemblance to the physical world than does a page of print describing a foreign city resemble the city. The internal model, as we have said, is closely tied to action systems and is not simply a perceptual model.

The internally stored model permits the organism to cope with the environment with a minimum input of information. In the case of a very well developed internal model of the environment only very small inputs of information are necessary in order to cope with the environment. Consider an extreme example: A man who has less than five per cent of his vision remaining and who is legally blind, may still find his way around the house and neighborhood with almost the same facility and skill as a fully sighted man.

He will also locomote with vastly greater skill than a man who does not have his small amount of vision. What this means is that he is able to construct his relationship to his environment at any time by utilizing both the cues coming through his limited visual channel and the internal much more detailed model. The same partially blind man will also be able to negotiate his way around new environments if they are similar to those with which he is familiar, but not with the same degree of skill. The same internal model of his neighborhood may help him find his way around a new town for certain elements such as street corners, gutters, sidewalks provide familiar cues, but such an individual easily becomes disoriented and unable to cope with the problems of locomotion if placed in a drastically different environment. As a matter of fact, many persons who have enough vision to move easily around their neighborhood are unable to cope with the problem of locomotion in the downtown area. What this means is that the internal model of their known environment does not provide an adequate basis for locomation in other environments.

While we have taken as our illustration the partially sighted man, the fully sighted individual is, in many respects, in not too different a position in matters of locomotion. The ordinary fully sighted man still has a very limited capacity for obtaining information about the world around him, and the information that is distributed to the cortex of the brain is interpreted in terms of the internal model. The incoming information locates him with respect to the internal model, and his nervous system appears to have a high capacity to compare the incoming information with the model in order to determine whether it does or does not match. A failure of a match to occur generally results in some kind of action including the intake of further information.

The traditional view of memory was that it is storage of data from past experience which permits the subject to re-experience internally, though perhaps in a faint form, previous impacts which the environment has made upon him. However, from the biological point of view, the storage of information does not serve this kind of function. The value of stored information is in the guide which it provides for action. What this suggests is that the memory storage system, as it has evolved, is largely a system for retaining information pertaining to the appropriatness of responses when particular inputs are provided. That is to say a system of conditional probabilities. This is, of course, the general model of storage used by most of those who work within the framework of S-R psychology. For example, for Hull (1943), storage was in terms of a habit hierarchy; for Hebb (1956), it is in terms of a set of phase sequences which lead to action as they run off and for Thorndike (1931) storage was simply in terms of S-R connections.

While a model of storage in which the stored information is intimately related to action systems is currently the preferred model, this does negate the possibility that some information may be stored which is not highly action-related. Even if it is conceded that some information can be stored which is not action related one must concede also that such storage is probably very inefficient compared with that which is action oriented. Much of the latent learning controversy revolves around the point of whether some perceptual information is tied to very weak responses or is not response tied at all.

Stored information may be tied to any response that the organism may be capable of making. An actor who learns a speech ties the storage to the verbal reproduction of the part he has studied. A hiker who studies a map to go from point A to point B retains information relevant to the activity involved. In fact, the mere looking at a map without the intention of deriving information for some such specific purpose is unlikely to result in the retention of much information.

The implication of what has been said about the storage of information is that the nervous system is such that the mere input of information does not result in efficient storage. For this reason, the mere exposure to the visual and auditory presentations provided by a film is hardly likely to result in efficient storage of information unless the viewer is deliberately seeking information which will help him to solve a problem or undertake some other kind of action. The mere viewing of a motion picture of, say, the life of peasants in the Alps is likely to leave little behind except a memory of pleasant experience. True, a little information may remain, but the nervous system is ill-designed for the storage of information unrelated to definite action systems.

While the stored conditional probabilities may serve as a guide to behavior in many situations, there are other situations where more precisely stored information is necessary for problem solving. Such information must surely be that which is stored in a completely reversible code and for which the inputs and the outputs are provided by verbal symbols or similar symbol systems. The importance of having information coded in verbal terms is well brought out in the classic research of Judd (1908) on transfer of training. The reader will recall that in this study children learned to throw darts at an object submerged under water. The depth of the object was then changed and it was demonstrated that those children who had been taught the principle of refraction (a verbal principle) were able to master the new situation more rapidly than those that simply had experience to guide them. The same basic results were found in a similar later experiment by Hendrickson and Schroeder (1941) who substituted the shooting of an air rifle for the throwing of darts.

An important relationship between the audio and the video in learning situations may be for the audio to provide a coding of the visual information. The suggestion is not that this is the only relationship between the audio and video displays but it is one important relationship.

Conclusions and Implications

The picture of the nervous system as an information handling system derived from neurophysiology is filled with implications for the design of audiovisual devices. The great advances in knowledge which have been made in this area since the end of World War II have an encouraging degree of consistency from one laboratory to another which, in turn, encourages the authors to draw from them implications concerning the way in which information can be most effectively transmitted in a learning situation. The following implications seem justified by the data which have been examined:

(1) The nervous system facilitates the transmission to the higher centers of information of particular significance to the organism and, at the same time, tends to inhibit the transmission of less significant information. The overall transmission system behaves as a system capable of transmitting limited amounts of information through the entire sequence of events which lead to the utilization of storage of the information. The Hernandez-Peon effect which has been reproduced by other workers and with sense modalities other than those with which it was originally demonstrated, indicates that the transmission of significant information through one modality produces a partial block in the transmission of information through other modalities. If this conclusion is correct, then it follows that information transmission is best undertaken through one sensory modality at a time. Of course, where the information transmitted is highly redundant, alternation of channels may occur without loss of transmitted information.

(2) Since simultaneous inputs through more than one sensory channel may produce inhibitory effects -- and the fact is that accessory stimuli often do reduce the sensitivity f the main channel through which information is being transmitted -- caution should be exercised in introducing background material through one sensory channel while another is being used to transmit the main message. The use of a single channel for transmitting information seems to be a safe rule except where the information transmission requires the use of more than one sense modality.

(3) Only a very small fraction of the information available at the receptor level is transmitted to the higher centers of the brain. In the case of vision the proportion of the information provided by the receptors which becomes available for use is probably less than one part in a quarter of a million, and hence learning situations should be designed in such a way that the relevant features of the visual display are those that are transmitted. This suggests that visual displays used for instructional purposes should exclude all irrelevancies and should be reduced, as far as possible to the simplest terms. The data from the direct study of audiovisual materials generally supports this contention.

(4) Since all information is coded by the nervous system, it is important that it be transmitted by easily coded dimensions. Vision has the advantages of providing more codeable dimensions than does hearing which is one reason why information transmission systems involving vision are so well developed.

(5) Monotonous inputs produce habituation phenomena which presumably prevent the higher centers of the nervous system from being overloaded with redundant or trivial information. A continuous change in sensory inputs appears to be important for maintaining efficient transmission.

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CHAPTER 5

THE PERCEPTUAL SYSTEM AS A SINGLE CHANNEL SYSTEM

ERIC

THE BROADBENT MODEL

THE PERCEPTUAL SYSTEM AS A SINGLE CHANNEL SYSTEM

In the early part of the century there was considerable but profitless argument about the capacity of individuals to divide attention between two tasks or between two sources of stimuli. The central difficulty seems to have stemmed from the fact the the concept of attention was not a clear one. While it implied that attention could be represented by a quantity which could be divided over a number of tasks or stimuli, no methods were developed which could be used to measure how attention was divided and what fraction was devoted to each task. This does not mean that the problem was not a significant one, for it was. The difficulty lay in the fact that it was stated in a way that did not lead to experimental study. The problem ceased to represent a focus of interest for psychologists because there appeared to be no way in which it could be attacked experimentally.

Thus the problem rested until an alternative approach was found through the impact of information theory on psychology. Credit for this new approach must go to D. E. Broadbent, whose vision has opened up a whole new avenue for research which was successful for four main reasons. First, it abandoned the introspective approach to the problem. Clearly, the latter approach had been quite unproductive even though it had seemed to be the direct and the obvious one. Here, as in other areas of scientific enquiry, the direct approach is not the appropriate one. Second, Broadbent guided his research by an information theory type of model which has been a highly productive one, in terms of the experiments to which it has led under his guidance and coupled with his own experimental ingenuity. Third, while earlier psychologists had discussed the problem in terms of the division of attention among perceptual and motor activities, Broadbent limits his discussion to the division of attention between perceptual tasks and does not introduce motor tasks. Fourth, the perceptual tasks involve inputs of information; that is to say, the inputs are messages and not stimuli to be measured in terms of simple physical quantities.

The basic experiment which seems to have initiated Broadbent's thinking on the problem was undertaken by him in 1954. In this experiment groups of three digits were transmitted to a subject, one group of three to one ear and one group to the other ear. The digits arrived at the two ears simultaneously in pairs at the rate of one pair of digits per second. Thus one ear might receive the digits 3-8-4 while the other ear was receiving 9-7-6. In this case the three and the nine would arrive at the same time, the eight and the seven, and the four and the six. The task of reproducing the digits calls for divided attention in terms of the classical divided-attention concept, for the simultaneous presentation of the digits excludes the possibility that the reproduction of the digits is made possible by alternation of attention from one ear to another. The odd finding in the Broadbent study was that the digits were not reporduced in order of presentation, the first pair, the second pair, and then the third pair. On the contrary, the digits presented to the one ear were all reproduced first, then all the digits from the other ear were presented as a group. In the case of the digits given above, the order of reproduction would be 3-8-4, 9-7-6 or 9-7-6, 3-8-4 and not 3-9, 8-7, 4-6. When subjects were deliberately asked to reproduce the digits in the latter order, they found it extremely difficult to do this, though with training some of them did succeed. Broadbent suggests that when subjects reproduce the digits in the latter order, they do it through some internal rehearsing and reordering of the digits and not through learning them in the particular order in the first place. In later accounts of the phenomenon and in discussion related to it, Broadbent gives reasons why reproduction in the original order is extremely difficult.

The phenomenon might well be one confined to the two auditory channels, and Broadbent clearly saw that similar experiments needed to be conducted which involved more than one sense modality. In a later study Broadbent (1956b) studied the effect of introducing information simultaneously through visual and auditory channels. In this second experiment two groups were used which were exposed to somewhat different conditions. The conditions, together with the percentage of correct presentations, are shown in Table 6.

TABLE 6

DATA SHOWING PERCENTAGE OF CORRECT RECALL FOR DIGITS PRESENTED UNDER DIFFERENT CONDITIONS OF INPUT. FROM BROADBENT (1956b). ONLY GROUP II RECEIVED THE VISUAL SIMULTANEOUS PRESENTATION, WHICH INVOLVED THE PRESENTATION OF SIX DIGITS PRESENTED ALL AT ONCE IN A LINE.

	Percentage of Correct Responses	
	Group I	Group II
Auditory - All six digits to the right ear at a rate of two per second.	92	90
Visual successive - All six digits presented at a rate of two per second to the eye.	60	43
Binaural - Two different digits presented simultaneously, one to one ear, and one to the other.	62	
Bisensory A - Two digits presented simultaneously, one to the right ear and the other to the eye.	77	
Visual simultaneous - All six digits printed on a line and visible for three seconds.		78
Bisensory B - Three digits presented successively to the right ear. Three digits presented all together visually for the duration of the auditory presentation.		95

There are several points in relation to this phenomenon that one must note. First, reproduction was generally achieved by producing all of the information from the one channel and then all of the information from the other channel. This was found to be the case both when the two channels of information involved different sense modalities and when they involved only one modality. Thus the order of reproduction of information is not in terms of the order in which the information arrives at the receiver. On the contrary, the tendency is for all of the information from one channel to be reproduced first and then all of the information from the other channel. Second, despite simultaneous presentation, correct reproduction was achieved in a large percentage of cases. In only three cases out of 160 was any other order of reproduction noted. Third, no particular tendency to reproduce the information from one sense rather than the other sense was noted. About half the subjects are reported as giving the visually presented information first and half the auditorially presented information. Fourth, data did not indicate that retention was poorer or better in the bisensory condition. Fifth, the evidence supports the position that in the case of the two senses involved in the experiment information can enter two channels simultaneously, but this does not mean that the information from the two channels can be used simultaneously.

Properties of Information as a Means of Separating of Messages

The Broadbent effect discussed in the previous section might well be a phenomenon which occurs when well defined sensory channels such as an auditory nerve or a lateral portion of the optic nerve are involved. The nervous system might be constructed so that information transmitted through one channel might be selectively passed on to the perceptual system only if that system was not otherwise occupied with information with higher priority, but the same selectivity might not operate if two sources of information were transmitted through the same nerve channel. A psychological theory of the transmission of information requires an answer to the latter question.

Broadbent has provided data to answer the latter question. Common experience must have suggested to him that if digits were read simultaneously into one ear by the same voice that only a confused noise would be produced. Physiology would also support the latter position, for two sources of voice modulated at a similar frequency would activate the same group of basilar membrane fibers. On the other hand, if two voices were operating in different frequency bands, then separate sections of the basilar membrane would respond and the messages would be transmitted down separate sections of the lateral section of the auditory nerve. Under the latter conditions the separation of the messages appears to be much more physiologically feasible than when the voices involve the same frequency range. In an additional experiment, Broadbent (1956b) transmitted two messages to the same ear, one of which had come through a high-pass filter and the other a low-pass filter. The messages transmitted were digits presented simultaneously in pairs. Under these conditions the same effect appeared. All of the digits in the one message were reproduced before the three digits in the other message. Much depended on the amount of electronic filtering. With little filtering the two messages became confused. Further filtering increased the separability of the messages, but still further filtering reduced their intelligibility.

The filtered information could be fed either into one ear or the high-pass filtered information could be transmitted to one ear and the low-pass information to the other. Broadbent found that shifts between two voices differentiated by filtering but fed into a single ear can be made more rapidly than shifts from ear to ear. In addition, he found that a bisensory presentation is less subject to confusion than two messages fed into the same sense modality.

The important conclusion to be reached from these findings is that data processing in the higher nervous centers of the central nervous system appears to process data from only one source of information at a time. The fact previously established that data from one sense modality or one sense organ is processed at a time would then be a special case of the generalization that information can be handled from only one source at a time.

Information is identified by the receiver as coming from a single source if it comes in through an identifiable sensory channel (such as a particular ear or eye), or if it has some particular property such as an identifiable pitch or coherance in meaning which distinguishes it from other sources.

The generalization which has just been stated is valid only when there exists a certain condition which existed at the time of the experiments on which it is based. This condition is that the source of information is supplying the receiver with as much information as he can handle. It is conceivable that when two sources are supplying information at a very low rate that information from both sources can be processed at the same time. However, the generalization may well hold under all conditions of information transmission but, when the rate of transmission of information is slow, the receiver may well have time to switch from one source of information to the other and back again.

It is reasonable to assume that the experiments which have been cited up to this point in this chapter represent information transmission conditions similar to those found in the use of audiovisual teaching materials in so far as such materials also represent situations in which information is being transmitted at a relatively high rate in relation to the information-processing capacity of the receiver.

Broadbent's Model of Perception and Communication

Broadbent has attempted to develop a model of the perceptual process on the basis of the empirical information he and his colleagues have collected as well as on information derived from other sources. At least two versions of his model have been produced. The first published version appeared in the Psychological Review (1957) and consisted of a mechanical model of the perceptual process. The model is ingenious and tantalizing in the ideas it suggests, but not as complete as a later symbolic model presented by Broadbent (1958) in his book.

The significant point to note in the experiments cited in previous sections is that the information transmitted through two sensory channels, or under some conditions from two sources, is not reproduced in the order in which it is transmitted. Under the experimental conditions from which the data were derived, all of the information from the one source is reproduced before the information from the other source. Any other order of reproduction of information is difficult. These data suggest that the information from one nerve is utilized before the information from the other source, and that the information from the second source is held in temporary storage for a few seconds until it can gain access to the system. The latter system can, presumably, handle information from only one source at a time. Broadbent refers to the temporary storage system as the short-term storage or S system. This storage system is a short-term storage system only. One can easily demonstrate that if information is retained in this storage system for any time, it ceases to be available and fades out of existance. Long term storage appears to involve a different mechanism. The evidence presented by Broadbent (1958) indicates that this mechanism provides short term storage for only a few seconds. The storage is probably limited to a certain quantity of information, but practically no knowledge is available related to the latter question.

The concept of a short-term storage appears in many places in contemporary psychology. Hull (1943) introduced the concept of a stimulus trace which is very similar. Then, in his 1952 revision of his system, the stimulus trace is given properties almost identical with those possessed by information inputs for a period of only a few seconds and the information retained fades rapidly.

A second important point to note is that at some point in the nervous system a selection is made of one of two sets of data to transmit to the utilization system. The other set of information is temporarily stored. Broadbent refers to the system that does this as a filter system to indicate that some data are transmitted further while some are blocked. Thus, a model describing the handling of small amounts of information must make some provision for a filter system as the term is used in the present connection.

Third, information is deposited into a system in which it can be utilized and then produce responses of both the perceptual and motor types. Broadbent refers to this system as the P system, a fairly noncommittal name with P standing presumably for perception. The P system has certain properties, an important one of which is that it can handle only one set of information at a time. This is why the filter system plays an important role. The filter permits only one set of information to enter the P system at a time, delaying other data until the P system has disposed of data already transmitted. In other words, it operates as a single channel for the transmission of information. The Broadbent thesis is that the perceptual system functions as a single channel system in much the same way as many computers function as single channel systems for the handling of data.

Before further discussion of the model, the reader is directed to the diagram of the model in Figure 2.

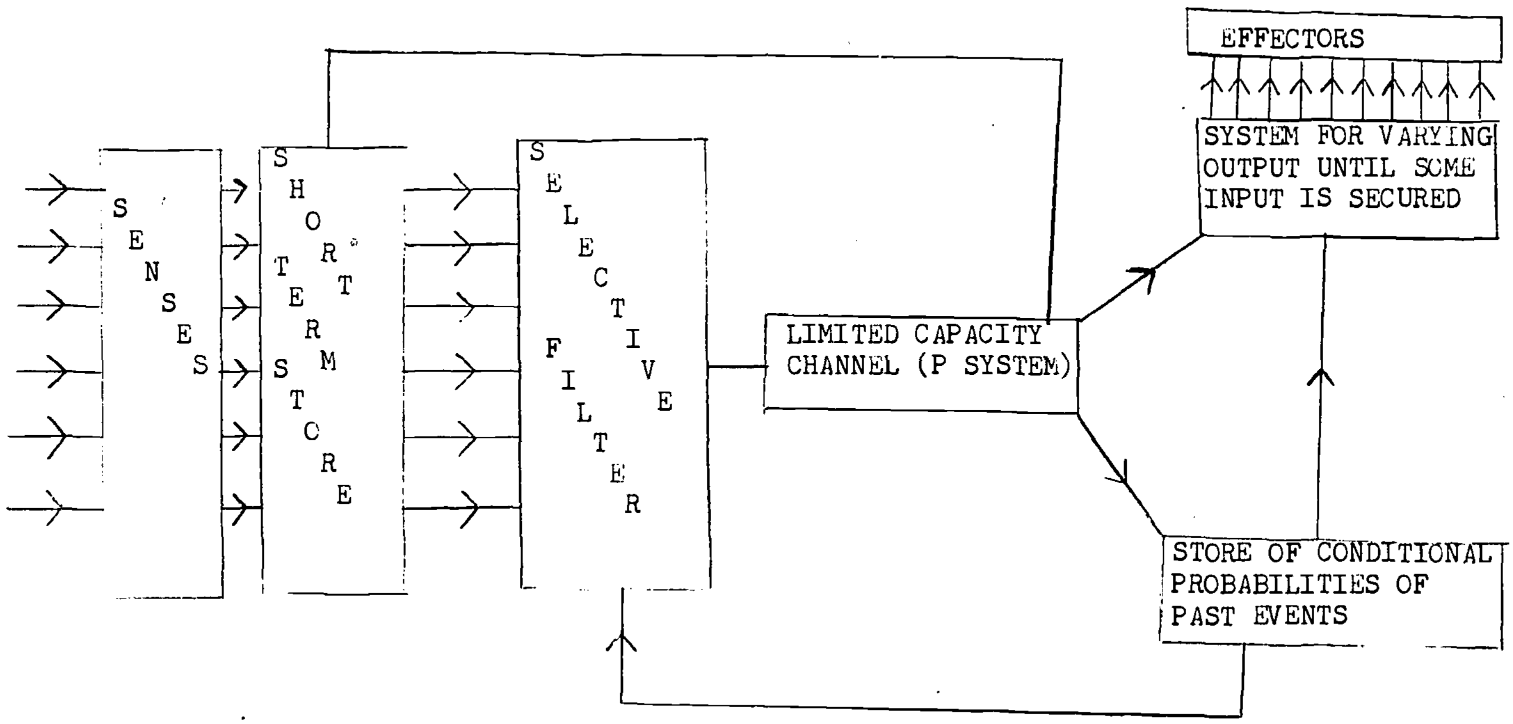

Fig. 2 Schematic representation of Broadbent's model of the perceptual system.

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The model shows that information transmitted through the senses first passes to the short term storage where it is held up to a few seconds. It then either fades or is passed by the filter to the P system, which is a channel of limited capacity. The P system should not be identified with the phenomenal field nor with other constructs which imply a conscious operator. It is strictly a construct introduced to account for experimental findings. The same may be said of the other aspects of the system.

Broadbent postulates that only information entering the P system can be retained with any permanency. Through the P system the information gains access to relatively permanent storage. In the diagram the unit concerned with the relatively permanent retention of information is designated as "STORE OF CONDITIONAL PROBABILITIES OF PAST EVENTS." The latter designation implies that information is stored in a certain form.

The P system also provides access to the effectors. This relationship is probably the least well developed of the constructs introduced into the system. The relationship of the P system to the effector system is not clearly spelled out. At least, this phase of the system does not have the degree of clarity found, for example, in the system described by Hebb.

While the life of information in the short term storage is only a matter of seconds, small amounts can be retained for longer periods through the operation of an additional mechanism. Broadbent's illustration is that of a person who is given a telephone number but who has to cross the room to the telephone. On the way he may rehearse the number to himself so that he may have it available when he reaches the receiver. However, if he is interrupted for just a few seconds while he is doing this he may lose the number and have to start again. Broadbent interprets this phenomenon as a cycling operation involving only the P system and the short-term memory. Each rehearsal puts back the information into the short-term memory. The short life of the information involved suggests that the process does not involve the permanent storage system. The cycling operation suggested is analogous to that used in some computers.

A Mechanical Representation of the Model

There are many ways in which the facts on which the model is based can be represented and Broadbent colorfully offers an alternative. In an article in 1957 (Broadbent, 1957) he provides a mechanical representation of most of the facts. This mechanical model has advantages of both concreteness and simplicity, though it is not as comprehensive as the symbolic model previously presented.

The basic mechanical model consists of an upright Y-tube as shown in Figure 3 . At the junction of the two upper branches is a flap valve which can shut off either one of the branches. This valve can be pivoted also by a handle. Balls may be inserted into either arm of the Y-tube.

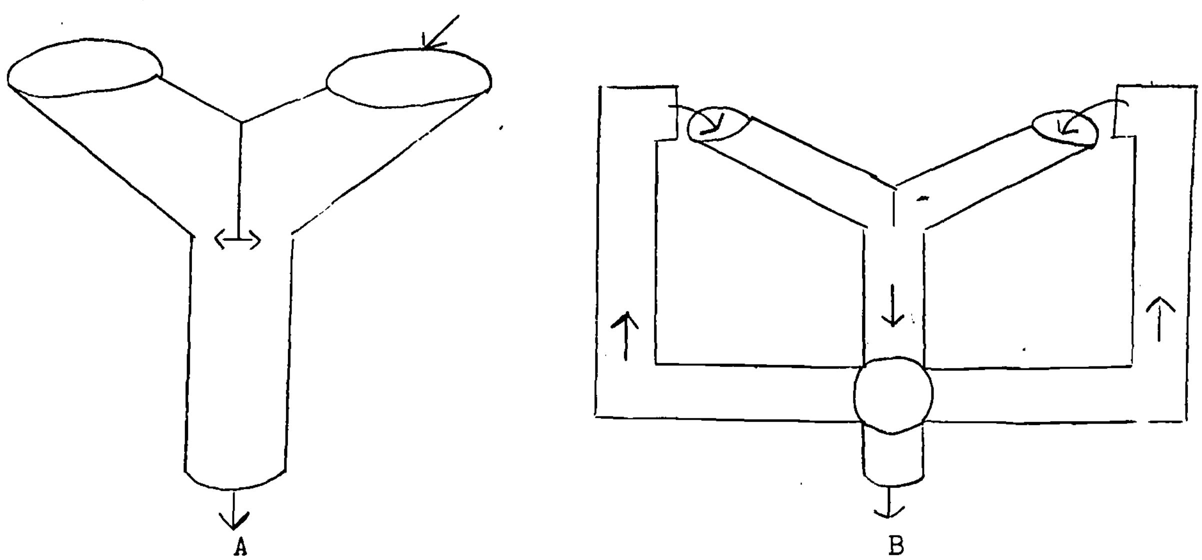

Fig. 3 Broadbent's mechanical model of information handling by the human receiver (1957).

In this model, the balls represent information and the Y-tube and flap valve represent certain aspects of the way in which the information is handled by the nervous system. The two branches of the tube represent two sensory channels through which information can be transmitted into the organism. The flap valve determines which one of the two branches can transmit information to the horizontal element of the tube.

In terms of the symbolic model of Broadbent previously described, the flap valve represents the selective filter and the horizontal element of the tube into which the balls pass represents the P system.

If balls (items of information) are inserted into both branches of the Y-tube, they cannot all pass the flap valve (filter). If the valve is pened on one side, then all the balls on that side will pass through first and then the balls from the other side can pass as the valve swings back. This is like all the digits which have entered one ear being reproduced first then all the digits which entered the other ear. When the flap valve is swinging freely, the first ball to arrive on one side will have the advantage over a ball coming in slightly later on the other side. That is to say, when no information is being received, the item of information to arrive first enters the P system regardless of sense modality. A ball which arrives with speed and force will have advantage over a ball arriving with less impact, which reflects the fact that strong signals have priority over weak signals. Two balls arriving simultaneously at the flap valve will jam, which reflects the fact that an overload of information jams the perceptual system. These and many other operations of the gadget represent, by analogy, common perceptual phenomena.

There are certain phenomena which are not well represented by the model. One of these is that messages held in immediate memory, as represented by the two branches of the tube, should not remain there indefinitely as solid balls would. The life of messages should be short. If the model provided an adequate analogy, then the balls should disappear after retention for about three seconds in one of the upper branches of the Y-tube. The elegant simplicity of the model would be spoiled by adding a complex mechanism which would remove the balls after they remained in one of the branches for more than three seconds. Mechanical models are always limited representations and much of their value is lost by increasing their complexity. Nevertheless, Broadbent does suggest one elaboration of the mechanical model.

He points out that despite the fact materials cannot remain in the short-term storage for more than about three seconds without fading, a person may take information from the S system, rehearse it, and thereby put it back again into the S system. In order to modify the mechanical model to represent this process, tubes must be added which come out at the bottom of the Y and which lead back again to the branches at the top of the Y. This is shown in Figure 3 . Thus a ball which enters the horizontal tube and moves to the bottom of this tube may then either be ejected from the system or may be channeled back into the top of the Y-tube again. This mechanism then represents the familiar rehearsal mechanism.

Broadbent is cautious in discussing his mechanical model. He is careful to point out that such a device is a convenience for reminding one of the results of numerous experiments. He suggests that it is more like a mnemonic device than an actual physical representation of events occurring in the nervous system. He even suggests that certain aspects of the model may be actually misleading. For example, the inputs to the system represent information and not stimuli. A person who examines the model may be led to infer that the organism cannot handle two stimuli simultaneously, but organisms can do this if the stimuli convey very little information. What the organism cannot handle simultaneously are two inputs which provide two substantial amounts of information. The two situations need to be contrasted with an illustration. A human organism can respond simultaneously to a tap below the knee cap and a bright light impinging on the eye. Both of these will produce reflexes even though the stimuli may arrive simultaneously. The reflexes convey relatively little information and none that has to be handled in terms of past experiences. The verbal messages, in contrast to the "stimuli" (as physically defined), carry large amounts of information, do not produce immediate and relatively automatic responses, and involve data processing. The contrast between the concept of a stimulus and a message is an important one.

The distinction is a critical one and there are even some questions whether it can be rigidly maintained. The essential difference would appear to be that information is either stored and/or used in the decision-making process while the transmission of a stimulus does not enter into decisions though it may influence behavior. Thus a tap on the patellar tendon produces a leg extension reflex but, generally, no information is stored or used in a decision-making process when this occurs. On the other hand, if a subject is only learning nonsense syllables, he is expected to be able after a short delay to reproduce them, a process involving storage and even decision making at a very low level.

An additional problem connected with the model is that it does not represent the fact that the span of immediate memory is approximately constant regardless of the amount of information included in each of the items. A person's span may be for seven units when the material presented is binary digits, but it is also seven units when decimal digits are involved even though the decimal digits transmit more information than the binary digits. At the best, the model is a convenient device which may be used as a crutch in thinking about certain problems of perception.

The Postulates of the System

While both the symbolic model and the mechanical models which have been discussed are convenient representations of the results of numerous studies, they are limited in the processes which they can describe. The difficulty is that the symbolic model is not a working model and, hence, cannot be used to represent many aspects of working relationships. The mechanical model, on the other hand, is a gross oversimplification and fails to summarize much important information. For this reason, it is desirable to reduce the relationships expressed by the models to a series of propositions or postulates which should be stated with the precision necessary for identifying clearly and unequivocally the evidence that would support and the evidence that would run counter to each particular proposition. Broadbent (1958) has provided such a set of propositions which are as follows:*

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"(A) A nervous system acts to some extent as a single communication channel, so that it is meaningful to regard it as having a limited capacity.

"(B) A selective operation is performed upon the input to this channel, the operation taking the form of selecting information from all sensory events having some feature in common. Physical features identified as able to act as a basis for this selection include the intensity, pitch, and spatial localization of sounds.

"(C) The selection is not completely random, and the probability of a particular class of events being selected is increased by certain properties of the events and by certain states of the organism.

"(D) Properties of the events which increase the probability of the information, conveyed by them, passing the limited capacity channel include the following: physical intensity, time since the last information from that class of events entered the limited capacity channel, high frequency of sounds as opposed to low (in man), sounds as opposed to visual stimuli or touch as opposed to visual stimuli or touch as opposed to heat (in dogs).

"(E) States of the organism which increase the probability of selection of classes of events are those normally described by animal psychologists as "drives." When an organism is in a drive state, it is more likely to select those events which are usually described as primary reinforcements for that drive. Thus food has a high probability of being selected if the animal has been deprived of food for 24 hours. In addition, all classes of events which have previously been selected closely before such reinforcers or before events leading to such reinforcers (see Principles (f) and (g) are more likely to be selected in future.

"(F) Given that two signals have been selected one after another, the conditional probability of the second, given the detected occurrence of the first is stored within the nervous system in a long-term (relatively slow decaying) store.

"(G) In accordance with Deutsch's postulates, when an animal is in a drive state it will indulge in appetitive behavior until one of the temporarily high priority events occurs at its sense-organs. Its behavior will then vary in such a way that it receives that ordered series of stimuli which, from a count of past conditional probabilities, has the highest probability of terminating in the primary reinforcement for that drive.

"(H) Incoming information may be held in a temporary store at a stage previous to the limited capacity channel: It will then pass through the channel when the class of events to which it belongs is next selected. The maximum time of storage possible in this way is of the order of seconds.

"(I) To evade the limitations of (H) it is possible for information to return to temporary store after passage through the limited capacity channel. This provides storage of unlimited time at the cost of reducing the capacity of the channel still further and possibly to zero. (Long-term storage does not affect the capacity of the channel, but rather is the means for adjusting the internal coding to the probabilities of external events; so that the limit on the channel is an informational one and not simply one of a number of simultaneous stimuli).

"(J) A shift of the selective process from one class of events to another takes a time which is not negligible compared with the minimum time spent on any one class.

"Of the above principles, (E) and (G) are the most tentative. The remainder seem to the writer to be reasonably well founded: The doubtful ones were included in their logical order for the sake of completeness. Certain other possibilities are worth further investigation, but cannot be regarded as even tentatively established. These ir lude:

"(K) There is a minimum time during which information from one class of event is sampled before any action is taken about it.

"(L) This minimum time is shorter in persons who are extraverted, by Eysenck's operational definition of that word."

Some Characteristics of the Immediate Memory System Which Distinguish It From the Long Term Memory

The immediate memory system is, of course, distinguished from long term memory in terms of both the quantity of material retained at any given time and the duration of retention. There are other distinguishing factors too which, insofar as they are established, strengthen the value of the model and give credence to the operation of a short term memory from which information is transmitted to the perceptual system.

Research over the last quarter of a century supports the position that the failure to retain information for any substantial period of time is not to any great extent a simple decay process but rather it is due to interference produced through other learning behaviors. The main effects which have been identified are proactive inhibition and retroactive inhibition. However, implicit in the writings of several psychologists is the concept of a short term memory within which information retained in it shows a rapid decay.

A number of experiments have been conducted by John Brown (1958) which have attempted to determine the extent to which the short term memory shows forgetting as a result of decay and as a result of retroactive inhibition. In these experiments the stimuli for short term retention were consonants presented visually and were referred to as the "required" stimuli. These "required" stimuli were followed by "additional" stimuli which did not have to be retained. These additional stimuli were either consonants and closely similar to the required stimuli or were digits, selected at random, and hence very different from them. The first of the series of experiments demonstrated that forgetting of the required stimuli occurred if the presentation of additional stimuli delayed recall for a few seconds.

In the second experiment reported in the same paper, Brown showed that the amount of forgetting depended only very slightly on the similarity of the "additional" material to the "required" material. He also showed that when the "additional" material preceded the "required" material that no additional forgetting effect was produced. This second experiment showed that the forgetting of the "required" material was produced to only a negligible extent by a proactive or retroactive inhibition.

In a third experiment a delay was introduced between the "required" and the "additional" stimuli. Such a delay was designed to permit the subject to rehearse, as he would in daily life in retaining a telephone number for a short interval. While subjects were not instructed to do so, they did in fact report that they "went over the letters" during the interval. The result of the interval was to decrease the amount of forgetting but the effect of the "additional" digits was still evident. In all of these experiments the amount of material presented was within the immediate memory span of the subjects.

These experiments support the contention that a short term retention mechanism exists which has very different properties from the long term retention mechanism. Just what is involved in the fading of the trace is an open question. Does the trace fade without leaving any mark at all behind it? Do particular features fade before others until the trace does not provide enough cues to initiate behavior? These are two of many unanswered problems.

The S system is a construct introduced to account for certain phenomena related to short term memory. Broadbent (1957) offers evidence to show that retention within the S system is of relatively short duration. His early data had already consistently shown that when information was presented simultaneously that the information reproduced last by the subject was the information least likely to be reproduced correctly. Such data suggested that the life of information in the S system is short.

Broadbent (1957) presented some additional data related to this problem. This later experiment involved the typical dichotic listening arrangement with a set of digits presented to one ear while another set of digits was presented to the other ear. In this particular case, six digits were presented to the right ear and two more digits were presented to the left ear. The digits to the left ear were presented in three different time relationships to those in the right ear, coinciding either with the first digits to the right ear, the middle pair of digits to the right ear, or the last pair of digits to the right ear. Thus the two digits presented early in the series would have to be retained longer than those given later. In each case the information given to the right ear had to be reproduced first. Other digit groups, varying in length, were also introduced into the left ear. Table 7 shows the information inputs of the two ears and the relative positions with respect to time of these inputs (Table I in Broadbent, 1957).

Twelve subjects were exposed to each of the first three conditions and twelve more to the last six. The percentage of completely correct recalls is shown in Table 8.

Subjects were asked to repeat back the digits heard in the right ear first and then the digits from the left ear. Reference to Table 7 shows that the critical digits transmitted to the left ear (the digits 1 and 2) appear in different positions with respect to the digits transmitted to the right ear. If they are transmitted early, then they must be stored for a longer time before being reproduced than when they are transmitted late.

TABLE 7

TABLE SHOWING THE INFORMATION TRANSMITTED TO EACH EAR AND THE TIME AT WHICH DIFFERENT DIGITS REACHED EACH EAR. THUS IN CELL A THE RIGHT EAR RECEIVED FIRST THE DIGITS 7,3,6,4 AND THEN THE SAME EAR RECEIVED THE DIGITS 5,4 WHILE THE LEFT EAR RECEIVED THE DIGITS 1,2.

	A	B	C
Right Ear	736454	736454	736454
Left Ear	12	12	12
	D	E	F
Right Ear	736454	736454	736454
Left Ear	12	1295	129587
	G	H	I
Right Ear	736454	736454	736454
Left Ear	958712	951287	129587
Scored Response for all Conditions		736454	12

(Table 1 from Broadbent, 1957, p. 7)

TABLE 8

PER CENT COMPLETELY CORRECT RECALLS FOR SUBJECTS EXPOSED TO CONDITIONS SHOWN IN TABLE 7

A	B	C
	Fast Speech Rate	
44	30	28
A	B	C
	Slow Speech Rate	
43	30	43
D	E	F
37	5	3
G	H	I
19	1	3

(Table II from Broadbent, 1957, p. 8).

The results seem to indicate very little capacity for the S system to retain information. At the fast speech rate (one digit per half second) the decline in recall produced by the delay is substantial, but why the same does not occur at the slow speech rate of a digit per second, which provides an even greater delay, is difficult to understand. The mixing of the information to be recalled with other information also reduces the extent to which the S system can deliver information to the P system when it is required. In other words, interpolated activity may be as important a factor as time in determining what information can and what cannot be stored for short intervals of time.

While the latter results give a picture of the S system as one in which information is temporarily held and then fades, not all the evidence fits the picture so neatly. In a study by Moray (1960) digits were transmitted to subjects in pairs, with one member of a pair transmitted to one ear and the other member of the pair transmitted to the other ear. Moray used a number of different conditions of presentation including simultaneous presentation, successive presentation and overlapping presentation. He also varied the speed of presentation. He could find no evidence that the material stored for the longest time in the S system was reproduced with the greatest frequency of errors. The criticism of the Broadbent position based on these data is not particularly strong, for Moray had only a limited amount of data and no significant differences were found between time in the S system and errors involved in reproduction. However, he did find when digits were presented simultaneously at three different speeds that the number of errors was related to speed of presentation, the faster speeds producing the greater number of errors. The latter finding is not consistent with the idea that information in the short term storage rapidly fades, for slower presentation means a longer retention time in storage. One way out of the difficulty presented by the data is to suggest that at lower speeds the subject may rehearse the material and hence improve its retention. Whether the latter does or does not happen is difficult to determine.

A much more damaging piece of evidence against the concept of a short-term storage which stores information according to the internal neural channel through which it is received is the fact disclosed by Moray (1960) that when simultaneous presentation is used, forty-three per cent of the errors of recall involved transportation of the digits from the one channel to the other. If the inputs were stored in terms of their sensory source, then this kind of transportation would not take place, unless, of course, a more complex model were developed than the one proposed.

Some Data Related to the Model from Studies Involving Order of Presentation, Order of Recall and Plan of Presentation

In the original studies of Broadbent, pairs of digits were presented simultaneously, one digit to one ear and one digit to the other. The order of recall of the digits was generally that of first all the digits transmitted to the one ear then all the digits transmitted to the other ear. Recall in order of presentation is extremely difficult and, for some subjects, almost impossible. However, the latter occurred only when the presentation rate was high. When the presentation rate was low, subjects became able to reproduce the digits in the order in which they had been presented. An interesting question is what happens when three digits are presented to one ear and alternating with these are three digits presented to the other ear. In such a case, the presentation alternates from one ear to the other. Moray (1960) tried this out and found that under these conditions the subjects tended to reproduce the material in the order of presentation. This result does not fit too well into the Broadbent model. One suggestion to account for the findings is that the information may be stored differently depending upon the method of presentation and, possibly, on the strategy adopted at the time of presentation. Broadbent et al. (1961) conducted an experiment to investigate the latter possibility.

In his 1961 experiment subjects had transmitted to them three digits to the one ear and three digits to the other with alternating presentations at the rate of a digit per second. The presentation occurred under two different conditions. One condition was that the subjects knew in advance the order of recall. The other condition was that the order in which the material was to be recalled was known only after the material had been presented. Two methods of recall were used, the ear-by-ear order of recall or the same order in which the stimuli arrived. If strategy at the time of arrival of a message determined the manner in which it was stored, then knowing that the digits were to be recalled in a particular way should result in a method of storage which facilitated that particular method of recall. The results of the experiment were negative. Knowledge of the order in which digits were to be recalled did not result in improved recall by that particular procedure. While this experiment needs to be repeated, the results at this time dispose of the concept that strategy at the time of the intake of information determines the method of storage. The effect of rate of presentation on storage is, apparently, a complex phenomenon. While research workers have found in some studies that a slow rate of presentation impairs recall, others have found the reverse.

Another possibility is that digits presented successively, since they cannot overload a single channel system at the speed of transmission used, may go directly to the P system. This has been proposed by Broadbent, (1958), in a study reviewed earlier in this chapter and seems to be the most plausible explanation of the major differences found between successive and simultaneous presentation. The data may be taken to suggest that there are difficulties in switching the input to the P system (switching attention) when two different sense modalities are involved and that such difficulties do not occur when switching across two channels within a single sense modality.

The Filter System

Selectivity of the inputs of information is partially determined by the activity of the receiver who may make bodily adjustments to improve reception or to block reception. Psychologists interested in problems of attention have long studied such adjustments, but they have been more concerned with the problem of arranging environmental conditions so that the maximum amount of information can be received by the sense organs rather than with the problem of restricting the input of information to an amount which the learner can successfully handle. While there are few references to the blocking of information at the sense organ level, experiments at the University of Utah have commonly reported that, in conducting studies of the audiovisual transmission of information, subjects exposed to high rates of information transmission involving both vision and hearing commonly place their hands either over their eyes or over their ears. Such actions may prevent the nervous system from becoming overloaded and provide evidence that the nervous system is limited in its capacity for handling information.

Considerable discussion has already been presented on research related to the filtering of information by the nervous system. The Hernandez-Peon effect, and the research which has grown out of the discovery of it, show that the higher centers of the nervous system are protected from being flooded with information by inhibitory processes which tend to block or partially block all information except that which has the highest priority at any given time. The exact location of the application of the inhibitory effect is not entirely clear, but one can say that it involves levels below that of the cortex. In addition, the inhibitory mechanism, or a component of it, can even have the effect of suppressing or partially suppressing the intake of information even down at the sense organ level. The evidence leads one to infer that inhibitory processes probably occur at all levels of the nervous system and have the effect of reducing the amount of information which reaches those locations where it is used for decision making and/or storage.

In contrast to the research on inhibition reviewed in previous chapters, the filter system postulated by Broadbent and the blocking function which it serves represent psychological concepts. Information is passed from the S system to the P system because it possesses certain characteristics. Broadbent is not concerned with the location in the nervous system of the filtering function. Nevertheless, the picture of information transmission and blocking which emerges from physiological research is very similar to that proposed by Broadbent on the basis of psychological data. One cannot help being impressed with the consistency of the two sets of findings and the strikingly similar pictures of the transmission and utilization information which they represent.

While physiologists have little to say about the characteristics of the information that is passed on to the higher centers for decision making and/or storage, psychologists can well regard this as one of their special realms of research in the investigation of the information-transmission process. In terms of the Broadbent model, the problem is that of determining the characteristics of information that passes the filter and goes on to the P system. In many ways the problem is similar to that studied by psychologists concerned with the problem of attention. Since attention phenomena are considered in their classical form in another chapter in this book, only those aspects of attention which Broadbent considers in relation to his postulated filter are considered here.

Broadbent (1958) points out in his book and in an article (1957) that the multiple channel short term storage passes information to the single channel P system according to the following rules (and also according to other rules which have not yet been identified):

1. If two messages do not arrive absolutely simultaneously, the first to arrive has advantage in obtaining access to the P system.

2. If two messages arrive simultaneously, the one which arrives with the greatest force (loudness, brightness, etc.) has the advantage in obtaining access to the P system.

3. One sensory channel may have an advantage over other sensory channels. This appears to be an open question with human subjects, though the priority of some sensory channels has been established for some species.

4. A message is more likely to obtain access to the P system if it comes through a channel which has not had recent access to the system.

5. Instructions given prior to the transmission of information may determine which one of two simultaneously transmitted messages will enter the P system.

6. The transmission of a highly redundant (monotonous) message eventually results in either the blocking of the transmission of the message to the P system or the sampling of the message from time to time by the P system.

7. If two or more messages with high information content are received through two different internal channels at the same time, the system may jam and information is not transmitted to the P system in an orderly way.

8. The factor of expectation leaves one in a quandry. On the one hand, it has been shown that messages which have high transitional probabilities in terms of previous messages have high priority for transmission to the P system; on the other hand, there is ample evidence to show that novel messages are also readily transmitted. Novel messages are, by definition, those that have a low probability of occurrence in terms of the previous history of the organism.

<u>The Problem of Direct Access of Information to the P System</u>

Broadbent has raised the problem of whether information must pass through the S system before it enters the P system or whether it can gain direct access to the P system. In two experiments (1957) he attempted to answer this question. The experiments, which required a quite complex design, involved thirty-two subjects in the one and twenty-four in the other. Although the results were clearly statistically significant, the fact that they are derived from a small group of subjects with particular characteristics suggests that they should be repeated with other subjects and perhaps also with other materials.

In Broadbent's first experiment, he asks the question in the following terms (1957, p. 3), "We can listen to only one voice at once, and the first words we hear are the best recalled. Can we sit passively while simultaneous messages arrive, and then listen to them in an order prescribed by the experimenter? Or must we listen to one of them as soon as it arrives? In the latter case we could not choose to listen first to the prescribed message, and will recall it no better than the other." In more technical terms Broadbent is asking the question whether the P system provides the normal route for information and whether the S system is merely a short term storage unit which comes into operation only when the P system becomes overloaded with information.

The details of the experiment cannot be described here nor the step by step argument related to the interpretation of the results. It is sufficient to point out that Broadbent concludes from his data that the questions posed false alternatives. The experiment involved the collection of data on the same subjects on two consecutive days and the results on the two days differed. The data from the first day suggested that all information first entered the S system and then was fed in parts to the P system. On the second day the data were consistent with the hypothesis that some information may pass directly to the P system and the excess data is held in the S system. On the basis of these rather limited data, the conclusion is drawn that in the early stages of learning, all information first enters the S system, but as the task becomes familiar some of the data may enter directly into the P system without entering the S system at all. Other interpretations are also possible, including the possibility that as material becomes familiar, delay in the filter system is reduced. The idea that the processing of data becomes more rapid, or even that it takes a different path when the message becomes familiar, is in keeping with personal experience. In addition, biological advantages would accrue if the S system were short circuited when familiar tasks were involved and, under such conditions, only the surplus of information was held in the S system.

What has been discussed here leads to the suggestion that the S system comes into operation only when the P system is overloaded. Thus, on a new task, where much information has to be taken in, the S system may be called upon to function since the P system is overloaded. As the task becomes familiar, less information has to be received in order for the task to be performed and the S system is no longer necessary.

Transitional Probabilities and Source Identification

The experimental results discussed in this chapter interpret most clearly those phenomena in which nonredundant information is transmitted through two sensory channels simultaneously for a period of a few seconds. From such data one can infer to only a limited extent what will happen when information is transmitted through multiple sensory channels over a more extended period. Under the short term conditions, information can be transmitted successively from the short term storage into the perceptual system and, if the duration of the message has not exceeded about a three-second limit, the entire amount of information may be made available for permanent storage. On the other hand, when there is a continuous input of information into two sensory channels, the intake is more than can be handled by the perceptual system. Under such conditions it would appear that some of the information provided by the inputs would be lost.

The last statement is based upon the assumption that the information inputs through the two channels are separate and distinct and have no redundancy. Under such conditions the Broadbent model would predict that the use of multiple channels would make it impossible to utilize all the information presented. If there is a high degree of redundancy, under some conditions it may be possible for the receiver to obtain information from channels alternately and not lose any of the information transmitted by the message. The latter would be the case if the two messages transmitted the same information on a parallel basis, as when verbal material is presented orally and the same material is presented word-by-word visually. Such parallel presentations are rarely found. Indeed, one of the few examples which approximates to this type of presentation is found in the administration of tests in which the directions are read by the examinee at the same time as they are read aloud by the examiner. Such a form of presentation only approximates the presentation under consideration because the examinee may well read ahead of the examiner and, hence, the inputs of information through the auditory and visual channel may not remain parallel.

When the visual and auditory inputs are matched and remain parallel, shifting from channel to channel may result in a loss of only the information transmitted during the shifting interval. However, such loss may not occur since the material may be sufficiently redundant that no new information is added during the shifting periods. The examinee may well shift from the visual presentation to the auditory presentation with a delay as much as a second without a loss of information because of the high degree of structure of the material.

Multiple channel presentations do not generally provide such orderly parallelism of the presentation of material. In a typical training film, information may be mainly presented through the auditory channel or mainly through the visual channel. There may be alternation of the use of channels and there may also be simultaneous presentation of relevant information. In addition, the typical sound movie provides many irrelevant sources of information which is only remotely related or unrelated to the main message that is being transmitted.

While the studies in the series which are considered in this chapter do not go as far as using materials of the complexity of a teaching sound movie, there are some studies involving the Broadbent model which have utilized connected meaningful material. Such studies involve, of course, material which is to some extent redundant, in contrast with the typical Broadbent experiment which involves nonredundant digits. Studies which involve connected meaningful material introduce a new factor into the perception and retention process, namely the transitional probabilities between words. Since audiovisual devices generally involve connected meaningful material in which there is a flow of meaning, it is important for us to consider experiments here which use such materials and which throw some light on the Broadbent model.

One of the earliest studies of the simultaneous transmission of two prose messages through the two auditory channels was conducted by Cherry (1953). Both ears received both messages. The two messages consisted of meaningful prose and were recorded by the same voice on the same tape. The task of the subjects was to repeat back verbally <u>one</u> of the messages, word for word, as it was played. This technique of reproduction is referred to as shadowing. The subject was permitted to play the tape as many times as he needed in order to reproduce the message.

The task appears to have been one of great difficulty, for the subjects took such steps as closing the eyes to cut out other channels through which distracting information might be transmitted. Of particular interest is the fact that the errors of reporting where the subject switched to the wrong source involved phrases which fitted the context and which hence had a high transitional probability. Such transitional probabilities seem to play an important role in the disentangling of the messages.

The fact that the transitional probabilities play an important role in the disentangling of such messages was shown also in a subsequent demonstration. Materials for this further demonstration (also Cherry, 1953) were prepared by stringing together cliches in a form which made them resemble closely a political campaign speech. A cliché involves, in essence, an arrangement of words in which each word has a high probability of following the other words. On the other hand, the probability of one cliché following another is low.

Subjects found the task of disentangling two speeches consisting of clichés an almost impossible one. The typical subject picked out clichés in about equal number from the two speeches. The important point to note is that clichés were given as wholes and were not cut, but the change from one speech to another occurred from one cliché to the next.

In the experiments and demonstrations just discussed, both sources of information were transmitted to both ears. Cherry also showed that the task of separating messages was greatly facilitated when one message was transmitted to one ear and the other message to the other ear. Messages, thus transmitted are referred to as dichotic messages. Under such conditions the one message could be attended to while the other was blocked. In addition, Cherry noted that the information through the blocked channel could not be reproduced, and was virtually lost.

A follow-up of the Cherry (1953) study with some extension of the findings was undertaken by Moray and Taylor (1958). In this study a number of passages were prepared which varied in the extent to which they approximated meaningful English. The technique used was that previously developed by Miller and Selfridge (1950). By this means, passages of 100 words in length were produced with approximated 1st, 2nd, 4th, 6th, 8th, 12th, and 16th order approximations to English. The reader may note by way of illustration that the sixth order of approximation is prepared by allowing a subject to see five words and asking him to add a sixth which is appropriate in the context. A new subject is then shown the four original words plus the word that has been added and is again asked to add a sixth, and so forth. In this way passages are built up in which each one of the words has a high probability, under normal circumstances, of following the previous five. In a tenth order of approximation, nine words are shown to each subject and he must add a tenth.

In the Moray and Taylor study, messages were presented dichotically. Typical English prose derived from a light novel was transmitted to one ear. One of the approximations to English was transmitted to the other ear. Subjects were asked to shadow the message involving the approximation to English. They found that the number of mistakes in shadowing varied inversely with the order of approximation to English, while the number of omissions varied inversely with the logarithm of the order of approximation. These results provide further evidence that the picking up of a message when a competing message is also being transmitted depends upon the extent to which the sequence of words corresponds to transition probabilities in the experience of the listener.

Moray (1959) followed up his earlier study of shadowing with a number of further demonstrations that, in the case of dichotic listening, material presented to one ear and shadowed by the listener results in the blocking of information introduced into the other ear. In the first of these demonstrations subjects shadowed a prose passage while words lists, seven units in length, were introduced into the other ear. The list of words was presented thirty-five times. When a word-recognition test was administered after the dichotic listening session, no trace could be found of anv recognition of the words to which the subjects had been exposed. In a second demonstration, subjects were required to shadow prose presented in one ear while instructions related to the shadowing activity were presented in the other. The instructions were given in a number of forms and included that of telling the subject to stop the shadowing activity. Some of the instructions were preceded by the name of the subject and some were not. Moray reported that instructions which were not preceded by the name of the subject rarely produced a response, but those that were preceded by his name produced a response in 20 out of 39 cases. As a matter of fact, in the various messages transmitted to the rejected ear in Moray's demonstrations, the person's own name was the only item that resulted in a transmission of the rejected message. In a third demonstration, prose passages were transmitted, one to each ear, with the transmission to one ear being shadowed. Digits were inserted into both passages. One group of subjects was told that they would be asked questions about the shadowed passage and the other group was instructed to remember as many numbers as possible. The two groups did not differ significantly at the five per cent level in the number of digits retained. Moray drew the conclusion that the attempt to alter set had no effect on the retention of the rejected message or on the capacity to reproduce it.

Moray discusses his results and those of Cherry (1953) and suggests that the selection of messages by the receiver is a central process -- at least on the central side of the chochlea or the cochlea nucleus. Moray suggested that there must be some information-monitoring mechanism which determines what information is allowed to proceed and what will be blocked from further transmission. On the basis of the fact that the only information that Moray was able to introduce into the rejected channel which had further effects on behavior was the person's own name, he suggests that only material "important" to the receiver will be transmitted beyond the monitoring system. Moray also suggests that since the Hernandez-Peon effect occurs at the level of the cochlear nucleus or even below, that the blocking of one of the messages in dichotic listening may be a different effect. This may or may not be determined from the data presently available.

Up to this point, evidence has been presented to show that a message is received with continuity either when it is transmitted continuously through a single neural pathway or when the elements of the message have high transition probabilities. There is some interest in finding out whether the one takes precedence over the other. Treisman (1960) conducted a study to explore the latter problem.

In the Treisman (1960) study, two messages were presented dichotically. One message consisted of typical English prose involving continuity and meaning while the other consisted of an approximation to English, either of a second order or eight order. The messages were such that the meaningful message was transmitted to one ear while the meaningless one went to the other. Near the middle of the 100 word message the ears were reversed, the one receiving the meaningless message now received the meaningful one and vice versa. Subjects were instructed to shadow the message in one ear.

Treisman found that when the messages were switched in the two ears, the subjects generally continued to shadow the message in the same ear as they had been instructed to do. However, some subjects occassionally repeated one or two words from the wrong ear at the break but rapidly changed back again to the right ear. Treisman also reported that the higher the transition probabilities at the point where the messages were switched, the higher was the probability of making this error.

Moray (1959), who found that the person's name was a stimulus that penetrated the filter from the rejected channel, suggested that there must be some kind of analysis of meaning or relevance prior to the filter. Treisman (1960) points out that if this is the case, then there must be some mechanism for analyzing the message both before and after it passes the filter -- a model of behavior which is lacking is parsimony. Treisman suggests an alternative explanation. Her proposal is that the filter does not block the rejected message completely, but permits it to pass through in a weakened or attenuated form. All information passing through the filter goes to a meaning analyzer and most of the attenuated messages from the rejected channel are not capable of arousing further activity. However, some of the messages enter the meaning analyzer and trigger words which have permanently low thresholds, such as the person's own name. Others trigger words which have temporarily lowered thresholds for activation, as would be the case of words which have, at the particular time, high transition probabilities in the context of the message from the accepted channel. The Treisman model provides a significant modification to the Broadbent model and accounts for phenomena which are not easily accounted for by the latter.

The monitoring of information in a rejected channel has at least a superficial resemblance to the monitoring of inputs of information which occur during sleep and which permit the subject to awaken when a given signal occurs. A study by Oswald, Taylor and Treisman (1960) has investigated, for sleeping subjects, cortical activity which results from various information inputs. The investigators, impressed with the fact that the person's own name has the capacity of entering the perceptual system even when it comes through a rejected channel, concerned themselves with the effect of the person's own name on his activity during sleep. Subjects had electrodes attached to their scalps through which EEG responses could be recorded. They demonstrated that cortical activity in response to the person's name occurred with significantly greater frequency than responses to other names ($p = .001$). The response of the cortex to a significant stimulus is described in the article as K-complex activity.

In addition, the subjects were instructed to make the hand movement of clenching the fist whenever either his name or one other specified name was spoken. Such hand movements tended to occur with greater frequency after the subject's own name than after other names in general ($p=.01$), but the "other name" to which he had been specifically instructed to respond did not produce a significant effect. The study shows that the cortex is capable during leep of discriminating stimuli.

The P System

Broadbent has much less to say about the P system than about any other part of his model. He makes it clear that the P system functions as a single channel, processing one piece of information at a time. He also implies that the system can handle information only at a limited rate but provides no data concerning what this rate might be for particular populations. Some data has already been provided from other sources on the estimated data-processing capacity of the human. One suspects that this capacity is much lower than it is commonly supposed to be. Studies at the University of Utah using nonsense syllables at approximately the 50 per cent level of meaningfulness have shown that about 10 per cent of the college students involved as subjects failed to learn at all when the rate of presentation was 1 per second in a rote learning task. Rates of presentation of one syllable per half second appear to be reaching the data processing capacity of most of these subjects. This fits well with the commonly accepted idea that it takes about 0.5 seconds for a perception to be completely structured. The latter estimate has to be accepted with considerable caution for structuring time may be expected to depend upon the complexity of the percept and the amount of information which it transmits. One suspects that less structuring time is involved, for example, if a receiver knows that he is to listen for one of ten digits than if he only knows that he is to hear one of all possible nonsense syllables.

In addition, it seems clear from physiological research previously cited that the P system, which may be identified with the higher centers in the nervous system, handles compressed information which has retained the more crucial elements of information about the environment. Compression would appear to be necessary to permit the P system, with its limited capacity for handling information, to function effectively in relation to a complex environment.

Implications of the Studies of Transmitting Complex Meaningful Material

The model which has been considered in this chapter was based largely on experiments which involved very simple materials such as digits and letters and the question naturally arises whether it is adequate for describing the more complex processes involved in the transmission of other forms of information. Most of the experiments which have been reviewed in the second half of this chapter were designed for studying the adequacy of the Broadbent model with more complex materials.

The data provided by these studies are generally consistent with the model, but they also add a number of important ideas. One of these is that channel switching will occur when the sequence of events in the two channels have high transitional probabilities. Whether the shifting from one sensory modality to another would occur under the same conditions is not clear at this time, but one could conceive of a sound movie which was so designed that the observer would shift back from the video to the audio and back again because the transitional probabilities called for this behavior. One suspects that use is already made of such transitions. When the audio states "Now watch carefully what is going to happen!" the cue is given for a switch from the audio to the visual channel and the switch is not left to chance. In the experience of the present writers in observing instructional movies such cues, with the transitional probabilities which they imply, are very rarely introduced by script writers.

A second important point raised is that the filter seems to duplicate many perceptual functions. This point brought out by Treisman simply implies that the model lacks parsimony in this respect. However, if it is taken seriously and an attempt is made to modify and reconstruct the model to overcome the difficulty a rather complicated model is likely to result. For this reason, the original model seems to present advantages even though it lacks parsimony.

Implications of the Model for the Design of Audiovisual Devices

The model which has been discussed in this chapter was not developed for the purpose of designing audio-visual devices, but rather was it a device for summarizing and collating research results and for suggesting directions in which subsequent research should lead. The main value for the design of audio-visual devices lies in the fact that it does summarize much that has been discovered and indicates the general nature of certain aspects of the perceptual process as described by such research.

First, let us consider certain functions that the model cannot perform. The model deals with the transmission of information, and hence does not describe certain other effects of stimuli. While stimuli transmit information, they also have such effects as raising or lowering the arousal level of the organism, interfering with the transmission of information, and indirectly facilitating or interfering with the reception of information through other channels. The model is not concerned with such inputs which may, nevertheless, play an important role in audio-visual devices.

Second, the model does not deal with the transmission of information in a situation in which there is a high degree of redundancy of the information transmitted. Broadbent does consider the limiting case of redundancy in which a task is completely monotonous with respect to the inputs involved. In the case of highly monotonous tasks, the inputs tend to be blocked from time to time or, in common language, attention begins to wander. Highly redundant inputs which are typical of most verbal communication lie somewhere between these two extremes. How subjects respond to such tasks is still a matter of conjecture.

Third, the model involves mainly immediate memory and the conditions under which information is transmitted and becomes potentially available for long term storage. The model has little to say about how long-term storage takes place, and neither does it have a built-in mechanism which accounts for the fact that subjects remember best that information which they have actively used.

From our present point of view, the importance of the model lies in the fact that it has something to say about the input of information into the human organism and the conditions under which such inputs are efficiently used. The important central thesis of the model is that the nervous system functions to some extent as a multiple channel input system and to some extent as a single channel transmitter of information. The implications for the design of audio-visual aids in terms of this model include the following:

If information is being transmitted continuously through two internal channels of different sensory modality and the information entering the two channels is separate and distinct, all of the information will not be used. The exception to this is when there is sufficient redundancy that only half of the transmission through each channel needs to be noted in order to reconstruct the entire message.

A cue given through one channel to a display transmitted simultaneously through another channel may be efficiently used by a subject if the display and the cue last for as short a duration as one or two seconds. Utilization of the information may also be efficient if the information is arranged so that the cue is transmitted to the perceptual system before the display. If the cue is auditory, priority for the cue can be ensured by using such factors as stimulus intensity (which the television producer uses in his commercials). In such a case, the short term storage may make it possible for the information from the one channel to be held while the other is being transmitted. There are some questions about this implication. One is that the experiments have not generally involved visual displays.

To a considerable extent the Broadbent model serves to formulate and raise questions concerning the design of audio-visual device rather than to provide a model in terms of which such devices can be constructed. Some of the questions which the model raises are the following:

1. If the same information is transmitted both through the visual and auditory channel simultaneously, is more information retained for subsequent use than when only a single channel of communication is used? The model suggests that such redundancy of information serves no purpose and that it may even confuse by overloading the system. A direct study of this problem by Van Mondfrans and Travers is reported in Chapter 3. The latter study provides data consistent with the Broadbent model.

2. If a sound movie is to be used for the purpose of developing object-word associations, the model suggests that the auditory word presentation should not occur simultaneously with the visual object presentation. Successive presentations should feed information to the subject at a rate which he can handle and should permit the anticipation of the channel from which he is to

receive. However, later research has shown that this inference is incorrect. The best method of developing word-object associations is to transmit both simultaneously. The reason for this is that word-object associations cannot be made until both the object and the word are known. Hence, the simultaneous transmission makes both elements in the pair available as quickly as possible.

3. If the audio and visual channels are used so that the learner does not know at any time which channel is the primary source of information, more information is likely to be transmitted if he is given systematic cues concerning which source is to be attended to at any particular instant than if he is given no such cues.

4. If the receiver of information, when an audiovisual device is used, has previously learned a code indicating important details of displays, more will be learned than when no such code has been previously acquired. Here again, the Broadbent model indicates that more relevant material will enter the P system when the filter is triggered to operate in particular ways than when it operates upon a basis which has not been incorporated in the plan for transmitting the information.

To what extent will particular inputs have priority of transmission to the P system as a result of their physical characteristics? For example, is a visual display in color more likely to displace and block an auditory input than is a display in black and white? How far does the intensity factor result in a particular input entering the P system? Just what will take priority over what is an important matter which must be studied further.

5. The model raises the possibility that the filter may have a tendency to pass audio rather than video information or the reverse, depending upon the life history of the particular individual. Almost nothing is known about this problem though it is one of considerable consequence for the planning of learning situations.

6. Broadbent (1958) raises the problem, and provides some evidence that under some conditions when a channel has been used for some time that information from another channel has an increased chance of entering the P system. However, the only condition for which this has been demonstrated is where the input for a particular channel is monotonous and involves the input of highly redundant information. The data still leave open the question of whether advantage is to be gained in switching channels when the information transmitted is considerably less redundant.

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CHAPTER 6

CHANNEL SWITCHING

The Switching Problem

The material presented in the preceding chapters has been sufficient to demonstrate two important principles. The first of these is that the organism has a limited capacity in terms of the amount of information that can be processed during a fixed period of time. This limitation of the organism seems mainly to be a matter of the time required for the central mechanisms to process the information provided by the stimuli, and can roughly be equated with the time required for perception. Because of this limitation, it is possible to present information at a rate faster than that at which it can be assimilated or processed by the central mechanisms. If this is done, then there is necessarily some sort of restriction in the amount of the information that is processed, the remaining information being either lost or handled at some latter time when the level of information has been reduced to the capacity of the organism.

The second principle is that when information is presented at a relatively high rate, the restriction in the information which is processed is by no means fortuitous, but rather follows the ordering of the information. Thus, since information is conveyed by stimuli, or more correctly by variations in the stimulus input, the information is normally ordered in terms of the source of the information, and the organism will select one source rather than another. In this vein, it is possible to attend to what we see to the neglect of what we hear. But stimuli are also ordered in terms of sequential probabilities, a factor which accounts for the redundancy found in normal connected discourse. With this type of ordering, it is found that a particular sequence of stimuli, or stimulus variations, will constitute a source, even if the input is varied over different sensory systems, and a person can attend to one message of this sort while ignoring another. Consider, for instance, a situation in which two people are discussing and demonstrating the performance of different tasks. In a case of this sort it is quite likely that rather than just hearing or just seeing both, an observer would process the information, both verbal and visual, provided by only one of the two people. He could attend to one source or the other, but not to both simultaneously, at least not effectively or profitably.

Supporting both of the illustrations given above, there is ample evidence to show that when the rate of information transmitted to the subject exceeds the rate at which the subject can process the information, the availabl information is divided in terms of the ordering of the stimuli, according to both physical and sequential characteristics, and only part of the information is received, or, more properly, perceived, by the subject. These principles are embodied in the model proposed by Broadbent (1958). He describes his model as a single channel model for the sake of representing both the limitations in the capacity of the organism and the restriction in the amount of information-transmission which occurs when the amount of information available exceeds the capacity of the organism. In his model, the limited capacity channel (the P system) represents the central processes involved in perception, and the selective filter (the S system) represents the regulation, by selection, of the information transmitted to the P system. While previous chapters have been concerned with the operating characteristics of the S system, the central problem of the present chapter arises from a consideration of the implications of this general model.

Since there is, according to Broadbent's model (and the data supporting the model), a selection process intervening between the sensory mechanisms and the central processes, it seems to follow that there is some sort of dynamic process involved in changing from one source to another. This is the problem of switching. It seems to be a problem that arises when information is made simultaneously available from more than one source, as is often the case with audiovisual presentations, and the information from either source may be relevant.

It is possible, of course, at least according to the characteristics of the model as it has been described to this point, that this is more a theoretical than a practical problem. For it is possible to conceive of switching, the process of changing attention from one source to another, as occurring instantaneously so that the only problems of concern in the design of audiovisual materials are those mentioned previously, the control of the rate on information and the selection of the most suitable medium, both in terms of ease of transmission and the subsequent storage of the information. If switching is indeed instantaneous (and there is no interference from the extra messages), then the process of information transmission could be maximized by providing some auxillary information which would be made available on some additional channel. At any time during the transmission of the primary message with the density of information below the capacity of the subject, the subject could instantly switch to another message to gain additional information, switching back to the primary channel as the level of information again approached his capacity. In such an instance, there would be no reason for cautioning against the indiscriminate use of multiple sensory modalities.

Even if the process of switching is not instantaneous, there need be no deleterious effect associated with switching, for it could be that although the process of changing attention from one source to another required a certain amount of time, the central processes involved in information processing could continue during the time in which switching occurred. Gilbert (1959), for instance, has found it profitable to distinguish between stimulus time and perception time. He found that his subjects could learn, at least for short-term recall, fairly long sequences of words with a very short exposure (stimulus) time, but only if there were no interfering stimuli presented before perception was complete. If, on the other hand, additional words were projected before the process of perception was complete, the perception of the preceding words was disrupted. Within this framework, a person might be able to receive the stimuli from one source and during the perception time, change his attention to another source, thus being ready for the stimulus when it arrived. If this model were to hold up, the only innovation required would be that of devising some method for cuing the change of attention. For instance, at the end of the stimuli on the auditory channel, an auditory and/or visual signal might be provided to indicate that the next information would come by means of the alternate channel. There are real problems with this proposal, for according to the best evidence available to date, the processing of the information provided by the signal would either be delayed until after the processing of the information conveyed by the preceding stimuli, in which case the total amount of information available for processing before shifting would be increased, or the information provided by the signal would intrude, thus probably disrupting the processing of the information that was provided on the channel.

The third alternative is that any time required for switching channels is, in effect, time out from learning. For instance, if a subject is presented with a signal from an auditory source and then is required to switch to a visual source, it might be expected that the subject would remain on the auditory channel until that information was processed, then to switch to the visual source. If the switching itself required any time, then it would be necessary to allow for both the processing time (the time required for the assimilation of the information which must be added to the stimulus time) and the time required for switching before initiating the message on the alternate channel. Stated somewhat differently, in order to achieve the highest rate of information transmission, the number of times that the subject is required to alternate attention between the auditory and the visual sensory modalities should be held to a minimum, for the proportion of the time spent in switching would increase with increasing numbers of alternations (from one channel to another).

Some Experimental Approaches to Channel Switching

Experimental concern for the problem of switching time has arisen mainly from studies that have been conducted in an exploration of attention and more specifically from studies conducted in the area of vigilance. Broadbent (1958), for instance, reviewed the literature on vigilance in developing his model. One of the primary facts that had to be dealt with was the fact that lapses in vigilance have a period of about 1 1/2 seconds. While such a lapse can be interpreted as a simple block in the perceptual process Broadbent was able to support the position that this phenomenon is better interpreted as a momentary shift in attention from one source to another and then back rather than as a simple interuption in the reception of information. Part of the support for his argument stemmed from an earlier experiment (Broadbent, 1954) in which he had tested the efficacy of having spatial separation of auditory sources. In this experiment, the signals consisted of simultaneously presented call signals (of the sort used in military radio transmissions) to some of which the subject was required to respond. At a slow rate of presentation (one pair every two seconds) he found that spatial separation facilitated performance and that the subjects actually attempted more responses with the sources being separated than they did when the signals (the different messages) came from the same source. His interpretation of this finding was that the separation provided a basis for the operation of the filter mechanism so that the subjects could listen to one and then change the object of their attention and listen to the other, doing a double-take, so to speak, of the second signal. In this fashion, according to his interpretation, the subjects were actually handling simultaneous signals successively. This type of process, incidentally, is supported by a variety of observations (Hebb, 1949). Now the finding that is of particular interest in the present context is that when Broadbent increased the rate of presentation to one pair every second, the experimental condition which provided for the separation of the sources did not facilitate performance. It seems that an interval of one second (or less) did not provide sufficient time to perceive one signal, to switch to the other source and perceive the second signal, and to switch back to the initial source in time for the next presentation. Since this feat was evidently possible in the two-second condition but not in the one-second condition, Broadbent concluded (1958) that a complete cycle including two perceptions and two switches requires between one and two seconds.

Following this finding, Broadbent (1954) undertook an immediate memory experiment in which he presented pairs of digits simultaneously, one digit to each ear. He found that when the rate of presentation was one pair of digits each second, the subjects were not very successful in performing the task of reporting the digits in the order of their arrival, but that the subjects were much improved in their performance of this task when the rate of presentation was slowed to one pair every one and one-half seconds, and did even better when the rate of presentation was one pair of digits every two seconds.

To be certain that this finding was not due simply to the arrangement of the ears, Broadbent (1956) replicated the previously described experiment but instead of transmitting the digits to the two ears, he transmitted different digits to the eyes and the ears. In this condition, pairs of digits were again presented simultaneously, but one of each pair was presented auditorily and the other visually. Once again, the subjects were successful in repeating back the digits in the order of presentation when the rate of presentation was slowed to one pair of digits every two seconds, but they experienced considerable difficulty with the faster rates of presentation. This general finding was extended to the case in which the digits were made more distinguishable by having them recorded by separate voices and subsequently passing them through electronic filters in order to arrive at further separation of the digits in terms of the frequencies they occupied on the auditory spectrum. In this case, the filter system could select a source in terms of the frequencies employed in the presentation of the digits, but not in terms of the particular sense modality employed, since both digits were presented simultaneously to both ears. With this sort of arrangement, it was possible for the subjects to alternate attention a little more rapidly, for they performed about as well with the rate at one pair every one and one-half seconds as they did with the rate at one pair every two seconds in the previously mentioned experiment.

Broadbent reasoned that since subjects can ordinarily perceive digits at the rate of two each second, (at least from one source to another), the fact that they are unable to recall the digits in the order of presentation when presented at the rate of one pair each second in his experimental conditions is due to the fact that they are required to alternate attention. Further, and this is the point of primary importance in the present context, the additional time required in the bisensory conditions in order to perform at the same level of efficiency as in the monosensory conditions can be attributed to the time required for switching. Since the subjects require between one and one-half and two seconds in order to be able to report the digits in the order of presentation although only one second is generally required to perceive two digits, Broadbent attributes the remaining time to the time required to switch twice, once from the original channel to the second channel, and once to switch back again. Since the difference in time seems to be between one-half second and one second, he concludes that on the basis of his data that switching involves from one quarter to one half of a second, depending upon the separation of the sources and probably, although he had no direct data to support this, upon the subjects employed. He had used British naval ratings.

Further data bearing on the problem of switching time came from the work of Cherry and Taylor (1954) who used a technique that was considerably different from that of Broadbent. They first recorded continuous prose on a tape and contrived apparatus that would enable them, in replaying the tape, to present the message to either side of a headset (or earphones) with which the subject was fitted. Thus, while playing the tape, they could present the message to the left side of the subject, to the right side, or they could alternate the message from one earphone to the other so that it was available to the two sides successively but never simultaneously. The experimental task they employed was one that has been called "shadowing," the requirement being for the subject to repeat the message that he hears in the earphones. Most subjects can perform this task quite readily with reasonably easy material that is presented at a normal rate of speaking. The strategy was to observe how well the subjects shadowed the message as they systematically varied the rate at which the message was switched back and forth between the two earphones. In this situation, then, the subject was presumably made to shift his attention from one side to the other or from one ear to the other, in a manner that was synchronous with the alternation of the message. Cherry and Taylor found, interestingly enough, that for each subject it was possible to select a rate of alternation that effectively inhibited the shadowing of the passage by the subject. When the passage was alternated at a rate somewhere between three and five cycles per second, the subjects were unable to articulate many of the words sufficiently well for the experimentors to be able to identify them. At the slow rate of switching, once every ten seconds, the subject is able to follow the passage very effectively. But as the speed of switching is increased, the articulation score decreases to a minimalat the point where the period of the switching was between .3 and .2 seconds. At this rate of switching, the subjects, according to Cherry and Taylor, "were observed to be making syllabic mutterings with only an occassional word correct" (p. 555). At higher rates of switching, the subject was once again able to shadow the message. A typical graph for a subject is shown in Figure 4.

It had been their hypothesis that some finite time delay would elapse while attention changed from one ear to the other and that the average time delay would be revealed by finding the rate at which the presentation time before switching was equal to the time required for switching. At the slow rate of switching, the subject is effectively changing attention from one ear to the other. As the rate of switching approaches the time required to change channels, then the subject remains out of phase with the presentation and all of the time is consumed in switching. Since the rate of switching determines the time available for perception, it is possible to solve for the time required to change attention from one ear to the other. In the present case, taking the rate that results in the minimal amount of shadowing at three cycles per second, switching time is 1/6 seconds, or approximately 160-170 msec.

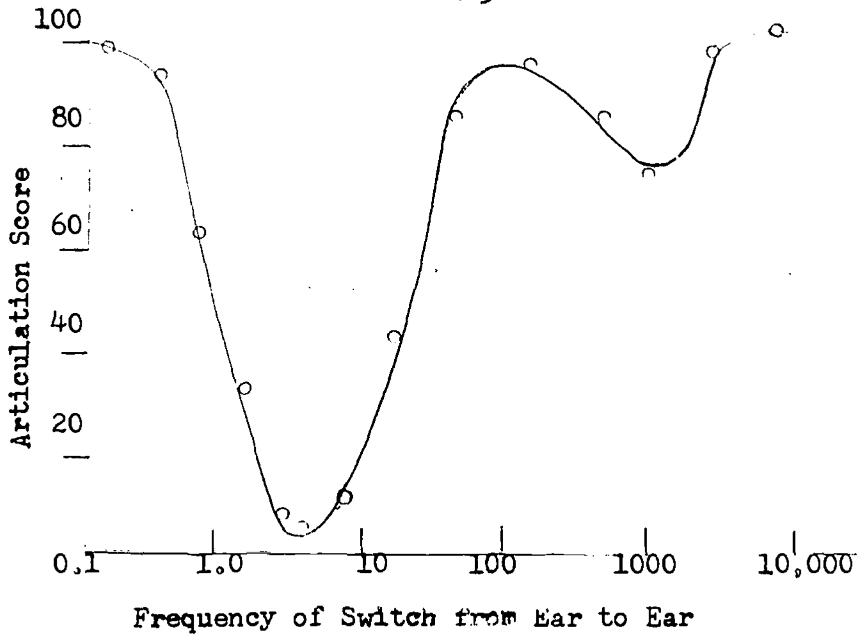

Figure 4 - Articulation score for one subject when continuous speech is switched periodically from one ear to the other. (From Cherry and Taylor, 1954).

It might be questioned why the subjects showed improvement as the speed of switching increased beyond the critical rate. In answer to this question, Cherry and Taylor surmised that the subjects, at the faster rates, simply stopped switching attention and, in effect, listened to either or both ears. At the faster rates, each ear would obtain a sufficient sample of any phenomenon to make it identifiable. Before leaving this study, it should be noted that with the rate of reading that was used in the main part of this experiment, approximately 138 words per minute, there was a syllable emission rate of about six syllables per second, or one syllable every one sixth of a second. Cherry and Taylor also used passages that had been recorded at both 85 and 36 words per minute to control for the correspondence between the time required for switching and the time required for the emission of a syllable and found that the dip in the articulation curves still occurred at about the same rate of switching, although the dips were not so pronounced when the lower reading rates were used.

Broadbent (1958) observed that the esitmate of the time required for switching based on the work of Cherry and Taylor corresponded with his own estimate. Although Cherry and Taylor's estimate places it at about 170 milliseconds, somewhat faster than Broadbent's own estimate, they were working with subjects that presented a university background and might be expected to be somewhat faster. It should be noted, however, that the topic of individual differences in perceptual switching has not been experimentally explored. It may be that perceptual switching is a characteristic that is susceptible to training.

While both series of investigations mentioned above support the position that there is a finite time required to change attention from one source to another, the studies have not escaped criticism.

Moray (1960) observed that Broadbent's technique of presenting two stimuli simultaneously afforded the subject direct access to the first stimulus of each pair but to only a trace of the second stimulus and surmised that this may account for the fact that successive recall was better than alternate recall in Broadbent's experiments. He therefore arranged for an alternation of the presentation of the digits, one to one ear and one to the other for a total of six digits. In addition, he used the conditions previously used by Broadbent. He confirmed Broadbent's earlier finding that there was a highly significant difference in the subjects' ability to recall the digits successively by channel and their ability to recall them alternately in the order of presentation. The former yielded much better results, but the data did not confirm a difference between successive and alternate recall when the digits were presented in a staggered manner. He proposed as an explanation for this that the subjects may not have been alternating their attention in any of the conditions mentioned to this point, but may have simply been "listening to both ears." This is similar to the explanation tendered by Cherry and Taylor to account for the ability of their subjects to follow the prose passage when the rate of alternation to the ears was greater than about five cycles per second.

In terms of Broadbent's model, there is no reason why the subjects in this situation should not, "listen to both ears," for his entire position is predicated upon the finding that the organism has a limited capacity for handling information, and it is due to this limitation in capacity that the S system restricts the input of information to the P system. The capacity of the human to handle digits, then, is most likely to be exceeded if the digits occur simultaneously, but does not occur if the digits arrive successively as they did in Moray's study. This finding, therefore, is not particularly troublesome for Broadbent's position. Another finding of Moray's, however, does serve to complicate the picture, for he found that a subject can easily reproduce digits that are presented sequentially at a rate of four per second. If this is the case, then it would seem that for digits, the upper limit of the time required to process the perception of a digit would be of the order of 250 milliseconds rather than 500 milliseconds as estimated by Broadbent in his calculation of switching time. Remember that Broadbent was allowing for two perceptions and two switches in one and a half to two seconds. If the perceptions require even less time, then the time allocated to switching must be commensurately greater, more of the order of 500 milliseconds or even more. Unfortunately, it is impossible to determine the time involved in the processing of the digits in the study conducted by Moray, for his successive condition allows for the possibility of simply holding the stimuli in short-term storage, a process held by Broadbent to occur prior to the P system.

Moray also suggested that the time required for the perception of digits might be appreciably lower than 250 milliseconds, for he found that although he was limited to this speed because of the time required to speak the digits, it is possible for subjects to recognize digits when presented only for the first 30-50 milliseconds although the normal length of the digits is greater than 200 milliseconds in duration when spoken. Although his subjects were able to recognize the shortened digits with almost unerring accuracy, it would be a mistake to confuse the required stimulus time with the time required for perception. Gilbert (1959), as mentioned above, showed that these two times are quite distinct. Further, the fact that only the first portion of the spoken digit is necessary for recognition indicates only that, among digits, all but the first part of the digit is redundant.

It is necessary to revise the estimated time required for switching to something in the order of 500 milliseconds, then the estimate obtained by Cherry and Taylor would have to be attributed to something other than switching time. It should be pointed out that their explanation was not entirely satisfactory to Broadbent (1958), for he had noted also that there was an incongruity in their interpretation. Cherry and Taylor also employed a condition in which, instead of alternating the continuous speech between the two ears, they presented interrupted speech to both ears. In this condition, the two auditory channels could function together and there was no need to alternate from one ear to the other. At the slow rate of interruption (which corresponds to the slow rate of alternation) the subjects correctly reported only 50 per cent of the words for this is indeed all that was available to them. But as the rate of interruption increased, they showed the same dip in their intelligibility scores as did the subjects in the condition requiring alternation. It seems hardly parsimonious to interject alternation as an explanation in the one case when it is far from suitable as an explanation in the other, at least with the data presently available.

It may be, of course, that the data pertaining to switching time has at this point become confounded with some other factor, a factor which might be presumed to account for the findings of Cherry and Taylor. It would seem that when the alternation of a presentation is occurring at such a rapid rate that only 100 to 150 milliseconds of sound are presented to either ear, there is not sufficient time for an adequate sampling of the discourse for the subject to arrive at an accurate determination of the message. Thus the time required for sampling would perhaps obscure any sort of "dead time" that might be attributed to switching. In line with this reasoning, Schmidt and Kristofferson (1963) calculated the mean period of attention for two observers (themselves), when observing the termination of pure tones and a neon light. This they found to be between 60 and 70 milliseconds. This was the time necessary for the separation of the terminations of the two stimuli in order for the observers to judge correctly the successiveness of the terminations. It may be that the "period of attention" for the sensory input used in this experiment, establishes the base sampling time necessary for a judgment concerning a stimulus, and that increasingly more stimulus samples are necessary with increasing complex stimuli.

In any event, the problem of switching time is not quite as complex as suggested by Moray, for it is possible, contrary to his fears, to rule out the possibility that the subject is always attending to both channels of sensory input. This feat was accomplished by Mowbray (1953, 1954) who used a situation in which the information required for the completion of a task was presented simultaneously to both channels. He maintained the channel separation and guarded against rapid alternation by providing irrelevant information during the time between the presentations of the relevant information and found that the subjects performed no better than they could be expected to perform by chance. It would be expected, however, that the subjects would have performed much better were they indeed able to attend to both sources simultaneously. Cherry (1953) had previously noted that a subject in this sort of situation is typically aware of only minor properties of the speech in the second ear, such as the basic modulation frequency (hence the sex of the speaker), and is often unaware of the language of the second passage.

In addition to this, there remains the evidence provided by Broadbent that there is some impairment of immediate memory when switching is required. This seems to be the case only when the organism is operating at the peak of its information-processing capacity, but it is precisely this condition in which we are presently interested. It is during this phase that Broadbent contends that excess information is shunted into a temporary storage, and it is this storage, in turn, that typically necessitates the rapid switching in attention. If it is not retrieved quickly, it is generally lost completely. The tests that have been conducted on switching, however, have had the disadvantage of making only the trace of the second stimulus available, a factor mentioned by Moray.

Broadbent and Gregory (1961) provided a situation in which digits were presented successively (rather than in simultaneous pairs), but alternately to the eyes and ears, and still found that recall was better when the subjects were instructed to recall all of the digits presented to the eyes (or ears) before recalling those presented to the ears (or eyes) than when the digits were to be recalled in the order of presentation. In this fashion they were able to overcome at least part of Moray's objection, for in this case the stimuli were equally available to both senses. But recall remained more difficult when the subjects were required to recall the digits in the order of presentation rather than first those presented visually and then those presented auditorily or vice versa. To this extent, they still provide some support for the thesis that switching requires a significant amount of time. But it remains impossible to calculate, on this basis, just how much time is required since they did not overcome the objection raised earlier that the time required to perceive a digit is less than the 500 milliseconds that was assumed in the previous calculation. If the time required is very short, then this leaves considerable time for the switching of channels. It would have been much better if they had calculated the decrement under the condition where switching was required, for this would, assuming that switching time is time out from learning, afford a different basis for the calculation of the time required for switching.

A Study of Switching in an Extended Learning Situation

Another problem limiting the generalizability of the results obtained in previous research is implied in the criticism that the studies mentioned above have used stimulus materials which require a very short time for perception, or, within the terminology of Broadbent's model, processing by the P system. The studies are limited to those involving immediate memory and shadowing, and the effect of switching time has yet to be demonstrated in a situation in which more permanent learning is involved. It is very possible that in the immediate memory situation, the material passes through the perceptual system only once, at the time that it is reproduced for the experimentor. A second difficulty, a corollary of the first, is that the stimulus materials themselves are well-known by the subjects (the materials are a well rehearsed part of their alphabet) and the sequential probabilities are greatly restricted. This condition, in turn, results in the fact that the time required for perception and/or processing is very short compared to what might be expected in a more typical learning situation or in a situation in which one can more realistically expect the learner to be processing information at a rate near the capacity of the perceptual system.

Changing the emphasis, for the moment, it seems to the present writers that what is required is an experiment in which more difficult stimulus materials are used to ensure that the perceptual system is loaded to capacity, and to use a learning task in which the learner has repetitions of the stimuli as is frequently the case in a paired-associate or serial learning experiment. A serial learning experiment would seem particularly suitable, for Feigenbaum and Simon (1962) find in fitting curves to serial learning data, that it is most appropriate to express the amount of learning as a function of the time allowed for perception rather than as a function of the number of trials. Since switching time is presumed to detract from perception time, the effect of switching should be revealed in a decrement in the total learning under a condition providing for switching when compared with the amount of learning obtained when no switching is required.

Such an experiment was executed in the Utah laboratories. Nonsense syllables were selected for use in the learning task mainly because they have generally low association values and are on this basis difficult. The subject requires a greater period of time to process the information. The syllables in the present study were selected from a list compiled by Krueger (see appendix A in Underwood and Schulz, 1960) and had association values ranging from 50 to 60 on Krueger's scale. The syllables had further been selected on the basis on pronouncability and lack of ambiguity (Van Mondfrans and Travers, 1964) so as to permit both auditory and visual presentation. The syllables were both recorded on magnetic tape and on slides. Experimental materials were then developed so that the entire sequence of ten syllables could be presented to the subjects at the rate of one syllable per second for a total of ten trials.

Condition I	Auditory presentation of syllables, sequence constant, no alternation of sensory modality;
Condition II	Visual presentation of syllables, sequence constant, no alternation of sensory modality;
Condition III	Auditory and visual presentation; random alternation of sensory modality within the sequence; sequence constant, 49 alternations over ten trials;
Condition IV	Fixed, single alternation of sensory modality, sequence constant, modality alternated on alternate trials, 90 alternations;

Condition V	Five syllables presented auditorily and then five visually, sequence constant, no alternation of the method of presenting each syllable; ten alternations;
Condition VI	Syllables presented by same method as in Condition V, but the sequence of syllables was modified into a single alternation sequence, 90 alternations;
Condition VII	Same as Condition VI, but syllables arranged in double alternation sequence, 50 alternations;
Condition VIII	Same sequence as IV above, but a double alternation sequence with 50 alternations.

Subjects for the experiment were obtained generally from elementary psychology and educational psychology classes with additional subjects being obtained from education courses at the University of Utah.

A preliminary examination of the results was sufficient to demonstrate that several subjects failed to demonstrate any sort of learning during the ten trials (their performance of the last five trials did not exceed their performance on the first five trials), and these subjects were deleted. It was also found that the subjects in Condition VIII performed at an inexplicably low level (it was later determined that a large number of the subjects had been obtained from an evening course administered by the Extension Division of the University), and this condition was deleted from the analysis.

The analysis of particular concern in the present context was computed on total learning scores for the conditions presented in Table 9 . It can be seen in this table that there was a large difference in the performance of subjects in the auditory and visual conditions, and that when the mean of these two conditions is used as the expectancy for performance in the audiovisual conditions (the conditions that provide for alternation), there is a sharp decline in learning that can be attributed to switching. It can be also seen that the amount of the loss in learning is generally a linear function of the number of alternations required by the experimental procedures. The subjects in the two conditions requiring 50 alternations performed at a lower level than the subjects that were not required to alternate, but the greatest loss in learning occurred with the subjects in the conditions requiring a total of 90 alternations. All of these comparisons were significant at the .05 level of confidence.

The major hypothesis of the experiment was that the alternation method of presenting the syllables, that is, the technique of switching between the auditory and visual sensory modality within the sequence of syllables, would result in an impairment of learning. This impairment would presumably accrue from the fact, according to the model proposed by Broadbent, that the organism can attend to only one sensory channel or the other when the information level is approximating or exceeding the information processing capacity of the organism. It was anticipated that a bisensory presentation of information would result in the transmission of less information into what he has termed the

P system (the perceptual system) because of the loss accruing from the time required to switch from one channel to the other.

TABLE 9

MEAN LEARNING SCORE FOR EXPERIMENTAL CONDITIONS AND COMPARISONS OCCURRING IN THE ANALYSIS

	Condition					
	I	II	III	VII	IV	VI
Alternations	0	0	50	50	90	90
Comparison Between Conditions	44.8	57.1	47.7	47.2	43.3	43.2
Means of I + II vs. means of others	51.5			45.3		
Means of I + II vs. means of 50 alternation conditions and means of 90 alternation conditions	51.5		47.4		43.3	

It can be seen in the data presented above that these results were generally confirmed. It is also possible, on the basis of these results, to estimate the time required for switching.

Assuming that the time required for switching is "dead time" and does not function as perception time, the decrement in learning in the conditions with the bisensory presentation of stimuli can be attributed to the switching time. Since there were 10 syllables presented at the rate of one syllable per second for a total of 10 trials, the monosensory conditions, the auditory and visual conditions, provide an estimate of the amount of total learning with 100 seconds of perceptual time. The alternation conditions, however, provide an index of learning for 100 seconds less the amount of time actually spent in switching sensory modalities. Since the conditions with a total of 50 alternations resulted in a decrement of eight per cent, it is concluded that 50 alternations required eight per cent of the perception time or a total of eight seconds. Eight seconds apportioned over 50 switches results in an estimate of 160 msec. for each switch in sensory modality.

A partially independent estimate of the time required for switching is provided by the conditions with 90 alternations. The total learning in these conditions was 16 per cent less than the total learning in the monosensory conditions that required no switching. This difference, reasoned as above, results in an estimate of 176 msec. as the time required to switch channels.

It should be mentioned at this point that the estimates of the time required for switching are probably conservative, for the analysis on which the estimate is based assumes that all of the subjects were switching with each change in presentation. In actual fact, as was revealed by an analysis of individual performance, some subjects attempted to learn all of the syllables from one sensory modality and then all those remaining.

Summary

The results of the research concluded to the present time show that there is a decided decrement in immediate memory, shadowing, and rote serial learning when the conditions of the experiment are such that the subject is required to alternate his attention. Further, the estimates of the time required for the alternation of attention from one source to another provide a minimal estimate of something less than 200 milliseconds. It seems likely that future research will reveal the actual time required to be something in the order of 300-400 milliseconds, the latter being a liberal interpretation of Broadbent's estimates. Further, there is the data cited by Broadbent (1958) which show that the momentary lapses of attention in vigilance tasks can be readily interpreted as a shift away from and back to the task at hand if we assume that the time of switching to be about 300 milliseconds.

The immediate implication of the findings presented to this point is that in the design of audiovisual materials, the rate of information transmission should be decreased at those points at which it is necessary to change attention from one source to another. Further, a greater attention must be given to the characteristics of a source, for, in the technical usage of the term, this does not correspond directly to the sense organs being stimulated. It is not at all farfetched to think that different regions of a visual display as constituting separate sources. What constitutes a source, since it is actually a restriction imposed by the nervous system, will vary as the subject becomes more familiar with the material available. Each element of the periodic table might be regarded as separate sources when a person is first introduced to the table, but with increasing knowledge concerning the table, increasingly large segments of it would function as a source until eventually the entire table itself might be a single source. There is, of course, a great deal of knowledge to be gained in this area, all of which will be important for the design of audiovisual materials. It should be noted that this usage of the term source refers to the division of simultaneously available stimuli. The division appears to be largely in terms of sequential probabilities.

A second and final implication is that if learning is to be optimized, that is, if the subject is to learn as much as possible in as little time as is necessary, then it is inadvisable to change sources indiscriminately. On this point, it seems likely that simply as a result of their life experiences, there is a certain expectancy on the part of most subjects that verbal material will follow verbal material, hence the ease with which Broadbent's subjects learned the visual elements together and the auditory elements together. But what is known of the normal (probable) transitions across sensory modalities?

Although there are probably many instances when we expect one form of stimulation to follow another, little is now known about these situations. But as they are identified, they can also be exploited.

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CHAPTER 7

CONCEPT LEARNING

Concept Learning and Audiovisual Aids

It is clear from the literature on audiovisual aids that one of the prime aims of such techniques is to facilitate the learning of difficult concepts. It is therefore assumed that the goals of audiovisual education are more likely to be achieved if the devices involved have been built on the basis of knowledge derived from the study of the learning of concepts in the laboratory.

Most of the concepts that audiovisual materials may attempt to develop are relatively complex. Consider such concepts as those of "democratic process," "disease," "freedom," and "leadership," and one soon realizes that the learning involved is a long jump from the learning of concepts as it is undertaken in the laboratory. However, what is learned in the laboratory will provide clues that may enable the creation of more efficient learning aids.

The special contribution of the studies under consideration which has significant implications for the design of audiovisual materials lies in the introduction of the idea that the learner adopts a strategy. This is the plan for gaining information while working toward the discovery of the attributes and the relationship of the attributes that are the defining features of the concept. This procedure may not be consciously recognized by the subject, although it may be clearly manifested in his behavior. The learner may, for example, focus his attention on a positive instance of the concept and then study subsequent positive instances to determine which elements remain the same and which are altered. On the other hand, he may also begin with a single positive instance and hypothesize there and then that a certain combination of the attributes is important while the others are irrelevant. This he tests when subsequent instances occur. Numerous different strategies may exist. In a typical life experience the learner controls the strategy which he uses, but, in a learning situation, conditions can be so designed that a strategy can be virtually forced on the learner. The implications of this will become plain in the discussion that follows.

The studies of concept learning to be reviewed in this chapter have relevance to current educational practices from another point of view. All of them involve a procedure which, in terms of current educational vernacular, would be referred to as a "discovery" method of instruction and learning. The familiar techniques of concept acquisition studies involve the presentation of a series of displays. The learner has to discover the characteristics of the displays which result in them being classified in one of two categories. The subject is provided with information concerning the correctness or incorrectness of his attempts to classify the displays. In some studies, cues are provided indicating to the subject what to attend to and what to ignore, thus restricting behavior as it is typically restricted in discovery methods of instruction.

A Definition of "Concept"

The Webster Dictionary defines concept as: "1; A thought; an opinion; . . .or 2. Philos. An idea, as distinguished from a percept; espl., as orig., an idea representing the meaning of a universal term and comprehending the essential attributes of a class or logical species; now, chiefly, an idea that includes all that is characteristically associated with or suggested by, a term; also, a mental image of an action or thing . . . ."

The usual lay usage of the term concept is more closely akin to the first of the two definitions above. However, in the study of concept learning problems, the second definition is the one with which we will deal. To illustrate, suppose that one were given the task of identifying those attributes that characterize friends and distinguish them from non-friends. Though the complexity of such a task is great, many people are capable of doing this -- at least to their own satisfaction. Children are often warned by their parents not to talk to or go with strangers because of the possible danger, but it is not assumed that all strangers are necessarily non-friends. It is just easier to make such a rule than to try to explain which strangers are friends and how to identify them. It is assumed that as the child grows up he will learn the concept "friend" for himself. Just what are the characteristics that would define the concept "friend?" To mention a few that are considered by Webster: "One who entertains for another such sentiments of esteem, respect, and affection that he seeks his society and welfare; one not inimical or hostile; one not a foe or enemy; one of the same nation, party, kin, etc., whose friendly feelings may be assumed; one who looks propitiously on a cause, an institution, a project, or the like;" and so on. It is clear there are a great many attributes and relationships that combine to make up the concept "friend."

In looking at the complexity of such a concept as friend, and then multiplying this by the large number of other like concepts a person forms throughout his lifetime, one soon becomes astonished by the abilities of the human organism. Yet, it is apparent that those abilities are exceeded by the sheer number of discriminable stimuli by which man is surrounded. Miller (1956) has reviewed several studies which have examined the limits of human information processing systems such as the eye, the ear, etc., with respect to different types of stimuli such as tones, colors, etc. His conclusion was that human beings must engage in a great deal of coding of stimulus information which in turn allows him to attend to those stimuli that are salient to the situation and to monitor the irrelevant stimuli in an abbreviated form. It is clear that by forming concepts, and by categorizing stimuli by concepts, the amount of information that must be processed is reduced. If, for example, we wish to tell another about one of our friends it would not be necessary to mention all of the traits that together characterize a friend, but rather, it would suffice to call him a friend and then delineate those characteristics that make him unique. It can be assumed that in this manner much, if not most, of the information about this friend will have been communicated, since the other person will also have a concept of the word friend which will be highly similar to yours.

It has been mentioned by Bruner et al. (1956) that the formation of concepts along with the reduction of the complexity of the environment, also reduced the necessity of constant learning. Once a category has been learned, and those attributes and relationships that identify and define that category have been learned, one does not have to learn these anew each time that he is presented with an exemplar of that category. Nor does he necessarily have to notice all of the attributes that place a given object into a given category.

There are several attributes that combine to make the category "human being". But in order to identify a given stimulus object as human one needs only to recognize some of these before he makes a positive identification since many of these attributes are redundant. Categories also, then, provide the means by which the objects in the world around us are identified.

Bruner et al. also mention (pp. 12-13) that categorizing is an aid to the processing of information because of the "direction it provides for instrumental activity." That is, if we know that a given stimulus belongs to a given category with which we have already dealt, then we also know how to react to this particular exemplar of that category.

Categorization also permits the "ordering and relating (of) classes of events" (Ibid. p. 13). When an object is placed in one category, it can be assumed that it will have certain relationships with members of other categories. We, therefore, do not have to have had direct experiences with all members of a given category in order to be able to surmise what will occur. The relationships of categories to other categories open new vistas with respect to a given stimulus because it is possible to go beyond one stimulus or even its category and postulate what the results will be when it interacts with other objects or categories.

It is obvious that concept formation or categorizing behavior is a valuable aid in enabling a living creature to order and cope with a complex environment. If a greater insight can be gained into the ways in which a person forms concepts, and into ways in which this behavior can be facilitated, it then becomes conceivable that man can learn to cope with an accurately interpret much more of what goes on around him.

The General Concept Learning Paradigm

The classic experimental study of concept learning is that by Hull (1920) which constituted his doctoral dissertation at the University of Wisconsin. In the introductory section of the report of the study, Hull indicates that he had been influenced by Herbart in the development of his research, and his problem was formultaed in terms which could be described as Herbartian. Hull describes the model of concept learning in the following terms (p. 4):

"1. The subject is presented with a number of experiences, either simultaneously or in succession, each of which contains a certain characteristic common to others.

"2. The subject is brought to compare deliberately the various situations presented with a view to discovering similarities and differences among them.

"3. Lastly the significant element common to all the experiences is deliberately sought out, found, and formulated in language."

While these three steps form the essential paradigm for research on concept learning, many variations were introduced by later experimenters. In the type of study developed by Hull, the learner was presented with a series of experiences related to the development of a particular concept, but these were interspersed with experiences related to other concepts. The justification for doing this was that in concept learning in daily life, experiences related to the development of a particular concept are interspersed with varied experiences from which other concepts are derived.

The material used for Hull's concept formation study was a group of 144 Chinese characters divided into twelve groups. Each group of twelve characters was selected so that the characters all included a common sign. The task of the subject was to learn to associate a nonsense syllable with that particular sign. In the learning task, the subject was presented with a Chinese character and was given 2.5 seconds in which to guess the syllables. He was then told the syllable and required to repeat it. Altogether twelve different syllables had to become associated with twelve different signs imbedded within the Chinese characters. A further review of the different Hull studies will be presented as they fit into the discussion which follows.

The next major contribution did not appear until 1956 when Bruner, Goodnow and Austin published their book on thinking. This is not to say that there were no researches conducted in the area in the intervening years, for there were, but these were not of comparable significance.

Bruner <u>et al</u>. proceeded, as did Hull, with Herbert's definition of concept development as a process involving the identification of the common element or elements in a set of experiences. The common elements are referred to as attributes and each experience is referred to as an exemplar. However, there is a difference in their interest in comparison with that of Hull. Bruner <u>et al</u>. were concerned with the process of the formation of strategies for solving the task and used a much wider variety of methods than did Hull.

Thus we see that both of the two principle investigators in this field used as their basic paradigm the one laid out by Herbart. Other important investigators in this area have also followed suit. The variations that have come are mostly variations within one or another of the three basic steps which Hull derived from Herbart, rather than variations that change one of the basic steps functionally. This will become evident in later pages of this chapter as the work done by various investigators is reviewed.

<u>Glossary of Terms Used in Concept Learning Research</u>

Before going further into a review of the literature of concept learning, it is necessary to define some of the terms used to insure that they will be properly understood. Most of the definitions given are of a general nature.

<u>Concept</u>: The set of attributes and their relationships that can be used to decide if a given event or set of events is a member of that category designated by the name of the concept. Using the above definition, by the concept of friend is meant those attributes and relationships that define the category "friend."

Concept learning: Concept learning is the process of categorizing stimuli with respect to certain salient attributes and relationships into logical or functional groups.

Categorizing: The rendering of discriminably different stimuli as equivalent.

Dimension or Stimulus Dimension: We will refer to those characteristics of an object that render it discriminably different from all other objects as dimensions or stimulus dimensions. Such stimulus characteristics as size, shape, weight, color, number, etc., are all dimensions.

Attribute: A particular point or value along a dimension is an attribute. For example, if one were presented with a red square, the stimulus array would have the attribute red along the dimension color and the attribute square in the dimension shape. (Note: When one is not referring to a specific stimulus it is customary to refer to attributes as having levels; thus, one speaks of bit, medium and small, circles, squares and triangles as levels along the dimensions size and shape).

Coding: In the appendix on information theory, coding is defined as a reduction in the number of signals needed to relay a given amount of information. The same definition will suffice here.

Relationships: In considering the patterns of attributes which combine in different ways to make different categories, one can use the word "relationship." In concept learning tasks Bruner et al. (1956) write of three different relationships which are common in this area: (1) conjunctive, (2) disjunctive, and (3) relational. These are defined as follows:

A conjunctive relationship generates a concept in which all the defining attributes have to be present in order for the object or event to be correctly categorized in a particular class. It is characterized by the conjunction "and." (For example, in order to be a positive exemplar it must be both red and triangular.) A disjunctive concept is one in which one attribute or another is sufficient to categorize the object or event. A win is scored in a boxing match either when there is a knockout, or the referee stops the fight, or the fight runs to completion and one of the contestants has more points than the other. (It might be interesting to the reader to point out here that a disjunctive concept can be resolved into two or more conjunctive concepts.) A relational concept is one in which the relationship between two or more attributes is of primary concern. Such concepts as "heavier than" or "larger than" fall into this class.

Cognitive Strain: Bruner et al. introduce the concept of cognitive strain which is the amount of "tension" associated with the cognitive task of concept learning. The "tension" created is a function of the memory load inherent in a given strategy. Strategies which require the learner to retain a great deal of information from one trial to the next are considered to involve a substantial degree of cognitive strain. The strain can be reduced by various procedures such as that of keeping a record of the information gained at each instance. The importance of the concept of cognitive strain lies in the fact that learners take steps to avoid cognitive strain. Note taking would be one such step.

Another is for the subject to adopt a strategy which is slow, cautious and certain to produce results. The studies considered here have little to say about the effect of cognitive strain as it ordinarily operates in classroom learning or in daily situations.

STIMULUS FACTORS

The Effects of Differing Numbers of Relevant and Irrelevant Dimensions on Concept Formation

Visual presentations designed for concept learning can be presented with varying amounts of relevant and irrelevant information. The concept of mass, for example, could be presented using illustrations involving complex objects such as automobiles and trains or very simple objects such as solid steel balls. Both kinds of objects could be shown to have accelerations dependent upon the quantity of matter they contained and both could be used to demonstrate the properties of mass in contrast with weight. In other words the number of relevant dimensions would be the same in each case. What would differ is the number of irrelevant dimensions. The steel balls would have color, shape and diameter as irrelevant dimensions, but the car would present a countless number of irrelevant characteristics. The same problem exists when a decision has to be made between the use of line drawings and half tones. The half tones carry many irrelevant dimensions while the line drawings carry little more than the essential information. For practical and theoretical reasons, it is important to determine the extent to which irrelevant dimensions affect the learning of the concept. There is also the additional problem of the extent to which learning in a situation involving few irrelevant dimensions can be transferred to a situation involving many irrelevant dimensions. Knowledge available at this time throws light on the former problem, but not on the latter.

Hunt (1962) has summarized the evidence on irrelevant dimensions citing a series of studies conducted by Bourne and his students. A general overview of these studies indicates that, as the number of irrelevant dimensions increases, the number of errors in concept learning also increases. However, it makes a difference whether the irrelevant dimensions are or are not redundant.

The problem is complicated by the fact that while an increase in the number of irrelevant dimensions, redundant or non-redundant, increases the number of errors, an increase in the number of non-redundant relevant dimensions in the learning of simple concepts also increases the number of errors. The effect is apparently one in which the amount of information represented by the stimulus array is of utmost importance. The addition of non-redundant dimensions to the stimulus array, whether they are relevant or irrelevant, increases the amount of information which the subject must process in order to solve the task.

In general, results show that changes in the number of relevant dimensions have a greater effect on the number of errors than do changes in the number of irrelevant dimensions. For example, Walker and Bourne (1961) varied the amounts of relevant information and irrelevant information and used Restle's (1955) mathematical model with some modifications from information theory to make predictions. The model predicted that a linear decrement in performance with increased irrelevant information would occur. The prediction was confirmed. This finding corroborated earlier experimental evidence. In addition, an exponential performance decrement resulted from the addition of non-redundant information. This result was also predicted by the model.

The effective design of audiovisual materials requires that much more information be available on this problem than is available at present. An introduction to a subject such as the structure of the cell in animal tissues could begin with presentations of drawings of cells which included only the essential features, or it could begin with photographs of actual cells which would include a vast number of irrelevant features (or it could begin with the examination of real cells). The photographs would show all of the essential parts of the cell but some of these would be difficult to observe and would be partially obscured by irrelevant features such as small amounts of foreign matter. The drawings, in contrast would have eliminated all the irrelevant features and could present the relevant features with greater clarity. One can suggest advantages of both of these procedures. The data presented in much of this book support the procedure of beginning with the simplified version. However, much more experimentation is needed on this matter before one of these procedures is advocated over the other.

A final point must be made before leaving the problem at hand. The statements which have been made about the effects of increasing the number of relevant and irrelevant dimensions have been derived from situations in which the role of the learner is one of discovery. There is a possibility that somewhat different generalizations would have been evolved if the learning situations studied had been closer to what is termed expository teaching. Typical audio-visual teaching materials do not generally call for a discovery process but rather are they designed after the pattern of expository teaching.

The Effect of Redundancy in Concept Formation

Bourne and Haygood (1959, 1961) have shown that redundancy of relevant information facilitates rather than inhibits performance on a concept learning task. This result is important, especially since in the previous section it was found that the addition of redundant irrelevant dimensions resulted in a performance decrement. However, in considering the case of redundant relevant information one must remember that the identification of any one of the several relevant dimensions solves the problem since all the others are redundant to it. For example, if in a three dimension problem the correct concept was large, red square, and these three attributes were redundant, (that is, they either all appeared or none appeared in any given exemplar), then the identification of any one of these attributes, be it red, large or square, would allow the subject to designate any given exemplar as being positive or negative. Insofar as this finding has generality, there are situations in which it might be applied to the planning of human learning experiences. The data suggest that while simplifications of the stimulus situation is desirable in many audiovisual presentations that the simplification should not be at the expense of redundant information.

The data from Bourne and his associates argue further for teaching concepts in a context which limits the transmission of irrelevant information, but caution should be used in making such a generalization, chiefly because optimum conditions for learning a concept may not be the optimum conditions for transfer.

Learning from Negative and Positive Instances

Early in the history of concept learning, research data appeared suggesting that less was learned from negative instances than from positive instances. The earliest result of this kind was reported by Smoke (1933). This result stood for nearly twenty years, when it was questioned by Hovland (1952) who pointed out that to arrive at such a conclusion one would have to know the amount of information contained in both negative and positive instances and also the amount of information needed in both cases to arrive at a solution. The complexity of the material used by Smoke precludes the possibility of estimating whether his negative instances provided less information than his positive instances.

In a later study by Hovland and Weiss (1953), materials were prepared so that the amount of information which could be conveyed by both negative and positive instances was known. The materials were also such that the subject could learn the concept either from negative instances alone or positive instances alone, or, of course, from a mixed series of both positive and negative instances. The following three conclusions were drawn in this study:

> "a. The correct concept is attained by a higher percentage of subjects when transmitted by all-positive instances than by all-negative instances."
>
> "b. Mixed positive and negative instances are intermediate between all-positive and all-negative series in difficulty of learning."
>
> "c. When the negative instances are displayed simultaneously, the accuracy of concept attainment is higher than when they are presented successively." (p. 182)

Hovland and Weiss go on to point out that performance with all-negative instances is inferior to that with all-positive, but that learning will still occur with an all-negative series of instances.

In the later studies by Bruner et al. (1956) a similar tendency was shown. Subjects tended to use less of the information provided by negative instances than by positive instances. One interesting finding in the Bruner et al. studies was the discovery that in the learning of disjunctive concepts the subjects actually use negative instances more effectively than positive instances. It is true, however, that the negative instances in this case carried considerably more information than did the positive instances.

Huttenlocher (1962) in looking at the results of the above named experimenters realized that the amount of information per instance was indeed an important variable. She desired to discover, as did Hovland and Weiss, the effect of positive and negative instances carrying the same amount of information per instance upon learning. She also wished to determine the effect that the order of presentation of positive and negative instances would have upon learning. It became evident that the order of presentation of positive and negative instances in the simplified experimental situation did have a significant effect ($p < .001$) upon the learning of concepts.

All of the tasks were solvable in just two instances with four possible orders; plus-plus, (that is, two positive exemplars) plus-minus, (one positive exemplar followed by a negative exemplar) minus-plus and minus-minus. A characteristic concept might be a black square. In the plus-plus condition the black square would be shown with another figure in the first instances and with a third figure in the second instance, thus leaving the black square as the only possible correct answer. As was the case in the Hovland and Weiss study the combination plus-plus was superior to them all and the order plus-minus was about the same as the plus-plus order with respect to amount of learning.

Attribute Identifiability, Coding, and Obviousness

Rate of concept learning is necessarily determined [illegible] gree, by the identifiability of the relevant attributes. On some areas of learning in typical educational situations the attributes involved in concept learning are difficult to identify and cannot be easily coded into language, while in other areas, attributes are well defined. Scientific concepts generally involve well defined attributes. The defining attributes of vertebrates in contrast with invertebrates are definite and unambiguous, and so are the defining attributes of such scientific concepts as mass, acid and so forth. Much less precise are the defining attributes of say "good form" in art or "style" in writing. The fact that the defining attributes of such concepts cannot be readily coded in words does not mean that they cannot be acquired, nor that they cannot be learned to the point where instances can be classified with a high degree of agreement among persons. Hull (1920) made the important discovery that in concept learning situation some persons could demonstrate through behavior that they had acquired a concept but still be unable to verbalize the basis for their decision. One suspects that the latter is true in acquiring many concepts in the arts. The student learns to make "correct" decisions when presented with instances but is still unable to give a precise account of the information he is using in arriving at those decisions. Hull's data are almost unique with respect to this problem since most modern research workers have used very simple materials with well defined attributes for correct instances. While concept identification without the ability to verbalize the correct attributes may occur with simple unambiguous materials, one suspects that it is primarily an occurrence when the defining attributes are complex and not easily described in words.

In studying the effects of the "obviousness" (defined in terms of the probability that a given stimulus dimension will be responded to rather than another -- a stimulus with a high probability that the subject will respond to it is said to be obvious) of stimulus dimensions upon the learning of concepts. Archer (1962) found that when the relevant information was obvious, the subject had an easier time learning the concept and when the irrelevant information was obvious the task was more difficult. A further finding was that when the relevant information was not obvious, it took significantly more time and errors to learn the concept, but when the irrelevant information was not obvious there was less of an inhibitory effect

An interesting sidelight raised by this experiment was the finding that women found form a less obvious dimension than size while men showed just the opposite. Archer suggested that one explanation for this phenomenon might be that the women did not have the same labeling ability with respect to shape as did men. To test further this hypothesis, Archer presented the stimulus materials to a group of forty men and forty women and asked them to state what they saw. The men saw "squares," "trapezoids," and "parallelograms," while the women saw mostly "squares" and "non-squares," or even "tipsy squares."

It is clear that there is a difference between stimulus dimensions with respect to the degree to which they are obvious, and that these differences affect the rate of learning.

A second problem is whether an attribute which is readily named is more readily learned than one which is not. While the more readily identified stimuli are generally those which are more readily named, one can conceive of a situation in which there are two stimuli which are equally easy to identify in terms of physical characteristics, but one has a name while the other does not. Would the fact that a stimulus had a name make it easier to learn as a result of this? To study this question, Rasmussen and Archer (1961) provided a group of 128 subjects with various types of pretraining. Their specific aim was to study the effects of teaching some of the subjects the verbal labels of some of the categories before the actual trials were begun. A control group practiced placing the various exemplars into categories on the basis of their aesthetic attributes such as color, shape, etc., but not with pre-training of a verbal nature. It was expected that the pre-training of subjects with respect to placing the exemplars into "named" categories would facilitate learning.

In order to control for previous learning, the experimenters used nonsense shapes which they then labeled with nonsense dissyllables. There was one ten sided figure designated "tarob" and one eight sided figure named "Latuk." Other dimensions varied were (a) size -- large or small, (b) number of figures presented on a single exemplar -- one of two of the same figure, (c) horizontal position on the screen -- the figure was either on the left or right of the screen, and (d) color -- green or blue. All possible dichotomous, conjunctive concepts were used, but of special interest were those in which shape was a relevant dimension, since the primary reason for this experiment was to ascertain what effect the "naming" of concepts has on the learning that takes place.

It was found that the interaction between the pre-training and the amount of learning and/or errors until criterion was reached was significant ($p < .01$), but not in the expected direction. Instead of the verbal pretraining facilitating the amount of learning going on to a higher degree than the aesthetic pre-training, just the opposite was true. It was suggested that this effect might be the result of the "set" introduced into the subjects that had received the aesthetic pre-training to pay more attention to the various stimulus dimensions which might have been relevant.

Those who had received language pre-training did do better in those instances where shape was relevant than in those where shape was irrelevant. This was to be expected since their pre-training would have much less in common with problems where shape was not a relevant dimension than in problems where shape was relevant. Those who had received aesthetic pre-training did better on all types of problems than did the language group.

Another possible effect that might be confounded in the above mentioned results is that of an apparent hierarchy operative in concept learning problems with respect to the "obviousness" of certain stimulus dimensions. Shape was possibly not as obvious as the other dimensions used.

The implication from these results is that in concept learning tasks in which the subject learns by a process of making decisions and obtaining feedback, the rate of learning will depend upon the extent to which the defining attributes tend to be responded to by the learner. Another deduction would be that, where the latter condition does not exist, cues should be provided so that the learner does not waste large amounts of time in following false leads.

Effect of Presentation Conditions and Effectiveness of Concept Development

The strategy adopted by the individual depends to some degree on the arrangement of the instances presented and on the order of presentation. Instances may be presented in two distinct ways. First, all instances may be presented simultaneously in a single display and the learner may choose the order in which instances may be reacted to. Second, instances may be presented one at a time with the order controlled by the experimenter. (There is a third possibility which is a combination of the other two in which the whole display is presented simultaneously with the experimenter pointing at various exemplars and asking whether or not they are correct, but we will not consider this separately). Examples of the first from educational practice would be found in a display of living organisms some of which were vertebrates and some invertebrates and where the learner was attempting to learn the difference between the two. Such displays are commonly introduced into recitation procedures. An example of the second method of presentation is found in the case where the teacher presents a series of slides, each one of which provides an illustration of either a vertebrate or an invertebrate.

In the case of the single display with multiple instances, Bruner _et al._ (1956) have presented evidence to show that learning is more rapid when the instances are ordered in some way within the display. The critical factor in the ordering is to make the attributes involved clearly visible. For example, a display of vertebrates and invertebrates would be expected to be more effective if the vertebrates were grouped separately from the invertebrates. If two groups are to be discriminated on the basis of several features, the grouping should be such that the several features stand out clearly as a result of the grouping.

Abstract versus Thematic Material and Ease of Learning Concept Identification

Bruner et al. have explored category learning where the material is completely abstract involving such attributes as geometric figures and colors, and learning where line drawings of "meaningful" situations involving human subjects are used. In the case of the latter "thematic" materials, the task of the learners was to identify attributes which would place a drawing in the "right" category. While a long series of researches have shown that in most serial learning and paired associates learning "meaningful" material is more easily learned than the relatively meaningless, and Underwood and Schulz (1960) have developed a rationale for this, the concept learning studies appear on the surface to illustrate an opposite effect. In the study under consideration in which meaning was an irrelevant dimension, the series of instances involving thematic material provided a more difficult concept learning situation than did the relatively less meaningful material. The phenomenon is due to the fact that the dimension referred to as meaningfulness, might more appropriately be described as a dimension of complexity. In a sense, the outline of a square is as meaningful as a picture of a horse, but the one is much more complex than the other.

The reason for the greater difficulty involved in the learning of the so-called meaningful material is almost certainly a result of the number of irrelevant attributes which are inevitably included in drawings representing complex events. The effective complexity of such drawings is reduced somewhat by the fact that subjects attend to certain attributes rather than to others, and if these happen to be the defining attributes then the undertaking of the task is greatly facilitated (as we saw in the section on Attribute Identifiability, Coding and Obviousness). For example, subjects tend to identify the sex of the individuals as an attribute and, if this is a defining attribute, then the task of the learner is greatly facilitated. The task would not be facilitated if the defining attribute of a "correct" drawing was the number of buttons on the coat worn by the figure since most subjects would probably have a low built-in probability of attending to such an attribute.

RESPONSE FACTORS

Response Requirements

The studies in concept learning differ with respect to response requirements. Some studies ask the subject to respond with an hypothesis as to the concept sought after each presentation of an exemplar. (For examples, see the studies of Bruner (1956) and Hovland and Weiss (1953).) Other studies have used as the task the assignment of the different stimuli into categories. (See Bourne and Bunderson, 1963; Bourne and Haygood, 1959; and Bourne and Haygood, 1961).

The nature of the response requirements will have an effect, in many cases, on the type of approach to a problem which will be adopted by the subjects. If the problem were to identify the correct hypothesis the subject would need to formulate beforehand at least some of the hypotheses which are tenable. In such a situation the occurrence of cognitive strain would be more likely to occur than in the categorizing of stimuli. The added burden of verbalization needed under this response requirement also adds to the difficulty by having to remember which hypotheses there were, which had already been discounted by the previous exemplars, and which were still to be tested. This would be quite a feat of memory. For example, if the stimulus array consisted of only two possible dimensions with two values respectively, then there would be many possible hypotheses to be tried. The dimensions might be color and shape. Shape could be either square or triangle, and color could be either red or blue. The different concepts could be:

1. Red
2. Blue
3. Square
4. Triangle
5. Red triangle
6. Red square
7. Blue triangle
8. Blue square
9. Blue or square*
10. Blue or triangle*
11. Red or square*
12. Red or triangle*

The difficulties in formulating, remembering and testing hypotheses becomes obvious as the number of relevant and irrelevant dimensions increases.

The other type of response requirement is that of categorization on the part of the subject. Part of the task of the subject would be that of identifying the characteristics that place different stimuli in different categories. After these characteristics had been identified (but not necessarily named as would be the case in the first mentioned response requirements) the subject would then assign the subsequent exemplars to one or another category by virtue of these characteristics. The act of categorization of stimuli rather than the verbalizing of hypotheses about them would appear to be somewhat easier. It has been shown that it is easier to place stimuli in their respective categories than actually to verbalize the relevant characteristics that place them there, as reported by Bruner et al., (1956). To skirt this problem in his book Hunt (1962) defined concept learning to include only those situations that involve the verbalizing of the concepts that have been learned.

*There might also be the disjunctive concepts red or blue, triangle or square, but these are not likely because of their inclusiveness.

Differences Between the Hull Technique and the Bruner et al. Technique

The two differences in response requirements mentioned above are accountable for the major differences between the Hull and the Bruner *et al.* studies. In the studies of Hull, the subject was presented with a series of Chinese characters and was given no clues as to which attributes to attend to in performing his task. The task was to group the various exemplars according to various patterns included in the Chinese characters. The different groups or classes of Chinese characters were named using nonsense names. When the correct nonsense name was paired with the correct group of characters, the task was completed. The subject's task was a classificatory one.

In the Bruner *et al.* studies, the subject was asked to solve the task by verbalizing various hypotheses as he proceeded from one exemplar to the next. The materials used by Bruner and his associates were much simpler, each presentation consisting of a card upon which a set of geometric figures were drawn with some of the figures differing along several dimensions such as size, color, shape, etc. After each exemplar was presented the subject was asked to hypothesize what the concept was.

The difference in the materials and techniques used by Hull and Bruner *et al.* accounted in all probability for the difference in the strategies used by the subjects in these two series of studies.

Factors in Subject Strategies

Common observation indicates that the strategy adopted will depend on the number of opportunities that are to be provided for identifying the defining attributes. If the problem is to be solved on the presentation of a single instance, then the only strategy to adopt is to make a complete guess. If just a few instances are to be presented, the strategy called for will be one of boldness rather than caution. Caution is appropriate when a large number of instances are to be encountered and a slow but sure procedure guaranteed to lead to knowledge is in order. Presumably, individual differences exist between subjects for the above statements assume that the learner behaves in a rational way. One might expect that some learners would never use a strategy involving a wild guess while others might habitually do so. In contrast, some subjects may be expected to proceed with an extremely cautious approach which cannot possibly permit them to solve the problem in the time available. A more explicit discussion of this area is found in Bruner *et al.* (1956).

These facts raise the possibility that in concept development tasks, using audiovisual presentations, there may be advantages in giving the learner cues concerning the strategy he should follow. Whether subjects will be generally able to follow the strategies indicated is a matter which will have to be empirically demonstrated.

Subjects faced with a concept learning task show individual differences in their approach to the problem. Approaches vary in efficiency which can be measured in terms of the extent to which they make full use of the information. Subjects do not necessarily use the most efficient approaches even when they are well trained on these kinds of tasks, perhaps because efficient procedures may make a demand on the memory of the subject beyond that which can be reasonably made, or because the subject just doesn't know the more efficient procedures.

Concept learning tasks may be undertaken under two distinct conditions. In the first of these, the subject himself chooses the instances that are to be judged and from which information is to be derived. The second condition provides no such freedom of choice for the instances are under control of conditions external to the subject. This second condition is typical of the teaching situation and audiovisual materials used for the teaching of concepts almost invariably follow this second procedure. Movies and recordings necessarily follow a procedure in which a fixed order of instances is used and in which the subject cannot call for particular instances.

When the learner can call for particular instances with particular characteristics there are greater variations possible in learner behavior than when he cannot exercise such control. Such variations in behavior are roughly comparable to the stiuation in which a student is studying on his own and can control the rate of presentation and the order of presentation of the lesson material to a great extent. Within the classroom instances occur without the learner having too much to say about their order.

When the learner can choose or call for instances, he is likely to be able to discover the defining attributes of a concept more efficiently than when instances are presented in random order from a population of instances. If the task involves discovering the attributes which cause a diagram to be designated as right rather than wrong, the learner may have established that the large diagrams rather than the small are designated as right and the ones involving curved lines rather than straight lines. He may still have to determine whether color in contrast to black and white is an essential of a right diagram. This he can do by choosing a diagram with a large figure with curved lines and without color. If he finds that this is <u>not</u> a <u>right</u> diagram then color is likely to be a defining attribute of a right diagram. He can do this in a single trial if he is free to choose instances, but in the condition where the subject does not have such control, he may have to wait for such an instance to occur. When the learner can select the instance from which he is to learn, a number of strategies are possible. However, our concern has to be here with the case in which instances are presented in an order determined by an agent other than the learner since this is the case most frequently encountered in education and in audiovisual aids.

Bruner and his associates were the first to point out that behavior during concept learning was different depending on whether the learner could select the instances or whether the instances were presented to him either in some order determined by a teacher or in a random order. Where the order cannot be determined by the learner but is determined by external conditions, the behavior of the learner is referred to as a reception strategy. That learners differ in reception strategies which they adopt is an important fact because the designer of a series of audiovisual presentations may design his series with the assumption that the receiver will adopt one strategy and the receiver may adopt a different strategy The subject s strategy may fail to utilize the cues which are incorporated in the series by the designer.

Two main reception strategies are described. These two strategies are not theoretically derived but are based upon the actual behavior of subjects in a concept learning situation. The two types of strategy are described as the whole strategy and the part strategy and although in the situation described persons tend to follow the one or the other there is nevertheless some variation of behavior and no strategy is followed with complete consistency.

In order to illustrate the difference in these two strategies consider the case of the student learning the characteristics of Dutch colonial houses which differentiate them from other houses. The student might be presented with a picture of a particular Dutch colonial house in order for him to learn this concept. The student could look at the picture and making the assumption that he is to be concerned only with gross features and not trivial details he could hypothesize that all the major features of the particular houses are the attributes that distinguish it from other forms of architecture. In doing this he notes the peculiar shape of the roof the size the color of the exterior walls, the form of the windows, the central location of the front door and others. This is the wholist strategy that is being adopted. On the other hand a student who takes the part strategy might decide that only the roof was the distinguishing feature, or only the roof and the position of the front door. This is the initial hypothesis of the partist strategy (or the focussing strategy as it is commonly designated).

When subsequent instances of a Dutch Colonial house are presented the procedure adopted will depend on whether the learner began with the part strategy or the whole strategy. If he had begun with the whole strategy then he would examine a new instance and determine whether it did or did not have the same characteristics as the original instances. If it is an example of a Dutch colonial house and has all the features originally hypothesized to characterize a Dutch colonial except for the color of the paint then he can eliminate the color of the paint as a relevant attribute. Again, if he is shown a picture of a house which is not Dutch colonial, but which has all the features of the original example except for the shape of the roof he then has evidence that the shape of the roof is probably a relevant characteristic of the Dutch colonial.

While the person who starts with a whole strategy identifies many attributes as his first hypothesis and then whittles them down as additional instances are presented, the person who begins with a part strategy selects relatively few and then adds additional attributes as needed though sometimes he will have to subtract. Bruner and his associates also note that subjects sometimes abandon particular strategies.

Although the part strategy is particularly dependent on memory and both strategies require that the learner keep track of what has happened and what has been learned the subjects in the experiments under consideration did not seem to benefit much from the taking of notes. The human learner falls far short of being the efficient retainer and utilizer of information which an ideal concept learner would have to be.

Now, it must be made clear that the discussion of strategies presented in the Bruner et al. volume is based on the behavior of subjects dealing with highly simplified stimulus materials. The task of the learner is further simplified by the fact that he is told specifically what attributes to attend to. In a real situation, such as that of learning the concept of a Dutch colonial house, the relevant attributes are even more numerous. Under such conditions it would almost seem necessary to provide cues unless the learner is willing to be exposed to a very large number of instances which would make learning very time consuming and tedious to the point where the learner is likely to give up. Very little is known about the strategies adopted when the learning of complex concepts outside of the laboratory is involved. Nothing is known about the effect on a learner of imposing a whole strategy when the learner may be accustomed to approaching the problem with a part strategy.

Searching Behavior and Concept Learning

A common criticism of audiovisual presentations is that they do not call for active behavior on the part of the learner. How far such active behavior is important in concept learning is not clear from experimental evidence, but one is tempted to generalize from other kinds of learning studies which suggest that relevant activity during the acquisition of a skill generally improves the rate of acquisition. A single study by Della-Piana (1957) throws some light upon this point. Della-Piana presented his subjects with a concept learning task in which the relevant attributes were embedded in figures. His experimental technique, as far as stimuli were concerned, was similar to that which has been widely used in concept-learning studies. He attempted to influence the amount of searching behavior shown by the subject by varying the directions and the procedure involved. For one group, the subjects were instructed to keep trying until they found a solution. In the alternative treatment subjects were immediately told the correct answer as soon as they made an error. Della-Piana was careful to control the time of exposure to each problem by allowing the subjects who were given the correct answer to continue to look at the feedback signal for a given amount of time. Della-Piana concluded from his data that the directions which encouraged a searching procedure produced superior concept learning.

Mediating Responses and Concept Learning

The use of simple materials with a controlled number of relevant and irrelevant dimensions has characterized research on concept learning in recent years. While the use of such materials has the obvious advantage of providing control over stimulus characteristics, it has also the less obvious advantage of reducing the complexity of the mediating processes operating which in turn has permitted the use of elegantly simple models of concept learning.

In the field of concept learning, the application of such theoretical models finds its roots in a paper by Bourne and Restle (1959) in which an earlier model of Restle (1955) related to discrimination learning was applied to the analysis of concept learning. The 1959 paper of Bourne and Restle also provides some supporting data. Bourne has followed up this work with a series of researches in which various aspects of the model have been explored.

In subsequent studies by Bourne and Haygood (1959), Walker and Bourne (1961), and Battig and Bourne (1961), using a simple concept learning task, data were presented which were generally consistent with the model. The simple nature of the stimulus materials seems to provide the conditions necessary for the demonstration of the validity of the Bourne and Restle model.

Bower (1961, 1962a) has presented data involving a paired associate task using nonsense syllables in which the analysis provides evidence that cue-responses associations are built on an all-or-none basis. In later studies using very simple stimulus material (1962b) and a concept learning task similar evidence also emerges. Bower (1962a) also points out that in other kinds of learning situations in which conditions have been grossly simplified, one trial learning has also been demonstrated.

In studies of the learning of concepts the model generally assumes that the learning of the hypothesis which goes with a particular stimulus element occurs on a single trial which may be any one of n trials. Before the trial on which learning occurs the behavior of the learner is random, but after that trial the stimulus is correctly coupled with the response.

Under such simplified laboratory conditions the subject is restricted in the amount of searching behavior which he must undertake. Furthermore, the learner does not have to vary his procedures in looking for the relevant attributes as he would almost certainly have to if the task were at a more complex level. The learner also has no problem of coding the information prior to the testing of hypotheses. In addition, the situation places few demands upon memory and thus the hazards of placing information in storage and taking it out again are reduced to a minimum. What these restrictions do is reduce the mediating processes which ordinarily enter into concept learning tasks in daily life. Under such simplified conditions it is hardly surprising that the learner either knows that, say, red is a relevant attribute or does not know. Such a bit of information as this highly restricted task is either known and stored or not known and not stored.

Some of the failures in reproducing demonstrations of all-or-none learning may well stem from these difficulties. The impression given is that any marked increase in the complexity of the stimuli will either mask or dissipate the effect. For example, Battig (1962) attempted to reproduce the effect in a paired associate learning situation, but could find no evidence of the phenomenon. In the interpretation of the Battig results it is important to keep in mind that the stimuli included nonsense shapes and digits. The nonsense shapes are clearly stimuli which are very difficult to code since ordinary languages does not have names for them. The difficulty of the subjects in coding the nonsense shapes may have introduced processes which would tend to mask any clear-cut all-or-none effect.

It is reasonable to assume that an important set of mediating processes relates to the selection of particular hypotheses to be tested with any instance encountered. This, in turn, involves two problems. First, there is the problem of how the organism acquires such a set of hypotheses to test. Second, there is the problem of how one hypothesis rather than another is to be selected by a learner faced with a particular instance. A position advanced by Restle (1962) is that the selection of an hypothesis is made at random from a population of hypotheses. Bower (1962b) advances the same assumption and, just as Restle, suggests further that the sample is drawn and is then replaced and, hence, is just as likely to be drawn on further occasions The mathematical aspects of Restle's hypothesis selection theory (he uses the term strategy, not hypothesis) are essentially similar to his earlier cue learning theory (1955).

The other aspect of the problem, namely, how rules come to be found is of major importance to the design of audiovisual materials.

While theories of concept learning have concentrated attention on such problems as those of cue selection, cue-response association, and hypothesis selection, they have had little to say about the problem referred to in an earlier chapter as that of stimulus coding. Dodwell (1961) has pointed this out in an article which stresses the fact that whether learning does or does not occur in a shape discrimination task may depend upon the capacity of the organism to code the information in a manner which permits such discrimination. Theories such as these of Estes, Restle, Bush and Mosteller, ignore this problem and find support in data derived from tasks which subjects in our culture code with great uniformity. Such tasks, involving squares and triangles of two sizes which are colored either red or white, eliminate the complex problem of coding found in developing concepts such as that of a cat.

Motivational Factors

There is very little evidence on the effects of extrinsic motivators in concept formation tasks. This is, of course, a reflection of the fact that there is very little known about human motives in general. It has been postulated by some scientists, however, that there is a "need" or "drive" that moves men toward the solution of problems even when a basic need such as hunger is not involved (cf. Bruner et al. 1956, pp. 15-17). Experimenters have noticed that often a great deal of affect is displayed by the subjects during concept learning experiment even when the only reward was to get the task done.

Another important factor to be considered in this section is the "set" with which a subject approaches a concept learning task. The phenomenon of hierarchical structure among various stimulus dimensions (i. e., obviousness) might be explained by the psychological sets brought to the situation by the subject. The instructions given to the subject can greatly affect this set. In the Bruner et al. technique the subject is often told which of the various stimulus dimensions were free to vary, and which were not. This has been found to be facilitating to learning because it actually has the effect of decreasing the number of irrelevant dimensions attended to and therefore decreases the amount of information that has to be processed to arrive at a solution.

If the subject should assume that an irrelevant dimension is relevant, and approach a problem with this "set", then the problem is made more difficult because two types of learning must then go on. First, the subject must learn that his assumption is wrong before he will test out others, and then he must go on and test out others. Other effects of set on the learning of concepts are much the same as in other learning tasks.

If the subject has little or no motivation to succeed in the task, it is reasonably certain that this will reflect in his performance. If, however, the subject's motivation is too great, it might act to his detriment as well. Since motivation is to some degree controllable by the experimenter by varying instructions, rewards or punishments and so on, it might be profitable to investigate this area to see if an optimum level of motivation exists at which the greatest amount of learning goes on.

Memory and Concept Learning

The role of memory in concept learning is a matter which has scarcely been discussed though it has considerable importance. A brief discussion is presented by Hunt (1962) who points out that little is really known about the function of memory in concept learning.

In one study, Cahill and Hovland (1960) explored the question of memory and concept learning, using as their two conditions a simultaneous or "unlimited memory" condition in which all of the previously presented exemplars are left in the view of the subject as well as the new exemplar, and a successive or "limited memory" condition in which the previously presented exemplars are not available to the subject except as he remembers them, and only the new exemplars are in view.

They found that only a very few errors were a function of the failure of the subject to assimilate properly the information presented in an exemplar. Most of the errors were attributable to failure to remember earlier instances in such a way as to see their implications.

These data indicate a close tie between phenomena of concept acquisition and of memory.

Hunt (1962) points out that, in theory, concept learning can proceed along two distinct lines. On the one hand the learner might store both the response and the feedback obtained from each instance. Each new response would then be made calling upon the information thus stored. On the other hand, the learner might begin by stating all the tenable hypotheses concerning the attributes which might have relevance for defining the concept and each instance would be used for eliminating some of these hypotheses. The latter procedure would involve memory at least to the extent of remembering which hypotheses had been eliminated by previous instances. The retention of hypotheses would involve a more limited storage facility than the retention of the specific information provided by each instance.

Several points stand out from the literature in the field which have relevance in the present context. First is the fact that subjects learning concepts differ in the strategies which they use and these strategies in turn make different demands upon memory. Second, a strategy which makes a high demand on memory tends to be one which is likely to be discarded in favor of one which makes less demand upon memory. A strategy which produces a demand upon memory produces cognitive strain which in turn may result in the modification of the strategy. Third, subjects do not make much use of equipment such as paper and pencil which might reduce cognitive strain by reducing the need to retain information. The latter may well be a result of training and the tendency of teachers to provide displays without requiring the students to make notes of their observations.

Bruner et al. (p. 154) cite data concerning the extent to which subjects use recording devices for retaining information about hypotheses they have tested with a particular instance. Where the attributes involved are many, the retention of the information gained becomes a difficult problem. The data indicate, however, that even when facilities for the recording of information are provided, subjects do not make use of these facilities to the extent to which they should if they are to perform efficiently. The reason for this is a matter for speculation. Subjects often report difficulty in retaining information in a concept development task so the lack of awareness of this difficulty is not the issue. One is led to suspect that the main reason lies in the fact that in this kind of task they have not previously learned to take notes to prevent information from being lost. Indeed, when similar tasks involve audiovisual aids such as sound strips, conditions are typically not congenial to note taking. One also suspects that many audiovisual aids might be much more effective if they were used in conjunction with a note taking or problem solving activity on the part of the viewer.

The implications of these findings would appear to be that when audiovisual materials are designed for use in concept learning the design of the sequence of experiences should be such that it minimizes the demands made on memory of the attributes and characteristics of particular presentations. Training in the use of methods of recording and keeping track of information might serve this purpose, but this would require a radical departure from the usual procedure which generally prevents the student from taking notes or recording the decisions which he makes.

Another issue related to the efficient use of memory in such learning is raised by the fact that the way in which information is coded may determine what can be retained. This position has been advanced by many writers, but Miller (1956) and Miller, Galanter, and Pribram (1960) have expanded on the point. Miller points out that a person can very easily learn to repeat in sequence a list of randomly arranged zeros and ones, if he is capable of coding them into a system with a different number base. Thus any set of three mixed zeros or ones can be coded as a single digit ranging from zero to seven. Thus a string of 24 zeros and ones can be recorded as an eight digit series which is relatively easy to remember. From observations of this kind, some scientists have been led to make the generalization that the efficiency of the use of the storage capacity depends upon the nature of the coding system used. The case for this position appears to be fairly strong.

Now consider the implications for this position, assuming that it is sound. If the teacher is presenting a series of slides to demonstrate the characteristics of, say Gothic architecture, a part of the problem of the student is to determine the defining attributes and the limits of these attributes for this style of construction. Connected with this task is that of coding the attributes. The student might look at a series of Gothic arches and attempt to remember their general form. He might also code this information into such terms as "pointed arches," "slender columns," "lace-like roof structures" and so forth. Available knowledge suggests that, unless coding of this nature takes place, the retention of information presented through the visual channel is likely to be small and inaccurate with a great deal of erroneous information added. Almost nothing is known at this time about the extent to which information delivered through one channel may be used to code information transmitted through another.

FEEDBACK

Effect of Post Informative Feedback Interval

Reinforcement theory of learning takes the position that the response-reinforcement sequences produces modification of behavior. What happens after reinforcement is irrelevant except where some form of retroactive inhibition occurs or where additional trials or experiences are arranged which contribute further to the skill that is being acquired. Yet common experience suggests that, after a response has been made and information is given concerning its correctness, one can benefit from further examination of the displays involved. The latter should be particularly beneficial where the response would be described as a guess. In such a case, the reinforcement would presumably reinforce the tendency to make random responses lacking any rational foundation, but the post reinforcement examination period would permit the learner to develop a rationale for his response.

Bourne and Bunderson (1963) have conducted a study in which the time of exposure of a display following informative feedback was studied. These investigators used a concept learning task involving the geometric designs in which each characteristic could assume one of two values. The subject was shown a design and pressed one of four keys to indicate the category in which he believed the particular design belonged. Immediately after the informative feedback had been given, the diagram could either be removed or could remain in view for an amount of time determined by the experimenter. Bourne and Bunderson found a significant relationship ($p < .01$) between the post feedback interval and success in learning the task. This factor interacted significantly with the task complexity ($p = .001$) with more being gained by delay in the case of the more complex problems.

These results appear to have important implications for human learning in situations that involve visual displays. If the display is removed too rapidly after the learner has been given cues about the significant elements, the result may be an inefficient learning situation.

Relation of Time of Informative Feedback to Other Learning Conditions

Informative feedback can be given at various times after a display appears. In the typical concept learning task the informative feedback is given following the response of the subject. Perhaps this procedure is followed because it is the one which fits reinforcement experiments and reinforcement learning theory has had a profound effect on American psychology. The informative feedback could be given simultaneously with the display or at any subsequent time, even after the display is removed. The problem with which we are concerned here is that of identifying the time of occurrence of informative feedback which is most effective for producing learning.

Bourne and Bunderson (1963) have reviewed studies in which there has been a delay introduced between the time of the response of the subject and the time at which the informative feedback is provided. The studies seem to show a clear cut pattern that delayed feedback has no deleterious effect. This finding is unlike that found in delayed reinforcement studies with animals in which some do and some do not demonstrate a deleterious effect resulting from the delay, the amount of decrement depending on the particular conditions operating. One may presume that, under some conditions, delay in feedback will result in the forgetting of the relevant stimulus characteristics to which the response was made but under other conditions retention will be adequate to permit the full use of feedback.

Nature of Solution or Task

A concept may be analyzed into at least two components, (1) rule and (2) attributes. For example, the correct concept might be defined by the attributes large, red, and square. The concept is a conjunctive one, that is, all three of the attributes must be present before the exemplar is correct. The "rule," then, is a conjunctive rule. The correct concept is characterized by a figure that is large <u>and</u> red <u>and</u> square.

There are two kinds of task requirements that may be imposed in a concept learning experiment. The subject might be required to identify the relevant attributes of the concept, or he might be required to find the rule which identifies the relationship of the attributes one to the other.

Most of the studies to date involve the subject in identifying the relevant attributes. The concepts that are to be attained are defined in terms of their attributes. Such attributes as shape, color, size, and number are familiar to the reader in concept formation studies. There are analogous situations in the more complex stimulus arrays that one confronts in life. What are the attributes that differentiate dogs from cats? Shape? Color? What are the attributes that differentiate good men from bad? And so on.

While it is true that most of the situations that we generally think of as concept learning stiuations are of this type, there are other situations that require subjects to do something different. Consider a problem-solving task in which the subject is to find the answer to a complex story problem in mathematics. Some attention will have to be paid to the relevant attributes of the problem, but the main consideration will be the rule or rules which the subject needs to know in order to solve this problem. Much of the work being done in the classrooms today is directed toward the learning of those rules necessary to solve problems. Most of mathematics is centered around "rules." And those sciences dependent upon mathematics for rigor and progress are also dependent upon these rules.

Haygood (1963) undertook a study that demonstrated that attribute learning and rule learning were indeed two different and independent aspects of concept learning. Most of the work to date in concept learning has been in the area of attribute learning, but with the emphasis upon rule learning in our schools it seems that much work in the area of rule learning should be undertaken. Progress toward the definition of a maximally-efficient problem-solving behavior in rule identification would be important to education.

Summary

The classic study in concept learning is Hull's 1920 study using parts of Chinese characters imbedded in Chinese characters of differing complexity. Although no measure of the complexity of the accompanying irrelevant parts of the Chinese characters was given, it can safely be assumed that the stimuli used by Hull are more complex than those used in later studies. This leads to the statement that Hull in this very first study actually presented his subjects with a situation much more like life than the usual laboratory study of today.

Since 1920 others have been working in this area and accumulating valuable information. The majority of these researchers have used the basic paradigm as laid down by Herbert and used by Hull. Within the framework of this paradigm several variables have been systematically varied with results that suggest to the audiovisual field certain problems with which to concern themselves and certain procedures to follow as well as areas of further exploration. Some of these are:

1. An increase in the number of non-redundant relevant and irrelevant attributes and/or redundant irrelevant attributes which the learner must process increases the difficulty of learning the desired concept. The addition of redundant relevant dimensions increases the likelihood that the concept will be correctly identified. Simplifications of the stimulus array seems justified in all cases except those in which essential information is removed. In many concepts, motion is not a relevant attribute, and it is questionable whether or not motion adds to the learning of such concepts. However, in some concepts, such as harmonic motion, the use of moving pictures is necessary to display the essential attributes of the concept. It is also true that some concepts, such as rhythm, do not need the visual channel at all. The addition of irrelevant information in any channel would tend to increase the difficulty of the task. It should be remembered, however, that many of the concepts learned under other than laboratory conditions are learned amidst a great quantity of irrelevant information, and that transfer might be facilitated under such conditions. This is an area that needs to be explored.

2. The type of strategy used by a subject is an individual matter, and one cannot conclude that all subjects will use the same strategy when confronted with the same situation. It is possible to affect the type of strategy used by a given subject by varying some or all of the factors which determine which strategy will be used. Some of these factors are: (a) the type of stimulus material, (b) the number of stimulus variables, (c) the type of response required of the subject, (d) the relative cost of errors, (3) the number of tries allowed the subject, and (f) the instructions given. More research needs to be done looking into the question of how these factors and possible other factors effect the strategies used. Research is also needed to determine whether it is possible to control the strategies used by at least the bulk of the subjects or learners. The results and their application would be an added insurance that the audiovisual aid would achieve its desired purpose.

3. There are, apparently, limits to the amount of information a human can process. One must, therefore, either limit the amount of information contained in a stimulus array or series of such arrays, or one must code the information to be learned in a manner such as to make less demands upon the subject. By planning the sequence of displays and audio materials so that the learner does not have to keep track of many items of information, excessive cognitive strain can be avoided on the part of the subject. It might also be profitable in some instances to provide the learner with note taking materials and time for taking notes, or provide him with a series of notes which would help him perform his task.

4. Positive exemplars result in the greatest amount of learning with the combination of positive and negative exemplars coming in second and the case of negative exemplars last. However, learning still takes place even in the case of negative exemplars alone. It is possible that with practice a subject could be taught to make more efficient usage of negative instances. Cues could be devised that would overcome the tendency on the part of subjects to fail to use negative information efficiently. More work needs to be done in this area.

5. Training using more different exemplars is more advantageous than training using fewer exemplars for a longer time. It is often the case with audiovisual aids that they provide only a very meager introduction to the various possible exemplars of any given class or category. It might be profitable to use some of the time allowed in an audiovisual presentation to acquaint the learner with more examples of the concept at hand.

6. One can control the stimuli to which a subject is attending much more efficiently when the stimulus array presented is stripped of all the irrelevant attributes. This would argue for less complex arrays with many of the now used embellishments being dropped. This control can also be greatly affected by instructions which point out the relevant attributes beforehand, or by adding a redundant dimension such as coloring the important parts of a visual display red. Correctional feedback also has the effect of limiting the amount of information in the stimulus array that the subject attends to. Several questions arise with respect to the use of cues and/or feedback. For example:

(a) If the attributes involved in the concept development task are visual, then should cues for identifying these attributes be auditory, or should they be visual (such as using arrows or the encircling of relevant features)?

(b) What should be the relationship between the cues of informative feedback and the presentation of the visual display? Presumably, cues should be given a few at a time or the learner may become overloaded with information.

(c) Another problem is the matter of the extent to which the learner should make decisions as a result of cues which may make the chances of errors very unlikely.

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CHAPTER 8

ATTENTION

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Introduction

In the latter part of the nineteenth century and first twenty or so years of the twentieth century, the phenomenon of "attention" was considered to be one of the major areas of importance in the study of psychology. From the middle of the 1930's until very recently, however, the concept of attention fell into disfavor primarily because of the popularity of the behavioral school of psychology which, according to Paschal, (1941, p. 385), Woodworth and Schlosberg, (1954, p. 73) and others, rejected the notion of attention as a "mentalistic" concept. During the 1950's interest in this area was regenerated and today theorizing, criticism, and experimentation, especially concerning the selection aspect of attention, and the condition of attention are again being pursued extensively.

Historical Development of a Definition and Theory of Attention

It seems evident, from the history of controversy surrounding the area of attention in psychology that a definition of and theory of attention depend, to a large extent, upon the phase of the process being examined.

The study of attention as an issue in psychology rather than in philosophy was begun as early as the 1890's with Wundt and his students who were concerned with psychology as conscious experience. Boring (1950, p. 338) pointed out that Wundt, viewed attention from the final stage in the attention process -- that of "apperception" and that attention meant "focus of consciousness" in his system.

According to Boring (1950, p. 537), James McKeen Cattell also studied attention phenomena and undertook some of the classical range-of-attention studies.

These early experiments on attention reached a climax with the studies of Titchener, for whom attention was part of the changing process of experience, specifically part of the selective process in "determining the focus of consciousness." In his scheme attention simply meant a "clearness" attribute in the sensory process.

Following Titchener's work came studies by two of his students -- Dallenbach and Geisler who elaborated on Titchener's "clearness" theory, and studied other aspects of attention such as range, distraction, degree, distribution, and other conditions. Stimulus qualities as determinants of attention were also investigated during this period. At this time, work was also being done on what Wundt called "active" and "passive" attention. These two classes of attention phenomenon have been designated by more recent theorists (Roback, 1955, p. 106-107), including those followers of Pavlov in the Soviet Union, as "voluntary" and "involuntary" attention (Milerian, 1957, pp. 84-91).

William James, the exponent of the new American school of psychology-Functionalism, which pointed the way for the development of modern American psychology, viewed attention quite differently from Wundt and Titchener. Functionalism was essentially concerned with processes rather than content and consciousness, and hence attention was considered as one of many processes -- specifically a selection process.

According to James;

> It is the taking possession by the mind, in clear and vivid form, of one out of what seems several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are its essence. It implies withdrawal from some things in order to deal effectively with others.
>
> (James, 1890, p. 403)

The essential difference between the Structural position and the Functional one here lies in the second sentence -- focalization rather than focus -- the on-going process rather than the end result.

While this does present the general viewpoint of the functionalists, there was disagreement among them as to the actual mechanism of the selection process (Paschal, 1941, p. 384). Angell believed it was the result of "action of the will." Dewey theorized that it was "an activity of the mind itself -- an active association," and James saw it as "anticipatory adjustment." James also suggested physiological mechanisms as being the possible instigators of the attention process. Paschal writes that, oddly enough, although the modern view of attention is an offshoot of the earlier functionalist position, (regarding attention as a selective process) as do Solley and Murphy (1960, p. 175), Paschal (1941, p. 385), Berlyne (1960. p. 77), and Brown (1960 implied), the "how" of the process has been experimented with very sparsely since the times of the functionalists, and it still remains for modern experimentalists to deal with the physiological and psychological mechanisms which influence the attention process. Indeed we know very little today about this process from a physiological viewpoint save that there seems to be anticipatory adjustment of the sense organs and hence the peripheral nervous system is involved, and that there exists the possibility of "blocking" out stimuli, such as the blocking of specific auditory attention somewhere along an auditory neural pathway.

Modern Conception of Attention

Since 1950 there has been a revived interest in the concept of attention. This interest has received its impetus from a number of sources. First, some of those investigating learning phenomena have been concerned with the fact that learning requires a selective intake of information and that the selection process can be closely identified with what previous generations of psychologists have referred to as an attention process. Second, psychologists investigating vigilance behavior are engaged in studies which not long ago would have been called attention studies. Thirdly, industrial psychologists have investigated the characteristics of an advertising display which attracts attention. Thus the area presents an array of ideas and findings which bear some relationship to the problem of designing audiovisual teaching materials and some relationship to the research reviewed in earlier chapters of this document. A difficulty encountered in relating material on attention to, for example, the perceptual studies reviewed in other chapters is that they are couched in a different language.

Among those psychologists concerned with problems of learning, the names of Donald Hebb and Donald Berlyne stand out as two persons who use the term attention in their writings and who appear to believe that it is still a useful concept. What they have done is to attempt to fit the concept of attention into a behavioristic framework.

Hebb is concerned, as are most modern theorists, with the selectivity part of the attention process. He defines attention specifically, however, as "central facilitation of a perceptual activity," and thus meaning the very same thing as "perceptual set" -- "a process which makes one thing seen more readily than another" (Hebb, 1949, p. 102). Other modern psychologists, for example Brown (1960, p. 105), take issue with Hebb for his statement that attention is identical with perceptual set. Nevertheless, one must consider that Hebb did point out that attention as it has been used in the literature has several meanings and that he is using it in only one sense. The inconsistency lies mainly in the fact that at one point in his book he equates attention and set (Hebb, 1949, p. 102), and later (p. 153) he maintains only that "perceptual set is another aspect of the phase sequence, closely related to attention." In these later pages he identifies attention as the "immediate facilitation from one phase or assembly action on the ensuing one," and implies that one's set has been established at an earlier point.

Berlyne has written on the subject at greater length than Hebb and has devoted both an article to the subject (1951) and more recently has elaborated on the topic in a chapter in a book (1960). Berlyne's earlier writing on the subject (1951) was produced at a time when he was evidently influenced strongly by the writings of the late Clark Hull.

Berlyne's Theory of Attention

Before trying to form an "objective theory of attention" (p. 137) Berlyne concerns himself with describing the outward behavioral manifestations of attention, and discussing the whole perceptual process (attention comprising a part of this process) in its relationship to behavior theory.

In reviewing the topic of perception, Berlyne suggests that we need to combine the "logical rigor" of Hull's behavior theory with the large quantity of data collected by the Gestaltists to form a useful theory of perception and enable psychologists to turn more to basic research dealing with "fundamental laws" of perception and other psychological phenomena, and drop some of the semantic quibblings with which so much time and energy is taken today (p. 138). He prefers to treat perception operationally through discrimination, saying:

> ...an organism perceives two stimuli or stimulus complexes alike if its responses to both...are in all circumstances identical.
>
> (Berlyne, 1951, p. 138)

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Thus, defining perception in terms of overt behavior it is quite possible to study this process experimentally.

Berlyne reviews selected principles related to learning which have applicability to perception and suggests a way of incorporating "attention" into this behavioral framework by regarding attention as "the momentary effective reaction-potential of the perceptual response." This is, of course, Hull's concept which he denoted by the symbol $s\bar{E}R$.

As determinants of attention, Berlyne cites stimulus intensity and change, motivation and value, postural adjustments and preparatory sets, and novelty and curiosity. All of these have been considered for some time by educators and producers of audiovisual aids as cues in designing educational materials.

To account for the fact that the perceptual field (often) consists of a stimulus on which attention is primarily focalized and several stimuli receiving less attention, Berlyne assumes that at any one time there is more than one response-tendendency present, and that each of these "has a reaction potential high enough to produce a response of considerable amplitude, but that they are incompatible, so that only the one with the highest $s\bar{E}R$ can exist at one time," (p. 144). Berlyne also hypothesized, however, that there may be at times "partial compatibility" allowing two responses to be evident at the same time, though only one is existing at full strength. This concept of attention appears to identify it with an information processing channel. One aspect of the environment produces a particular internal response while other aspects of the environment at the same time fail to produce internal responses or produce very weak responses. This is the single channel information-processing model couched in Hullian terms.

Berlyne's chapter on attention in his book Conflict, Arousal, and Curiosity (1960) deals with the process far more extensively than did his earlier article. In his later work he relates information theory to the problem of attention, a relationship which is really implicit in his earlier writing. The two aspects Berlyne describes in information language concern: 1) "the problem of how much information is being transmitted," and 2) the selectivity aspect -- "which items of incoming information will occupy the organism's limited information -- transmitting capacity," (Berlyne, 1960, p. 45).

The classical study by Moruzzi and Magoun (1949) is cited by Berlyne as indicating that the part of the central nervous system most involved with what he calls the intensity of attention is the recticular formation, or the reticular activating system, extending through the mid and lower brain.

Berlyne then directs the reader to consider three problems of attention from the selection aspect. The first problem is that of attention in performance. Here the individual is confronted with more than one stimulus with "incompatible responses." The problem is which stimulus will produce a response. The second problem is that of attention in learning. In a learning situation, when an organism is being reinforced when it is receiving several stimuli, which stimuli will become most strongly associated with the response? Finally, Berlyne notes the problem of attention in remembering. "When the organism is receiving a number of stimuli, which stimuli will he be able to remember on future occasions" (Berlyne, 1960, p. 52).

The major portion of Berlyne's chapter on attention is devoted to a review of the literature which has been concerned with these three problems of attention. He finally concludes that the literature seems to indicate that the laws which determine attention in performance, attention in learning, and attention in remembering are similar. These laws "seem to include many of the factors that affect response strength in general" (p. 77). To his own theory of attention, then, in this later work, Berlyne seems to have added little save the introduction of the information theory language use of the term attention.

Studies of Stimulus Characteristics Related to Attention Phenomena

Laboratory Research

In 1951 Berlyne carried out three experiments to test the effect on attention, of changing the stimulus. In the first or "familiarization" phase of these experiments the subject was presented with one, two or three identical stimuli. In the next phase a novel stimulus was introduced, the novelty manifested in a change of color, or shape of stimulus, or both. Finally, the subject was instructed to respond to one of three stimuli presented in this phase by pressing one of three keys. The results showed very clearly that the subjects attended more to the novel stimuli than to the familiar ones, and that this effect was more sharply defined in the second than in the third phase of the experiment. Comparing these subjects with a control group, the experimenter concluded, on the basis of the behavior of the control group, that the change of stimulus had produced the results. In 1957 Berlyne repeated the experiment with similar conclusions (Dember, 1960, p. 351). These results seem to agree with the general principle of advertising (see Nixon, 1937, p. 213), though the advertisers call it the "element of contrast."

A number of studies dealing with the effect of stimulus complexity on attention using animal subjects have been completed. Among these are investigations involving choice — flexibility using rats as subjects, Krechevsky, (1937) and Dember, Earl and Paradise, (1957) and Welker (1956) also compared the play and exploratory behavior of chimpanzees with simple and more complex toys. All of these studies concurred that the choice of normal animals was, significantly, the more complex or varied stimulus. (These studies are extensively reviewed elsewhere in this monograph.)

Experiments showing the effect of stimulus complexity on attention have also been performed using human children and adults. Berlyne, again, using very young children (three to nine months old), as subjects, placed cards of differing complexity of design in front of his subjects, in the order from most to least complex, and recorded which stimulus was looked at first by his subjects. His results agreed with the Welker (1957), Krechevsky (1937) and Dember *et al.*, (1957) studies which used animal subjects. Berlyne's infant subjects preferred the complex stimuli to the simpler stimuli. Dember made the observation that Berlyne could have carried this experiment further by recording the length of time the stimulus was observed.

In a study using adult subjects, Berlyne grouped the stimuli into six categories with four pairs of stimuli in each of five categories, and two pairs in the sixth category. Each of the categories was to represent a different aspect of complexity. The aspects were: "irregularity of arrangement amount of material heterogeniety of elements, irregularity of shape, incongruity, and juxtaposition." His results again corroborated earlier findings: the adults spend most time per figure observing the more complex of the pair of figures. The effect was most evident in the heterogeneity category. These subjects, however, in contrast to the young children showed the tendency to fixate first to the left (rather than on the more complex figure). This, the experimenter felt, was a learned effect carried over from the habit of fixating first to the left in reading in this culture.

Berlyne points out a very important factor qualifying his results, however. He admits that the "more complex" stimuli used in his studies were not exaggeratedly complex, and that had he used "too complex" stimuli, his results might have been quite different, if not the opposite. This brings up the principle of "optimal levels," which is restated stimulus complexity which Dember states in the following words: "Each individual can be thought of as having a preferred or ideal complexity level. The ideal complexity level is characteristic of the individual at a given moment in time and with respect to the specific stimulus attribute" (Dember 1960, p. [illegible]).

In a much earlier study Shacter (1933) found a similar effect. Shacter gave children tasks to perform some of which involved complex stimuli while others involved simple stimuli. An example of a simple task was that of arranging pieces of colored paper exactly as they were arranged by the experimenter. A version of the same task utilizing more complex stimuli involved copying an arrangement of photographs and geometric designs. The children who served as subjects and who were aged from three to five years persisted substantially longer on the complex tasks than on the simple ones. Oddly enough there was little difference in the length of sustained attention in the younger children than in the older children.

Finally, Dember (1960) opines that complex stimuli not only have positive effects on the attraction and holding of attention, but may also be useful as rewards in instrumental learning.

Also noted in Dember's review were studies bringing out the effects of monotony, or "forced attention to simple stimuli" upon behavior. It was reported that intellectual break-down, emotional disturbances, and possibly hallucinations could be the results of prolonged monotony.

Generally, when viewing a "field of stimuli," the viewer's attention shifts and fluctuates from one part of the field to another. This type of shifting and fluctuation is called, by Woodworth and Schlosberg, "ordinary," in contrast to more peculiar and unexpected kinds of oscillations.

By photographing eye movements with a special camera for that purpose, it has been found by Buswell (1920) that the modal value of about four fixations a second is a general estimate of "the rate of ordinary shifting of attention" over the stimulus field (Woodworth _et al_., 1954, p. 77).

Photographs of eye movements during the process of silent reading have also been taken and the rate of eye shifting has been found to be as great as five fixations per second in nontechnical reading. Here Woodworth and Schlosberg prefer not to regard eye fixations as units of attention because, as they say, the reader is attending to the meaning of the whole, rather than to particular words.

Experiments have been performed, as well, to determine how long attention can remain fixed upon one object or stimulus. Billings (1914) had his subjects seated before a picture. He instructed the subjects to attend to one object in the picture, and to press a telegraph key when their attention was straying to another part of the picture of field in general. A record was kept by a moving drum which was connected electrically. The average time before the first shifting of attention was about two seconds. It is strange to think that human beings can concentrate on a particular point for just such a brief time. One can appear to attend to a complex stimulus for a longer time "but only by shifting from one to another part of the object" (Woodworth, _et al_., 1954, p. 77).

Also discussed by Woodworth, _et al_., are the changes in perception of "an ambiguous figure" which is defined by them, (p. 78) as "a stimulus complex capable of eliciting either of two perceptual responses, one of which has the initial advantage and persists until enough fatigue or satiation has accumulated to switch the advantage to the alternative response;" the change of perception continues back and forth as each response becomes fatigued or satiated, as long as the subject is attending to that stimulus.

It is believed that probably the factors of fatigue and satiation also operate in ordinary shifting of attention, but in this case another factor also operates, which is, say Woodworth _et al_. (p. 78) "attraction toward an object glimpsed in indirect vision." Whereas, only the former factor is said to operate in the shifting of perception of an ambiguous figure.

Another type of fluctuation "sensory fluctuation" is described by the so-called "attention wave" which is said to have a phase when the stimulus is perceived, and one in which the stimulus is not perceived. An example of this type of fluctuation would be the ticking of a familiar clock in the same room when one is at such a distance from it that sometimes the ticking is heard and at other times it is not. The noise of the ticking seems to fade in and out. This type of experience is also to be had with weak visual and cutaneous stimuli. An experiment was performed by Wiersma (1901) in which, by holding a ticking watch at various distances from his subjects, he was able to increase the duration of time in which the ticking was heard by increasing the strength of the stimulus, that is, moving the watch closer to the subject. This type of thing was also done using visual stimuli, with similar results.

This change in perception, which these studies exemplify, is explained by Woodworth, (1954, p. 79) as a fluctuation in the sensitivity of the receiving apparatus; very weak signals will be received only when the apparatus is functioning at peak efficiency.

There has been much speculation as to the physiological basis of such fluctuations none of which seem to have been positively substantiated at this date. One such speculation is that the attention wave phases, positive and negative, correspond to that fluctuation in cerebral circulation known as the Traube-Hering wave. This speculation has been the basis of an experiment done by Griffitts and Gordon (1924) in which there was reported a statistically reliable (level of significance not given) though slight increase of "disappearances" of the stimulus noticed at the crest of the Traube-Hering wave, and reappearances of the stimulus during the rise of the wave.

Some of the early studies such as those of Schacter (1933) and Bestor (1934) attempted to relate measures of intelligance and the extent to which attention to particular stimuli was sustained. No significant relationship was found and one would hardly expect there to be one. If the length of time that attention is sustained depends upon the time taken to process information, then the brighter child might be expected to manifest a shorter duration of sustained attention. On the other hand, since the brighter child is capable of deriving more information from a particular situation, he might be expected to spend longer with it than would a duller child. The relationship between duration of sustained attention and measures of intelligence is obviously very complex.

Applied Research

Not all research on this problem has been conducted on the basis of ivory tower interests.

A number of books dealing with the principles of effective advertising have been concerned with the attraction of attention or determiners of attention. Most of them emphasize as the most important determinants of attention -- the elements of contrast. There have been empirical studies testing the effectiveness of the use of color as a stimulus quality in advertising. Nixon (1937, p. 356) reports a study by George Gallup, the famous pollster, of the relative attention value of black and white versus color in advertising. Gallup's results indicated that color did not "always add to the effectiveness of advertisements."

Nixon also noted "laboratory tests" which found "strong probability that the contrasting areas will be the first resting point of the reader's gaze." Several examples of different ways to use the element of contrast in advertising extracted from Nixon's list are presented here:

1) contrasting a white background with masses of black or heavy black lines;
2) spots of color against white or against another color;
3) placing an advertisement in such a way that it is framed by a substantial area of white space;
4) using white against black;
5) bordering with a contrasting color;
6) novel illustrations;
7) crossing heavy lines or having them converge;
8) the use of unusual angles either for the whole advertisement or for parts of it;

9) unusual type faces, or unusual angles or position of lettering.

Nixon admits that there is little experimental evidence for some points, such as the idea that lines in advertisements "lead the eye to a desired point," but states that this idea is subscribed to widely by layout men. This is another example of a factor that may operate to make one particular stimulus more of an "attention getter" than another.

Burtt, in his well known Applied Psychology text, (1948, pp.688-731) reports some of the most definite general findings concerning determiners of attention derived from studies popular during the 1940's that used eye-movement cameras.

According to both eye-movement and memory tests, doubling the size of an advertisement "increases attention value by 40-60 per cent, and not by 100 per cent. ...The upper part of a page gets more attention than the lower half, and the left half more than the right half." As noted earlier, color and the use of blank spaces as a border have "relative rather than absolute value."

The studies of stimulus characteristics which have been reviewed lead to the hypothesis that subjects behave to a great extent as though they spent long enough with a particular source (stimulus) to process the information derived and then move to other sources. When complex and unfamiliar stimuli are presented, these will hold the attention of the individual much longer because they transmit more information which takes a longer time to process. This would appear to be true also in a reading situation. The reader's eyes pause long enough to process the information but no longer. Familiar material requires less processing time since less of the total information has to be processed. One only has to read the first five words of the Lord's Prayer to know precisely what follows.

The findings suggest that an audiovisual display which fails to hold the attention of learners is likely to be one which, for one reason or another, is not transmitting enough information to fully utilize the information processing capacity of the learner.

The phenomena related to fluctuation of attention would appear to involve two distinct processes. One involves the alternation of two responses as in the case of ambiguous figures. In such a case the incoming information is processed in two distinctively different ways. The other is a fluctuation in the efficiency of receiving information.

Conditioning of Attention

Only three sources which discussed the conditionability of attention were located. Solley and Murphy, (1960, p. 175-209) discuss this problem most extensively and review the sparse experiments which seek to condition attention. By "conditioning" attention is meant an individual may be first taught to attend to certain stimuli, and once the attending process has been learned, these particular stimuli will be attended to more readily than the others. and be capable of holding attention more successfully.

Guthrie (1952, p. 122) was an earlier proponent of the idea that attention could be thus conditioned, but experimental work with this idea seems to have been carried out, so far, only by Solley and Murphy (1960) and Walters (1958), and earlier by Piaget and his coworkers (1942 to 1956). Solley and Murphy proposed that most "acts of attending" are learned in the manner of other learned behavior by the Skinnerian scheme of "operant conditioning," though they believe that attention may also be conditioned by the classical Pavlovian method. By this they mean that if an individual makes receptor adjustments, or is engaged in some searching behavior, and is reinforced immediately, the probability of his repeating that attentive response will increase.

The main finding of Piaget was the generalization that the young child is most likely to attend to dominant objects in the field. Solley and Murphy suggest that as the child matures he "learned to deploy attention in more complex ways and this balances out the earlier 'centration effects' (or) automatic overestimations of stimuli in the center of the attentional field," and this enables him to adapt to conditions in the external world (Solley, et al., 1960, p. 189).

Solley and Murphy then go on to describe some, as yet unpublished, experiments carried out in Solley's laboratory which deal with the conditioning of attention in children.

The subject of Solley's conditioning experiment were nine and ten years old. In the first experimental task a conditioning panel was placed before the subject. Four model animals were placed in alcoves on the panel. Lights in the alcove were turned on randomly illuminating one alcove at a time. The child was instructed to name the animal in the alcove which was being illuminated. The subject was to perform this task every time an alcove lit up, thus he was to switch his attention to the animal being illuminated. One quarter of the subjects were positively reinforced about eighty per cent of the time when they switched their attention to one of the figurines and not others. Reinforcement consisted of the experimenter saying "Fine," "You're doing good," and so forth. One experimenter sat in front of the subject and counted the number of times the subject looked at each figurine, while another experimenter sat behind the subject and did the reinforcing.

The results showed that the child tended to look at the reinforced animal in between lighted presentations, or would name the illuminated figure and then look quickly at the rewarded animal. After some training, Solley noted, the children could not keep their eyes away from the rewarded figurine.

The second task involved search and was a "transfer task". Forty new plastic models of animals and people, all of which had been painted white to remove color cues, were scattered at random on a peg board, (the search panel). A subject was shown one of the four original animal models (from the conditioning task) and told to find it on the peg board and point to it as rapidly as possible. Between presentations the subject looked away while the experimenter removed the located animal, and put on another in another place on the board. Each animal was looked for sixteen times, and the time required for location was noted. The results showed that the reinforced figurine from the first task was found by the subjects more quickly than the unrewarded ones.

Walters (1958) had attempted earlier to condition attention using adult subjects. The design of his experiment was much more complex than that of Soley and, from the description, it is difficult to determine the exact nature of the procedure. However, in the first experiment which he conducted there was no evidence of the conditioning of attention but, in a second experiment which utilized superior controls a significant effect was found.

The concept that attention can be conditioned would appear to have important implications for the use of some new educational media. For example, during their early years of life, children are conditioned to attend to television screens. The rewards for such attention would appear to be substantial and include the appearance of novel events, various sought-after emotional experiences, and a high level of environmental change. The conditioning of attention which thus takes place in the home is probably readily generalized to the school situations. Observers of television classes in schools typically report that children do attentively watch television screens in schools even though the lesson which is being transmitted appears to be deplorably dull. A similar kind of phenomenon is seen when school movies are shown. Regardless of the merits of the movie, the children will watch the screen with rapt attention. Children have obviously not been so well conditioned to watch teachers.

Studies of Vigilance Behavior

The early studies of attention phenomena utilized experimental conditions in which the subjects were involved in tasks which kept them quite fully occupied. More recently applied psychologists have become interested in attention to tasks which would ordinarily be described as very boring. Such tasks generally place the human guinea pig in a situation where he has to observe the occurance of very rare events which, even at the best of times, are quite difficult to observe. The interest of applied psychologists in such studies stems from the fact that many men in the military must perform very similar tasks. These are referred to as vigilance tasks.

Studies of performance on vigilance tasks has yielded important information concerning the handling of inputs of information by the nervous system. These studies provide knowledge which has a close relationship to much of the research discussed both in this chapter and in others.

The term "vigilance" has had a long and ambiguous usage. One of the first occasions on which it was introduced into technical literature was by the neurologist, Head (1923) who used the term to denote a state of effective activity on the part of the central nervous system and which was to be contrasted with a state of low activity such as occurs during sleep. The term as it was used by Head is similar in usage to the term "arousal" as used by Hebb (1958) and Bindra (1959). Such terms rest on a flimsy foundation of neurologizing which can be avoided in the present discussion even if it cannot be avoided in other contexts. Since the Second World War the term vigilance has acquired a different meaning and has come to be applied to certain tasks, referred to as vigilance tasks which have been of great importance in military operations. These tasks all share certain characteristics in common. They involve equipment which provides signals indicating some state of affairs requiring action on the part of the operator, but the signals are rather rare events. For example, a typical vigilance task is that of watching a radarscope for the presence of blips which might indicate the presence of enemy aircraft. Such blips are generally rare events. Similar kinds of equipment have been used in submarines for the detection of vessels in the vicinity. An important military problem is that of arranging the conditions of observation so that these rare signals are detected and reported by the observer. This turns out to be a very difficult problem to solve.

The broad category of vigilance tasks emerged as a concept in military research, but only after many years has there developed a fairly precise concept of what such tasks involve. This is a matter of specifying the task dimensions which McGrath (1963) has attempted to do. The main criteria which he specifies for determining whether a task is or is not a vigilance task are the following:

1. The intensity of the signals to be detected is low and often near to the threshold. The signal itself may be either a change in some continuing signal as when a tone is given a slight change in intensity or pitch, or it may be a stimulus which begins at zero intensity, increases, and then returns to a zero value.

2. The signals which are to be detected during vigilance tasks occur rather infrequently. In some tasks they occur as rarely as ten per hour but in others a much higher rate of occurrence is found, sometimes as high as 960 per hour. The latter would generally be considered to be at or beyond the limit of what is generally considered to be a vigilance task.

3. In vigilance tasks the signals occur at random intervals. However, the mean number of signals per unit of time and the standard deviation of the time between signals may very.

4. A requirement of the task is that the person performing it remain continuously oriented towards it for a period of time which is typically one or two hours.

While the phenomenon of vigilance is of particular interest in the present context, in that it provides examples of research in which a comparison is made between instances in which the signal is either auditory or visual with instances in which the signal is transmitted through both modalities, research in the area also throws light on attention processes. First, let us consider some of the general phenomena related to vigilance, keeping in mind the fact that no attempt is being made to draw a parallel between vigilance behavior and behavior in an activity such as that involved in watching a movie. Our interest in vigilance resides in the fact that it provides a means of studying some of the conditions under which sensory inputs are either made available to the perceptual system or are lost as far as their informational content is concerned.

The most apparent experimental effect found in studies of behavior in vigilance tasks is that the observer's behavior declines in effectiveness as time goes by. McGrath, Harabedian and Buckner (1959) who have reviewed studies in the area report that the decline takes place rather rapidly with very clear evidence for it being manifested by the end of ten minutes and the decline continuing generally for about thirty minutes. Following this period of decline, performance stabilizes at a lower level. For example, Mackworth (1948) using his clock test found that the first half hour was significantly more favorable to signal detection than was the remaining hour and a half.

A discovery with important implications is that there is less decline in those situations in which there is a relatively high rate of signal presentation. One suspects that this is very similar to the phenomenon familiar to every school child that a slow and dragged out presentation of subject matter results in a wandering of the attention of the listener. Information transmission rate appears to be an important factor in determining the frequency of responses to signals. This phenomenon has been reported by many investigators including Jenkins (1958) and Kappauf and Powe (1959) using quite different vigilance tasks. The common interpretation given to this phenomenon is that organisms have only limited capacity for sustained activity without inputs from the environment. Both Sharpless and Jasper (1956) and Oswald (1959) have summarized available knowledge about this problem. Hebb (1955) has also stressed the point that organized higher nervous activity can be maintained for only a short time without inputs from the environment. The main difficulty in applying such concepts at the present time is that in most commonly occurring learning situations there is no satisfactory way of estimating the rate of input of the information and of thus no way of ensuring that the information input is adequate to maintain organized activity but not so great as to produce disorganization. Davis (1959) has provided evidence that when the input falls below a certain level, somatic activity increases. This can be interpreted as producing an increase in the proprioceptive stimulation to compensate for deficiencies in inputs through other channels. Other interpretations are, of course, possible. Deese and Ormand (1953) and Deese (1955) provide data showing that the per cent of signals identified is related to the number presented per hour.

A particularly interesting finding has been brought to light by Sipowitz _et al._ (1962) who demonstrated, in the particular vigilance task which they used, that the provision of a reinforcement to a response to a signal resulted in an increased frequency of signal detection. The reinforcements used were knowledge of results, money, and both of these combined. The data could be interpreted as indicating that the incentives thus introduced have the effect of raising the arousal level of the subject which in turn produces an increased signal detection rate. Other mechanisms may also play a part. McCormack (1959) conducted an earlier experiment which supported the results found by Sipowitz _et al._, (1962) in which evidence was provided that knowledge of results improves signal detection. These data suggest the interesting hypothesis that the decrement shown on vigilance tasks may be simply a matter of extinction. The identification of the signals may be a task so impoverished and lacking in reinforcement that the identifying response tends to become progressively weaker.

A study by Pollack and Knaff (1958) which preceded that by Sipowitz _et al._ (1962) had failed to demonstrate the effect of reward, but the reason for this would appear to be that Pollack and Knaff reinforced overall performance. For reinforcement to be effective in this situation it seems that it must follow the paradigm in which the reinforcement is contingent upon a specific response; namely, the response of signal detection itself. Immediate reinforcement contingent upon a response is the crucial factor involved in producing the improvement.

Another important observation made by Mackworth (1957) in reviewing substantial related data is that the occurrence of the performance decrement occurs even though the signals are both increased in detectability either by increasing their magnitude or by extending their duration.

The data summarized up to this point suggest that the perceptual system receives information from particular sources but that there is a declining ability to receive information from any particular source which is a function of time. The data suggest, but do not demonstrate, that the declining attention to particular inputs occurs even on tasks which do not fall within the boundaries ordinarily set of vigilance tasks. The fact that the decrement occurs when signal frequency is increased or when the signal is made more easily perceptible suggests that this is probably a very general phenomenon. However, it is related to the concentration of signals and one may infer that learning tasks which are well designed for the classroom will show a much smaller decrement than those used in the study of vigilance behavior.

Some additional important data are provided by Broadbent (1963). He finds that when subjects performing a vigilance task are asked to report signals when they are not sure, then they do not show the usual decrement. A decrement does occur, but it is in terms of their sureness that a signal has occurred and not in terms of the number reported. These data suggest that "missed" signals are not signals which the subject failed to receive, but signals which he received but failed to process. Decrement is not then a matter of the complete blocking of perceptual activity, but a failure to utilize the information received.

The decrement found in vigilance studies is clearly a perceptual phenomenom. Broadbent (1958) has drawn attention to this fact by pointing out evidence to support that position. He cites research to show that while persons engaged in a vigilance task show a decrement in performance with the passage of time, that a similar decrement is also shown by those who observe the performers. The point is an important one for it supports the position that when the nervous system is set to take in information by a particular channel, that it becomes steadily less capable of handling information through the same channel. While the data are derived from a situation involving a low information input, common observation suggests that a similar phenomenon probably occurs when the density of information input is greater but that the decrement is probably then less. Many people cannot listen to music very long without their attention wandering to other matters such as the physical appearance of the artist, the reactions of the audience and other potential sources of information. There is considerable experimental evidence to support the position that channel blocks occur with any prolonged task. Even when the inputs of information are relatively high there are so many different conditions that increase or decrease the frequency of occurrence of such blocks that clear-cut advice cannot be given to indicate what should be done to reduce such a decrement.

Of particular interest in the present context is the performance on those vigilance tasks in which signals are transmitted through more than one sensory

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modality. Such tasks can be set up in a number of different ways. One way is to present some of the signals through one modality and some of the signals through the other. Another procedure is to provide all signals simultaneously through both modalities, in which case the task involves completely redundant information. In addition, mixed situations are used in which signals may come either auditorally, visually, or through both modalities simultaneously.

While most of the evidence which has been reviewed up to this point supports the position that no advantage is achieved in most situations by transmitting simultaneously either redundant or nonredundant information through two separate modalities, vigilance behavior presents an expected exception. According to the Broadbent type of filter theory, the continued utilization of any one channel for the reception of information slowly increases the chances that information will be received through another channel. Thus, the use of the auditory channel for the reception of messages in the course of a vigilance task, slowly increases the chances of receiving a message through the visual modality. If the auditory decrement has already advanced far, then the performer becomes more likely to receive a visually transmitted message. Thus, when the same signal is given by both the auditory and the visual modalities at the same time, if it is missed on the auditory channel, there is a chance that it will be picked up on the visual channel. The expectation, in this case is that multichannel presentation will improve the frequency of signal reception.

A number of investigations have been made on the effects of using more than one sensory mode where each is relevant to the vigilance task. It is important, at this point, to draw attention to evidence that there are broad individual differences with respect to sensory mode favored by observing subjects. Indications are that a "good watchkeeper" is often "good" by the visual mode or the auditory mode but frequently not both. Buckner, Harabedian and McGrath (1960), and Buckner and McGrath (1961) indicate that the inter-correlations for performance of individuals on auditory detection performance and on visual detection performance range between .20 and .30.

Buckner and McGrath (1961, 1963) investigated the question of watch-keeping effectiveness under simultaneously monitored auditory and visual signals carrying redundant information and each of these modes carrying nonredundant information in the same watch. In addition, both modalities were employed under independent conditions, that is, a subject stood an entire watch while employing only one modality. The visual task called for detection of a brightness increment in a light emitted through a one-inch-square aperture of ground glass. The auditory signals were presented through earphones at 750 cps. Increments in loudness were to be detected. In all there were five experimental conditions compared as follows:

1. visual only - detection of brightness increment
2. auditory only - detection of loudness increment
3. audiovisual - detection from the simultaneous presentation of both modes (redundant information).
4. audio and visual - 1/2 of signals by each modality (non-redundant)
5. 1/3 visual, 1/3 auditory, 1/3 (redundant) audiovisual.

Results are reported as probabilities that a given signal transmitted through a given mode would be detected. These probabilities are 0.76 for the visual, 0.86 for the auditory and 0.91 for the audiovisual redundant presentation. One can postulate a mechanism for accounting for the latter superiority. If the information coming in through the different modalities were scanned for relevant signals, then the missing of a visual signal would mean either that the individual had gone to sleep, a possibility which is rejected here, or that he was concerned with inputs from sources other than the visual. If he is doing the latter, then one would expect him to pick up some of the auditory signals although the proportion cannot be determined. In any case, on the basis of this hypothesis one would expect him to pick up more signals when a signal is transmitted through both sensory modes than when it is transmitted through one. Unfortunately, nobody has yet transmitted a signal through three sensory modalities to determine whether there would be a still further improvement. A model in which the various modalities obtain access in turn to the perceptual system perhaps in a random sequence leads one to expect perfect signal detection if a signal is transmitted through all sense modalities provided that the subject is in a waking state.

While the most important outcome in the present context is that signals transmitted through two sensory modalities are more easily detected than signals occurring through one, some other findings are also of interest.

The same investigators also found that, when mixed visual and auditory signals were presented in the same session, the detection rate was not significantly different from when the signals were displayed in separate sessions with only one modality used in each session. These data suggest that the perceptual system does not systematically scan inputs in order, but that it can monitor the entire input system for particular categories of information. If this is so, then there may not always be loss of input to the system during switching such as Broadbent suggests (1958). Of course, the phenomenon of watching for particular categories of input through any sensory modality may well occur only when there is a very low input of information.

An additional finding was that when all three classes of signals occurred on a single watch (auditory, visual and simultaneous auditory and visual) the mean detection rate was not significantly different from the detection rate observed when each type of signal was displayed separately in a separate session. This finding is somewhat puzzling. It suggests that the attention process can be set to receive signals through either one of two channels.

A point of considerable interest with reference to the present problem is the finding by Buckner and McGrath (1963) that when redundant signals are used, transmitting information through both the auditory and the visual modalities, there is less decrement in performance than when a single modality is used. Whether the same effect would be evident in situations where the information transmitted has a higher density is a matter which still has to be examined in the laboratory. The same research also showed that there was a greater decrement for an auditory task than for a visual task. The latter is to be expected since the input of visual information is dependent upon the maintenance of a particular posture while auditory inputs are not.

Finally, Buckner and McGrath found that when in a single session both auditory and visual signals were to be detected, that there was a tendency for the subject to improve on the more detectable of the signals and to deteriorate on the less detectable. In the case of this study the most easily detected signals were the auditory. This is interpreted as the development of selective attentiveness. It may well be that the state of awaiting for signals to come through any channel may be a difficult state to maintain and, hence, the observer tends to give more and more attention to particular channels. Results which shed additional light on the above findings have been reported by McGrath (1962). In the earlier experiment where more than one sensory modality was employed simultaneously, Buckner and McGrath presented the concept of "performance sharing." This was defined as the phenomenon where subjects initially attend to the signals less easy to detect, and as the watch proceeds, performance is shared to an increasing degree with the more easily detected signals. That is to say, the proportions of detected signals increase for the easier mode and decrease for the more difficult one. McGrath (1962) attempted to verify the phenomenon of "performance sharing" with the hope of assigning its effects either to the watchkeeper's preference for the auditory mode over the visual or to the "relative detectability of the signals." In this second study, conditions were also arranged so that the more easily detected signal was in some watches in the auditory channel and in some watches in the visual.

The analysis of the data showed that the performance sharing phenomenon was a result of signal detectability and was not due to a preference for detecting signals in one sensory modality rather than the other.

Baker, Ware and Sipowicz (1962) also studied the relative detection rate of signals given separately through the auditory and the visual channels with signals given simultaneously through the two channels, but unlike the others who have studied this problem did not find that the redundant presentation resulted in a significant improvement in performance. While they point out that the nonsignificant differences were in the expected direction (hardly a persuasive argument), they are in contrast with the clear cut results which have already been reviewed. The differences may well be attributable to the nature of the task. In the Baker, Ware and Sipowicz study the signal involved an interruption of the auditory or visual stimulus rather than an increase. Why such a difference in the task conditions should make a difference in the results is hard to see. In addition, the signals may also have been easier or harder to detect than those in other studies. There is also the possibility that the subjects could be considered to come from a different population with different motivations with respect to the task.

There are numerous variations which can be introduced into the presentation of two vigilance tasks simultaneously through two sensory channels. In one such variation, Baker (1961) arranged for a central vigilance task involving the identification of the presence of a spot of light at any one of the four corners of a sheet of ground glass. Some of the subjects were required, in addition, to perform a subsidiary task which involved either a change in the general level of illumination of the room or a change in the general noise level. On these subsidiary tasks the noise level and the light level were returned to normal by the subject making the appropriate response of pressing a key, but some subjects were given additional knowledge of results through being presented with a number indicating the time taken to recognize the light becoming louder. Control groups undertook the same primary task but with no secondary task.

Baker found a difference significant beyond the one per cent level in the performance of the groups involved in a secondary task as contrasted with the control groups which were not so involved. Of interest is the fact that the presence of the secondary task on which there was knowledge of results enhanced performance on the primary task. The difference between the experimental group in which the secondary task was in a different sensory modality from the primary task did not differ significantly from the group in which the subsidiary task involved the same sensory modality.

The research on audiovisual tasks under discussion does not in any way run counter to the single channel model of the perceptual system, for the information inputs are infrequent. What it does suggest is that the inputs may have complex effects which cannot be interpreted simply in terms of the handling of information.

A particularly interesting point which comes out in the Buckner and McGrath (1961, 1963) study is that the vigilance decrement is reduced by the use of multiple sensory inputs. In this latter study the decrement in performance is always markedly less for the dual sensory input situation, then comes the auditory input, and finally one finds the visual input which is most subject to decrement. What these data suggest are that decrement is produced by forced attention to a particular sensory channel. Such forced attention is greatest in the case of the visual presentation for in that case the receiver must maintain himself in a constant state of physical orientation towards the source of the messages. If he does not do this, he is less likely to receive. On the other hand, auditory signals can be received even when there is no deliberate state of readiness to receive them, particularly if they have certain physical properties such as high intensity or relatively high pitch.

Blocking

In performing many types of continuous tasks, it can be observed that there are fluctuations in efficiency similar to those discussed in the previous section. One kind of fluctuation, however, very important in accounting for certain attention phenomena has not been considered, but will be discussed separately in this section to emphasize its importance. This kind of fluctuation has been called "blocking" of attention in "mental work" by Bills (1931, p. 230). Blocks show themselves as momentary lapses in performance which occur with periodicity throughout a mental task. Although it was Bills who named this phenomenon and studied it most extensively through the 1930's, this type of fluctuation had been studied as early as 1911 by Woodworth and Wells. Woodworth and Wells studied these fluctuations or "hesitations" in a color-naming test. Sterzinger, in 1924, also investigated blocking in a somewhat more complicated task. In the latter experiment, the subjects were presented with a long series of letters grouped in different ways. Their task was to "cancel every letter" that was standing by itself, sandwiched between two vowels: and to cancel every group of two letters which followed another group of two letters. The subjects could go at their own pace, but could not go back over their work. The results showed errors of omission and these errors seemed to show periodicity within the individual performance.

Bills' (1931) first study was entitled "Blocking: A New Principle of Mental Fatigue." Bills defined the term "block" as referring to "those periods experienced by mental workers, when they seem unable to respond, and cannot, even by an effort, continue until a short time has elapsed" (Bills, 1931, p. 230). For the purposes of his study, however, a "block" is defined operationally as a "pause in the responses equivalent to the time of two or more average responses" (Bills, 1931, p. 231).

While Bills looked for the source of the block in some process mediating between the intake and processing of information and the production of a response, modern psychologists would tend to seek the source either at the input end in the form of some kind of perceptual blocking or at the output end in terms of a blocking at the response end. An immediate suggestion would be that the phenomenon of blocking observed by Bills is a simple example of reactive inhibition such as has been defined by Hull (1943). Since the activities which are performed in the demonstration of blocking are repetitive in nature, the reactive-inhibition interpretation is plausible, and one can well conceive of a subject as he repeats a response building up an inhibitory tendency which would ultimately prevent the response from being made. A short delay in responding such as occurs on blocks would then dissipate enough of the inhibition to permit the response to take place again. However, the evidence that follows tends to support the position that blocking is mainly a perceptual phenomenon rather than one involving a terminal response to each particular input.

The purposes of Bills work were: to find the principles operating behind this blocking phenomenon, to determine the factors involved in their occurrence, to find the relationship of blocking to general decrement and fatigue, to find its "relation...to the principle of refractory phase, and...to the occurrence of errors, and to the amount of previous practice in the task" (p. 230, 1931).

In some preliminary work Bills found that blocks tended to occur more often in "homogeneous" tasks which were continuous, and in which the responses were to occur more frequently. The fact that the degree of blocking appeared to be more related to the nature of the task as it was presented than to the nature of the response suggests that the phenomenon is perceptual. For these reasons the following tasks were chosen for the experiments: "1) alternate addition and subtraction; 2) reversible perspective; 3) color naming; 4) opposites; and 5) substitution" (Bills, 1931, p. 231).

The experiment involved a year's work using fifty advanced college students as subjects. The subject received his instructions on printed cards, and sat at a table to perform the tasks. The experimenter sat at another table behind the subject and recorded the responses. An assistant sat with the experimenter to record the subject's errors. Since blocking was defined operationally in the way it was, a block varied for different subjects according to the subject's average speed. For example, if the subject responded at a rate of only thirty times a minute, a block would be as long as four seconds (Bills, 1931, p. 231).

The data from his first experiment showed a decline in number of responses per minute over the seven-minute work time, a proportionally greater increase in number of blocks per minute, and an increase in length of the blocks. The task involved simple addition and subtraction. Another result of Bills first experiment was the evidence of an individual rhythmic periodicity of the blocks. The overall average rhythm, he found for all ten subjects was about one block every seventeen seconds, but individual subjects varied. Some subjects would block every ten seconds, some every half minute, and one sometimes would not block for two or three minutes.

The six experiments described in his 1931 study differed from each other mainly in type of task. The results of the remaining five experiments will be summarized more briefly, as the results for all six experiments are quite similar.

The task in the second experiment, in which the subject was to try to reverse his perception of an ambiguous figure, was intended to show blocking under a condition in which "control of set by voluntary effort was the main feature" (Bills, 1931, p. 234). The subject indicated his achieving a reversal by saying "Now" to the experimenter. His instructions were to try to cause the reversals to happen as often as possible.

The data for experiment 2 showed a seventeen per cent decline in responses per minute over seven minutes, a thirty-five per cent increase in freuqency of blocks, and a seven per cent increase in length of block over the experimental period. The practice effects were similar to those in experiment 1. Bills stated that, being based on 280 measures each, "the averages are quite reliable" (1931, p. 235).

Color-naming was the task used for the third experiment because it was assumed to be a good test of speed and apperception, and also because it was highly homogeneous. Twenty-one subjects were used, naive with respect to the experiments. The work period was ten minutes this time, and "every subject reported only twice, once in a preliminary practice series." (Bills, 1931, p. 235) and once during the experimental session.

The results for this experiment were very similar to those of the earlier studies. One additional finding was a relation between the individual subject's average work speed and both length and number of blocks. Bills (1931, p. 236) found that "correlation between speed of work and frequency of blocks equals -.33, and correlation between speed of work and length of blocks equals -.70." Bills noted (1931, p. 236) that if there is a relationship between errors and blocks, this finding would agree with "the well-known experimental fact that fast workers tend also to be more accurate than slow workers and less variable in performance."

In the fourth experiment, the task was to replace letters orally for digits presented in rows using a code -- a certain letter to replace a certain number. The task was chosen for its simplicity (cutting down on practice time), and homogeneity. Twelve new subjects were used -- the experimental series lasted three days, ten minutes a day, and the subjects were told to work as fast as possible. The only important difference between the results of this experiment and those of experiments 1, 2 and 3 is a slightly decreased frequency of blocks. In this experiment the blocks occurred only about every twenty-four seconds, and Bills felt that this decrease might have been due to the two days of practice which preceded this experimental series. In this experiment, also, another characteristic examined was a tendency for responses to "bunch up" about half way between blocks, and then decrease again as the block was approached, giving a wave-like effect which was "scalloped in formation, rather than sinusoidal." It was found that "fatigue tends to exaggerate the bunching" (Bills, 1931, p. 243).

The results of experiment 5 in which the subject was furnished with a sheet of 100 words and told to give the opposites as fast as he could were similar to those of the previous four experiments. The same twelve subjects were used in the fifth experiment as had been used in the fourth. This time a daily practice session was given prior to the three experiment days. The number of blocks per minute on this task was considerably less than on tasks in the earlier experiments in this series, but the task also appears to be more complex than the other tasks.

Because the experimenters found very few errors in experiment 5, a sixth experiment was performed in which the subject was to work continuously for an hour. The experimenters hypothesized that "accumulating fatigue would increase the number of errors, and that more reliable statistics regarding the errors would be obtained" (Bills, 1931, p. 241). Twelve subjects worked in the experiment, in which for six the task was color-naming, and for the other six, substitution.

The results of this experiment showed that the average speed remained practically the same over the hour, but that frequency and size of blocks increased over the work period. The change was evidenced in the "greater bunching and less regularity of response," as well. In regard to error, the results showed that there was a consistent tendency for errors to occur in conjunction with blocks.

Bills (1931, p. 245) also tried to relate the periodicity of blocking rhythms to such physiological rhythms as the Traube-Hering wave, but found no relationship, though he indicated, further work should be done along that line.

In general then, Bills presented the following findings related to the blocking phenomenon:

1. In continuous and homogeneous work, blocks occur with rhythmic periodicity. The average frequency of such blocks is about three per minute, though individuals vary widely in blocking frequency.
2. Practice reduces size and frequency of blocks.
3. Prolonged work increases size and frequency of blocks, and tends to exaggerate the wave-like bunching of responses.
4. People who respond rapidly seem to have fewer and shorter blocks than people who work more slowly.
5. Errors tend to occur along with blocks.

In 1935, Bills published another paper dealing with the causes of mental blocking. The 1935 study was based on the assumption derived from the 1931

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study that mental blocks serve as enforced rest periods during continuous work, to counteract fatigue and consequent decline in performance. The decrement in performance, theorizes Bills, would be steeper and even more exaggerated were it not for blocking. This is an inhibition interpretation which is rejected here.

Another study was designed to discover whether mental blocks vary directly in length of time and frequency of occurrence with the homogeneity of the task and amount of "competition" in it (Bills, 1935, p. 173). In order to study this problem, two main experiments were performed, the first to investigate the effect of the number of competing responses, and the second to study homogeneity of task.

In the first experiment sixteen subjects were used. Their task was to name colors arranged on charts. Three different types of charts were used in order to give three different conditions, each involving a different number of competing responses. In the first chart five different colors were scrambled in arrangement and thus there were five competing responses. After the subject read the chart through once in its normal condition, the chart was turned on its side, and read by the subject in that position, and so on, until it had been read in four different positions. In the second chart three different colors were used, in like manner, and in the third chart only two colors were used. The responses were recorded on a kymograph and analyzed later, to determine the number of responses per minute, and the decrement over the experimental session which lasted ten minutes (Bills, 1935, p. 173).

The results of experiment 1 in this new series showed a decrease in number of responses which varied directly with the condition -- the greatest decrease was shown in the condition with the greatest number of competing responses, and the smallest decline was shown where the competing responses were fewest. In Condition 1 the decline in number of responses per minute was ten per cent, in Condition 2, 5.3 per cent, and in Condition 3, 3.3 per cent. The amount of blocking was also shown to vary with the condition, the largest amount of blocking occurring in the condition with the most competing elements. A comparison of the blocks for the first half versus the last half of each work period, for each condition showed that there was an increase in number of blocks per minute during the work period, and that this increase was greater for one condition than another (Bills, 1935, p. 174). It was found that in Condition 1 the blocks increased from 3.4 to 3.7 per minute, there was not any increase in blocks over time in Condition 2, and in Condition 3 the blocks increased from 2.9 to 3.1. The length of the blocks also varied in the expected direction, the longest blocks occurring in the most competitive condition. However, the results are limited by the fact that tests of significance were not applied.

The task selected for experiment 2, to test the effect of a very homogeneous task on blocking, was the same as that used in the Bills and Robinson study (1926). It involved continuous writing of letter sequences. The amount of homogeneity could be varied by simple "varying the number of letters in a sequence." For example, the sequence fgfgfgfgfgfgfg would be more homogeneous that the sequence mnlopmnlopmnlopmnlop.

The task involved in this study is different in many characteristics from those used in previous studies. While the tasks previously used by Bills required the performer to take in information before responding, the task involved in this study reduced inputs of information necessary to perform the task to a minimum. The sequence of responses could be considered to be generated internally to the subject. If blocking occurs on such a task, one could not interpret it as being the result of perceptual blocking, but rather would one have to consider it to represent a typical demonstration of reactive inhibition.

In Bills' 1935 experiment using this task, the device used by the subject for recording responses in order that the experimenter could record the responses kymographically, was a stylus, which was "just clumsy enough in operation... that subject's mental reactions went ahead of his manual responses" (Bills, 1935, p. 176). The result was an increase rather than a decrease in responses, and there was practically no blocking. This being the case, the results were not used. Instead, a student of Bills repeated the experiment under his direction, and a different recording technique as well as an increased sample size was used. In the latter study, twenty-four subjects were used. These subjects wrote the letter sequences using an ordinary pencil but special paper. The experimenter observed and recorded responses kymographically from behind a screen. Condition 1 in experiment 2 used a six-letter sequence, and Condition 2 used a two-letter sequence. Three different versions of the two-letter sequence were used to take out the factor of letter differences. The six-letter sequence was abcdef, and the two-letter sequences were ab, cd, and ef. Different subjects went through conditions in different orders to "equalize practice effects" (Bills, 1935, p. 177). Each work period was ten minutes. The results showed that the decline in speed varied with the homogeneity of the task, there being a greater decline in the more homogeneous condition. The average number and length of blocks was shown to be greater in the more homogeneous condition.

While the earlier experiments had shown that the frequency of blocks increased with the number of competing responses involved, the previous experiments appeared to Bills to demonstrate that an increase in the complexity of the stimuli tended to decrease blocks.

Also reported in the 1935 study by Bills (p. 181-185) was another study comparing blocking in vocal and manual responses. A task was used in which responses could be made either vocally or manually. Thirty-two naive subjects were used, and the task consisted of reacting alternately vocally and manually to colors arranged in rows. Half of the subjects began with the vocal -- five minutes vocal, five minutes manual, etc., and the other half began with the manual response. The session consisted of four five-minute alternations. Rank order correlations were used to compare vocal and manual response records. A correlation of approximately .63 was found between average numbers of responses per minute in the two different response conditions, indicating a "good deal of similarity in the elements involved in the respective processes" (Bills, 1935, p. 183). A correlation of .62 was found between average number of blocks per minute under the two response conditions which Bills found even "more significant." And the correlation was .72 for average length of blocks under the two conditions. It was found that the subjects reacted vocally faster than they did manually, that blocking was slightly more frequent under the vocal condition, but that the length of blocks was slightly less under this condition. Average work curves were also obtained, both for blocks per minute and responses per minute by averaging the subjects' performance for each five minute period and, keeping the curves for those subjects who began the task vocally separate from those who began with the manual response. It was found that the work decrement did not carry over to the opposite task. Bills (1935, p. 185) interpreted this finding to mean that a large part of the decrement that develops is specific to the particular response system involved. This particular experiment supports a reactive inhibition theory of blocking which is not supported by his original data. Bills rightly concludes that the blocks are in part motor blocks.

A third study was done by Bills (1935b) to investigate several oscillation rates which he believed explained the blocking phenomenon. The tasks used in the study and methods of statistical analysis were rather similar to those of his earlier studies. The explanations given are not particularly convincing.

In 1938 Martinson completed a study on blocking, following the work of Bills, who by this time had published seven articles in his series of experiments on blocking. Martinson's study, however, had a new emphasis which was a physiological one although it is a natural outgrowth of Bills' findings of the rhythmical occurrence of blocking, and the idea that they are natural physiological rest periods. She attempted to determine whether or not there was any relationship between the alpha brain potential and mental blocking. Alpha waves were defined as those brain waves, measured by EEG, which have a frequency between eight and twelve per second. Martinson studied the "percentage of occurrence of the alpha rhythm, and the frequency of the alph rhythm," (1938, p. 144) under conditions of rest, under conditions of "normal response," and under a blocking condition. Particular comparisons were made of the occurrence of the alpha waves in conditions of normal response versus conditions of blocking.

The six subjects who were graduate students with "a high percentage of alpha waves" lay on a cot in a dark room. "The brain potentials were recorded from the left occiput with the inactive electrodes on the lobe of one ear," (Martinson, 1938, p. 144). Their task was to give, verbally, with the greatest speed possible, opposites of words which were presented to them verbally by the experimenter. The experimenter sat in another room, recording, but a two-way communication system enabled the subject to receive the stimulus word, and the experimenter to receive the response. The subject also recorded his own response by "pulling a cord attached to a break-key at the moment of response. The session was forty-five minutes divided into a control period of five minutes, a ten-minute response period, another five minutes control period, etc. The "control" periods were relaxation periods for the subject. A certain percentage of "frustration" words, words which had no natural opposites, (i.e., how, note, finger, etc.) were included among the words which had opposites, and the times during which the subject was responding to the frustration words were referred to by Martinson as "frustration periods" (1938, p. 145).

Martinson concluded that the data showed no relation between either percentage of occurrence of alpha waves or frequency of such waves and the mental block. In interpreting those negative results, she hypothesized, that this coordinating process in attention, as shown in the periodicity of blocks between responses, used as a rest period to counteract the impairment of performance due to fatigue, need not be a cortical process but might be controlled by a portion of the central nervous system lower than the cortex. Since alpha waves have been fairly well proved to be of cortical origin, she stated, her negative findings concerning the relation of these brain potentials to mental blocks may be further evidence that the coordinating of attention may be subcortically controlled. There is still, however, conflicting evidence on this point, and Martinson also pointed out that the methods available at the time at which she did her study may not have been sensitive enough for measuring the brain potentials. It seems, therefore, from this study and from other scarce physiological evidence that the evidence that has been amassed concerning the area in the central nervous system, which control blocking of attention, is still too crude and inconclusive to allow us to form a physiological theory of the blocking phenomenon. Indeed, the experimental work which has been done on attention in general from a physiological point of view is so meager that a physiological or neurological theory of attention has not been well formulated to this date.

Implications of Research on Blocking Phenomena

The two previous sections of this report have both dealt with various aspects of blocking phenomena, though blocking in the vigilance area is generally referred to as a missed signal. The data reflect a typical inability to maintain an orientation to a particular source of information for any extended period. In addition, a similar phenomenon appears to take place at the output end where there is difficulty in maintaining an even output of responses.

The extent to which there is blocking of inputs depends upon the characteristics of the source towards which orientation is to be maintained. When the source has a relatively low density of information, blocks are more likely to occur than when the information density is high. Vigilance tasks present the case where the density of information is particularly low. However, this is not an argument for providing a very high density of information transmission in order to reduce the occurrence of blocks. Experiments at the University of Utah show that increasing the rate of transmission of information rapidly reaches a point where some subjects cease to learn. These subjects manifest a complete block to learning under these conditions. Whether such blocking is similar to that shown when there is only a low density of information remains to be seen, but the important point to note is that there is an optimum density of information for reception and this optimum may well vary from one person to another.

The fact that blocking of outputs can be reduced by changing the output channel from manual to vocal is to be expected in terms of what is known about reactive inhibition. The question remains open whether shifting the input channel will reduce blocking at the input end. One suspects that it would, but this is a matter of considerable interest in the design of audiovisual materials which still needs to be demonstrated.

Implications of Research on Attention Phenomena for the Design of Audiovisual Materials

It has long been known that the major factors in the control of attention are stimulus factors. While the obvious stimulus factors that have been listed such as intensity have no great implications for the design of teaching materials, some of the more recently discovered factors do. Particularly important are the factors of complexity and novelty.

While complex stimuli tend to hold the attention better than simpler displays, this does not mean that audiovisual materials should be elaborated in order to improve their attention getting properties. What has to be remembered is that the "complex" stimuli used in psychological experiments are generally much simpler than those present in any single frame of a typical motion picture developed for instructional purposes. What the finding does imply is that the complex stimuli held the attention of subjects because they provide a flow of information during the time when the attention of the subject is held. Very simple stimuli provide little information and a source which ceases to provide new information ceases to hold the attention.

Related to the attention value of complex stimuli is the attention value of novel stimuli. The interpretation given to this fact by the present writers is that a novel stimulus provides much new information to be processed and holds the attention of the observer for the time that it takes this information to be processed. Such a mechanism has obvious biological advantages. An organism that did not attend to novel events and did not carefully process the information derived from them would not be likely to survive for very long. In contrast, familiar events require only very small inputs of information for them to be adequately understood. We do not have to listen to the entire speech of a campaigning politician to know what he stands for and we may have difficulty in attending beyond the first paragraph. In contrast, a lecture on an unfamiliar topic may well require us to listen to the entire communication.

This interpretation suggests that the designer of audiovisual teaching devices must be sure that it provides a flow of new information to the learner. In the pursuit of this goal the factor of complexity must not be misinterpreted. Relatively simple presentations may provide sufficient complexity to hold attention, provided they yield a continuous flow of information. In addition, the fact must be taken into account that the use of novelty means that the presentation has to have high potential for transmitting information.

A second important finding which comes out of the research reviewed in this chapter is that the use of a particular sense modality appears to result in that modality becoming less and less capable of transmitting information. While this finding comes out of research on vigilance, where the rate of transmission of information is low, the same effect may well occur with higher rates of transmission. This is a matter which needs to be checked upon with empirical research.

Third, the fact that attention can be conditioned is a fact with important implications for learning in school. The teacher as well as the designer of audiovisual materials can take advantage of the fact that children approach learning situations with dispositions to attend to certain sources of information rather than to others. One suspects that children in the American culture have been conditioned to attend to television screens long before they reach the elementary schools. This conditioning would give them a predisposition to attend to such screens. In addition, even if the school televised broadcasts were dull and tended to extinguish the attention of the children, some reconditioning would occur each evening when the children returned to their homes. Ultimately, one presumes, that the children would learn to discriminate between those television screens to be attended to and those to be ignored. The film has, of course, also acquired positive value for the child through his out-of-school experiences.

Finally, some interesting questions are raised by the finding that in vigilance tasks there is less decrement in performance when two modalities are used than when the same information is transmitted through one. This is one of the few findings in this entire report which supports the simultaneous use of two sense modalities for the transmission of redundant information. Research needs to be undertaken to determine whether the same phenomenon would be found in learning situations involving a higher density of information than those used in vigilance tasks.

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CHAPTER 9

MODEL FOR INFORMATION TRANSMISSION BY MEANS OF AUDIOVISUAL MATERIALS

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Model for Information Transmission by Means of Audiovisual Materials

In this chapter an attempt will be made to bring together the numerous scientific discoveries reviewed in previous chapters which have the relevance for designing situations in which information is to be transmitted through more than one sense modality to a human receiver. The emphasis in the research which has been reviewed has been on the perceptual aspects of the process, that is to say on those processes that are involved at the input end. Some studies have also been reviewed concerned with so-called participation techniques which focus on outputs in relation to the acquisition of information.

The Schematic

A schematic of the information transmission process as it emerges from the research which has been reviewed is presented in Figure 5 . The schematic is a modified Broadbent model.

The model presented here, and the model proposed by Broadbent (1958) are closely similar to other models found in technical literature. For example, Feigenbaum and Simon (1963) have developed what they refer to as the EPAM (Elementary Perceiver and Memorizer) model. The EPAM model involves a temporary storage and a single channel processing system. The model was built in the context of data derived from serial learning, but appears to fit data from a rather wide variety of contexts.

A few general comments about the representation provided are in order at this point to prevent some misunderstandings that are likely to occur.

First, the schematic does not represent a set of clearly identified neural structures, but a set of operations which appear to be performed on data.

Second, the schematic represents a set of constructs inferred from data. The constructs involved are substantially different from those that are typically discussed in books on audiovisual materials, but they are believed to be much more consistent with available knowledge.

Third, the constructs represented are often sketchy, largely because they are derived from limited and very incomplete information. There may sometimes be alternative representations which have plausibility, but those that are presented are believed to have greater consistency with the data and greater plausibility than the alternatives. Some of the constructs are believed to be derived from an overwhelming amount of consistent evidence.

The sections of the report that follow describe the components of the information-receiving process represented in the schematic. These sections are heavily dependent upon material previously presented but avoid the repetition of evidence which has already been cited.

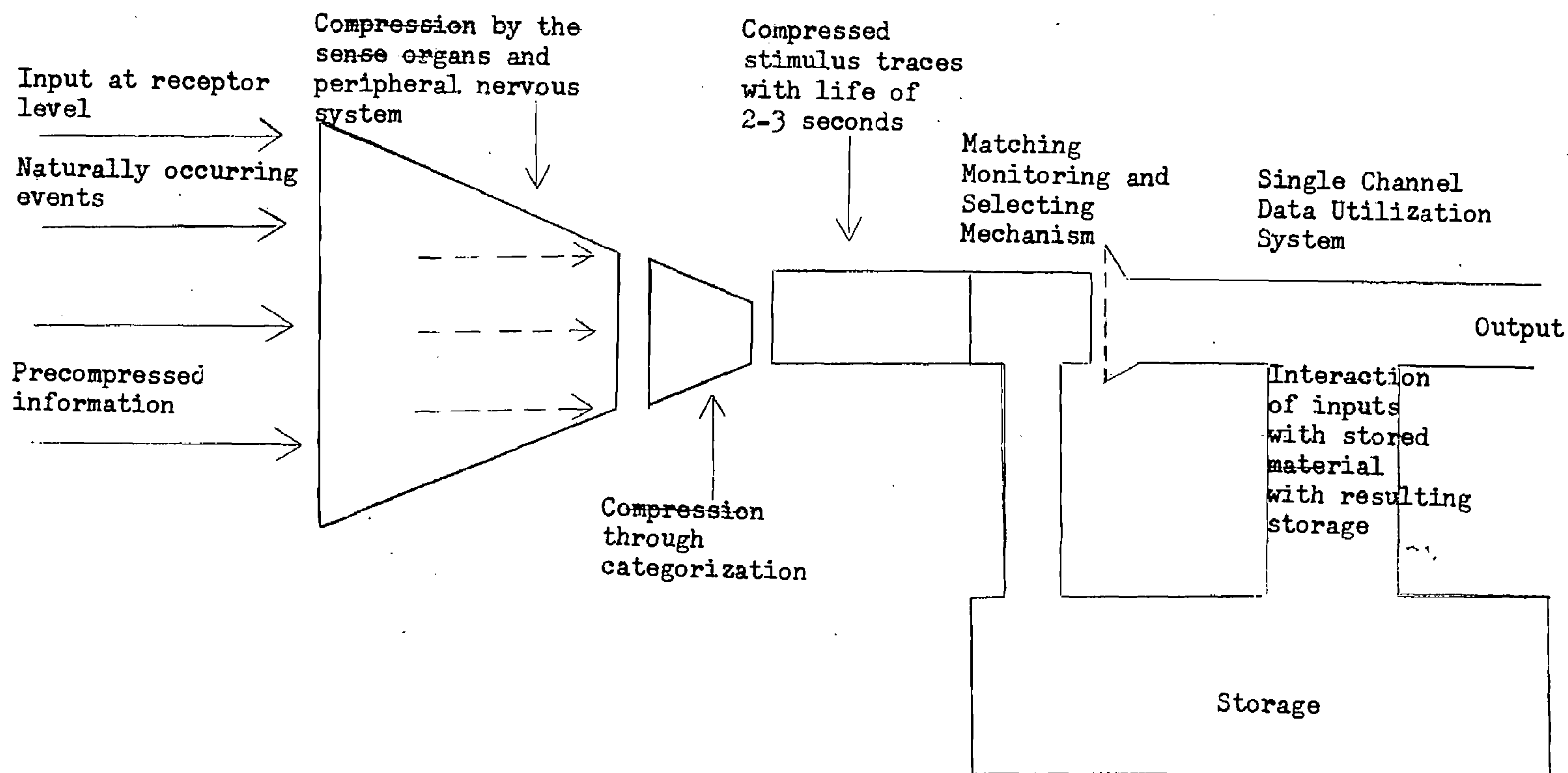

Figure 5. Model of the information transmission process adapted from Broadbent (1958) for the design of audiovisual materials.

The Compression Process

The information provided by the environment undergoes compression at various stages during its transmission. Information may be compressed by the instructor prior to the impact of the information on the sense organs or it may be compressed after it has activated the receptors. Precompression of information, that is to say compression before it is transmitted to the human receiver, appears to have considerable advantages in promoting learning. Precompression permits a rational decision to be made concerning what is to be retained and what is to be eliminated, while compression by the nervous system involves at least some rather arbitrary processes. This position is substantially at variance with the position of present developers of audiovisual materials who have emphasized the great value of realism in modern methods of transmitting information, a policy which avoids compression. The latter position has illusory attractiveness, for the nervous system is a mechanism which does not transmit information in all of its original wealth of detail, but rather does it select and discard information according to a set of built-in rules.

Although precompression has substantial advantages over the procedure of transmitting information with all of its realistic wealth of detail and leaving the task of compression to the nervous system, the process of precompression has to be undertaken in a way which is compatible with that undertaken by the nervous system. In the case of visual information a considerable amount of information exists concerning the manner in which the nervous system compresses information, but much less is known about the compression of information transmitted through other sensory channels. In the case of vision, the evidence seems clear that most of the information is transmitted through boundaries and, hence, a representation which emphasizes the boundaries and de-emphasizes other information provides an effective means of transmission. The line drawing satisfies the condition for the effective transmission of visual information and it has been demonstrated empirically that it is one of the most effective methods of presentation. One may assume that a line drawing sometimes compresses information beyond that which would be undertaken by the nervous system. When this occurs, what are the problems encountered by the learner when he comes to apply the knowledge thus acquired to a situation providing a lesser degree of compression? The answer to such a question is not available at the present time and must be derived from research.

The boundaries of objects are obviously characteristics of particular importance in any transactions with the environment. Information concerning the position and nature of the boundaries is obviously necessary for making physical contact with the objects, for grasping or holding them, determining their size, and in performing other common operations related to them. Emphasis on the information transmitted by boundaries has obvious utility to the human organism and is not a completely arbitrary information-compression procedure. One presumes that other compression procedures have high biological utility built into them and are not simply processes which cut down information on an arbitrary basis to prevent the system from becoming overloaded.

The compression of auditory information presents problems which are being studied, but no well defined mechanism has been identified. Attempts have been made to utilize processes referred to as time compression which involve either a process of speeding up speech with a resulting increase in the basic modulation frequency or by a process which involves chopping out sections at random. Such processes do not appear to compress speech in a manner which offers any great advantage for facilitating the transmission process. The clipping of phonemes is another alternative which probably offers greater possibility of undertaking a process of compression external to the organism similar to that which takes place within the organism.

At higher levels of the nervous system another compression process takes place. This is the process which has been referred to as categorizing behavior. Just where such a process begins is a matter of controversy. Some categorizing or coding may well take place at the level of the first sensory nucleus, but it must be of a primitive nature and require much coarser discriminations than the categorization involved at the higher levels of the nervous system which is referred to as concept learning or concept utilization. Some compression of this kind would have to take place prior to the operation of any selector mechanism. Selection is generally in terms of the relevance of the input to the ongoing activity of the organism, though very intense stimuli as well as pain related stimuli gain immediate access to the higher centers. A selector mechanism would have to work with both compressed and categorized information if it were designed with any parsimony.

Temporary Storage: The Stimulus Holding Mechanism

Theories of learning and perception during the last quarter century have tended to introduce the concept of a temporary holding mechanism which intervenes somewhere between the input at the receptor level and the utilization level. Hull (1943, 1952), following a suggestion made much earlier by Pavlov, proposed that an afferent input is followed by a perseverative trace (s) which lasts a few seconds but declines rapidly to zero. A very similar construct has been introduced by Broadbent (1958) who has proposed a temporary storage device which holds signals for a few seconds. The data on which Hull based his construct were derived almost entirely from experiments with rats, but Broadbent has used exclusively data from experiments involving human subjects. It is a matter for surprise that the two constructs thus derived are so close in agreement one with another. Both agree that the trace held in storage can be utilized by the organism for only a matter of two or three seconds, after which time it has weakened to the point where it can no longer influence behavior. Both writers agree that the mechanism permits the organism to delay making certain kinds of responses and that the postulation of such a holding mechanism is necessary to account for certain experimental results. The mechanism is particularly important to the model proposed by Broadbent in that it permits the organism to utilize information provided simultaneously by two sources if the messages are short and last perhaps no longer than two seconds. The model also accounts for the fact that short messages may also be presented simultaneously through two sensory modalities and still be received in the single channel P-system, once again provided the two messages are short.

A controversial issue is whether information held in temporary storage can be transferred directly to permanent storage without entering the utilization system. Studies on incidental learning provide a somewhat superficial suggestion that they do, but an argument could be made that the material learned by such means does actually enter the utilization system.

The Selecting, Monitoring and Matching System

The model adopted here follows closely that of Broadbent (1958). The particular mechanism discussed in this section corresponds to the filter of Broadbent which leads to a single-channel P-system. The mechanism as it is described here performs the functions of matching, monitoring and selecting. The latter prevents the utilization channel from becoming overloaded. The mechanism postulated here has an outlet to the information utilization system which functions as a single channel. If the selector mechanism did not function, the utilization system would become jammed with information and could not function effectively. It is, of course, only one of a series of mechanisms which limits the input of information so that only manageable quantities have access to the higher centers. Previous compression processes serve very much the same end. Let us consider each one of the three functions specified in the title of this construct.

There is much evidence which points in the direction that the inputs are matched with information previously stored. Evidence derived from the study of subhuman organisms fits well with the daily experience of man which shows a striking tendency for novel objects to command attention. Novelty is defined objectively as being that to which the organism has not been previously exposed. Modifications to an open space in which a rat has frequently spent time will result in the rat attending to the novel features. Whether the rat will actively explore or merely watch the novel aspect that has been introduced will depend upon the strain of rat, but the attentiveness of the rat to the novel aspect of the situation is assured. The survival value of this kind of behavior is clear, for an organism which did not heed changes in its environment would not survive very long.

The continuous matching process which is inferred to take place insures that whatever is different from that which is anticipated in terms of previous experience has priority in obtaining access to the higher centers which are here referred to as the utilization system. This fact should not necessarily influence the practices of the designers of audiovisual materials for the response to the unusual often involves an emotional response which may not provide a favorable condition for learning.

A second point to note is that the mechanism under consideration has to provide a continuous monitoring of the information coming in to the organism. This is a concept which would be easily misunderstood for it does not imply the existence of a homunculus. The monitoring system could simply be a data analyzer, set in such a way that it could assign priorities to the various categories of compressed information available to it. Thus inputs of information of high value to the receiver would be passed on in preference to information of a more trivial character. Statements involving the receivers name or statements directly related to his needs, such as "Here is the money I owe you," are likely to be transmitted further. The selector mechanism obviously has to have a system of priorities for determining blocking or transmission of the inputs of data.

The priorities of the selector mechanism can clearly be modified in a number of different ways. Need states are well established as influencing sensitivity to particular classes of information. The hungry man becomes acutely aware of signals indicating the presence of food. The person searching for a daily newspaper is highly responsive to white objects or parts of white objects projecting from underneath other objects. From the point of view of the teacher, the most important point to note here is that the priorities can be changed by instructions given before information is made available. Thus the teacher can say, "In the film you are about to see, I want you to observe......" The instructor may also lower the priorities of certain information by statements such as, "When you are watching the movie forget about what is happening in the background for that is quite unimportant." Such instructions influence the priorities which the selector mechanism applies to the incoming information.

The selector mechanism can obviously transmit only a very small fraction of the incoming information to the utilization channel. Since this is the case, it is of great importance to the survival of the organism that the transmission be other than arbitrary. The capability of the human to cope with a very complex environment attests to the extraordinary capability of the selector mechanism to set up a set of priorities which have survival value.

The Utilization Channel

Broadbent was the first to point out that a selector mechanism, or a filter mechanism as he called it, was essential for the final utilization of information, since the final process appeared to involve a single channel system.

While reference is now commonly made to the perceptual system or the utilization system as being a single channel system, the concept of a single channel is not entirely a clear one. The concept finds its origins in electronic systems which may be designed so that a transmission system can carry only a single item of information at a time, though many items of information may follow one another through the system in rapid succession. A telephone line used for the transmission of a single speech message approximates a single channel system of transmission. The electrical changes at any point along the line can be represented graphically by the movement of a point on a graph. Such a transmission would involve one dimension other than time, the one dimension being the energy level. In this sense the transmission of auditory information derived from a single source can be represented as single channel system for transmitting information. Since most of the data considered by Broadbent is data involving the transmission of speech, the concept of a single channel transmission is clear, for one can conceive of speech being transmitted through the utilization system much as telephonic communication is transmitted through a wire.

Now it is quite clear that the transmission of information along the afferent bundles such as the auditory and the optic nerve cannot be represented by a single channel system. Such transmission systems are complex for they do much more than transmit information, performing also other functions such as compression and analysis. At a later stage, analysis occurs so that one single source can be separated from another source and this presumably occurs prior to the operation of the selector mechanism. Beyond the selector mechanism, and probably even before, the restriction in the case of auditory transmissions is more than that the input can be represented by a single point moving with respect to some axis in addition to a time axis, for the information transmitted will be selected in such a way that it forms a sequence in which the transitional probabilities are similar to those built into the receiver by experience. Thus it is possible to keep track of what one speaker is saying despite the fact that others are speaking at the same time and are attempting to transmit different messages. Events which arrive in a sequence corresponding to the stored transitional probabilities represent, in a sense, a single channel transmission of information, even though each event in the sequence may be complex. In such a case, the single channel concept refers to the fact that only a single series of transitional probabilities is involved.

The transmission of visual information does not fit the model of the telephone wire at all although the auditory system may approximate this at the ear drum. Visual information can, of course, be transmitted by means of a single channel system as it is in the long-distance transmission of pictures, but at no time during the physiological transmission process can it be conceived as being transmitted in such a way. The transmission process at the retina and optic nerve level would be represented by a set of parallel channels which can be activated simultaneously. Presumably, when the information reaches the centers involved in utilization there are many simultaneous inputs, in what sense, then, can one speak of the utilization of visual material as involving a single channel system?

The answer lies also in the fact that visual information, as auditory information, is utilized in sequences which are such that the transitions from one input to the next are consistent with the receiver's built-in expectation. The visual information follows a sequence representing one set of expected transitions and, in this respect, does not represent a series of parallel inputs each of which follows a particular system of transitions. In this sense, the utilization of visual information can be considered to represent a single sequence of visual events and the utilization channel can be considered to be a single channel system.

In a further sense also the utilization system can be considered to have properties of a single channel. These would be the fact that when information from one sensory modality is being used, the inputs from other modalities are blocked by the selector system, though they continue to be monitored for priority of access.

Thus the concept of a single channel utilization system is basically a psychological one, and not physiological nor one derived from electrical engineering.

The utilization system is limited both in its single channel characteristics and in the amount of information that can be processed through it. Time from one input to the next appears to be an important variable as shown in a study by Bugelski (1962), not merely because of the length of exposure as such but because the longer exposure permits a greater number of operations to be performed with the stimuli, which in turn has an effect on learning. The Feigenbaum and Simon (1963) model which closely resembles the Broadbent model incorporates the idea that all inputs of information require a certain processing time and, since this occurs within a single channel system, the information handling capacity of the system is limited.

The single channel transmission system is also limited in the amount of information that it can utilize per unit of time. This becomes very apparent in the case of speech when the speed in terms of words per minute is increased, as it can be merely by increasing the speed of transit of a tape on which it is recorded. The fact that the pitch is raised by this process has, almost certainly, nothing to do with the unintelligibility of the speeded material for speakers with high-pitched voices are perfectly intelligible at typical speaking speeds. What apparently happens is that the utilization channel becomes overloaded and the analysis process which ordinarily takes place breaks down and fails to function.

Another condition also limits the amount of information which can be handled by the utilization system. Numerous studies point to the fact that the human learner has difficulty in processing large quantities of information from an audiovisual display while, at the same time, undertaking some psychomotor performance in relation to the display. The latter was found to be true not only when psychomotor skills such as knot tying was involved but also when the required activity was that of note taking. In the latter studies the interference with the input of information produced by the learner's activity is quite evident, which suggests that input processes can be and probably should be studied separately from those that involve simultaneous inputs and outputs. What is said here should not be taken to imply that persons cannot learn to produce a steady flow of motor behavior while receiving information, for it is clear that such skills can be learned, though only with considerable difficulty. Examples of such skills are seen in shorthand and in the immediate translation of one language into another in the manner performed by translators in the United Nations. Before leaving this matter, a point to note is that such skills are difficult to learn and require very extended training, probably because of the large amount of information involved in the transmission. Of course, there is no difficulty involved in performing a psychomotor skill while taking in small quantities of information, as in driving a car, for most psychomotor skills involve such simultaneous inputs and outputs.

The Storage System

The conception that storage involves both a temporary and a more permanent system of storage goes back to Hull (1943) though similar notions had already appeared in the work of Wundt. In recent times there have been two major psychologists who have stressed a similar conceptualization of the storage mechanism. Hebb (1958) has stressed the importance of what he calls "holding mechanisms", a concept derived from electronic devices which provide temporary storage of information. Broadbent (1958) refers to a temporary storage mechanism which he refers to as the "short-term storage." Both Hebb and Broadbent imply in their writings that such short-term storage or holding mechanisms retain information for only a short time and are not substitutes for the system which stores information on a more permanent basis.

Present knowledge seems much more capable at this time of generating plausible hypotheses concerning the manner of functioning of temporary storage mechanisms than it is in providing hypotheses concerning the mechanism of permanent storage. Hebb speculates that temporary storage, or the temporary holding of information, is produced by nerve impulses being transmitted through circular chains of neurons. There is some physiological evidence which lends support and credence to such an hypotheses. Such a mechanism would involve those neurons which are normally activated by the particular input and would provide for the continued activity of the particular nerve cells, but without implying that any kind of permanent storage is involved. It assumes that the compressed and coded information is represented by the activity of these particular cells but does not suggest how the coding is related to the original inputs. The suggested mechanism would appear to present difficulties when one comes to account for the fact that temporary holding does not generally last for more than a few seconds. The proposed mechanism, at the best, can account for only limited aspects of short term retention of stimulus traces.

The long-term storage problem is much more complex. One must assume that the information thus stored is highly compressed and fragmentary, but capable of reconstruction so that something approximating the original stimulus inputs can be reconstructed. The fact that what may be judged to be very fragmentary visual information can be reconstructed into a good representation of the original visual presentation has been demonstrated to be possible by Cherry (1962), who suggests that much less may be stored of the inputs than is commonly supposed.

While the coded inputs may be stored as such, there is another very important characteristic of inputs which has to be stored for behavior to be the way it is. This characteristic is the tendency for certain inputs to follow certain other inputs; that is to say, the probability that sequences of categories of events will occur. These are if-this-then-that relations. It is when sequences of events do not correspond to expectancies, -- when sequences do not correspond to past sequences -- that information gains perhaps its highest priority for entering the utilization system. Just how such antecedent-consequent probabilities are stored is a complete mystery, but one can say that they are stored almost certainly in terms of categories of events rather than in terms of coded specific events.

Implications for the Design of Audiovisual Materials

The conceptualization of the information transmission process outlined here is believed to have certain implications for the design and use of audiovisual materials. The evidence supporting the position taken also throws doubt on the validity of many of the so-called principles of the design and utilization of audiovisual materials found in typical textbooks on the subject.

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First, the evidence indicates that multiple sensory modality inputs are likely to be of value only when the rate of input of information is very slow. The common practice of filling both the audio and the visual channels with a continuous flow of information would seem to have little support, except perhaps that it may satisfy some of the compulsions of film producers. The silent film with the alternation of picture and print would appear to find much theoretical support as a teaching device.

Second, the quest for realism and the emphasis on realism which has characterized the audiovisual field emerges as the worship of a false god. While one cannot deny that educational materials must help the learner to perform transactions with a real world, the conclusion does not follow that a high degree of realism should be incorporated in teaching displays. Man does not transact his affairs with the environment by responding to the vast wealth of detail which physical processes transmit to his senses, but rather is he highly selective in the information which he uses and the cues to which he responds. A learning process which involves the presentation of that information derived from the environment which is of value to him, may well provide a much better learning procedure than a realistic presentation which includes a vast and overwhelming complexity of irrelevant detail. The learner may ultimately have to learn to discriminate the relevant cues within the context of a realistic situation, though the internally occurring compression process may eliminate the need for learning this discrimination. For example, a line drawing of the wiring of a television receiver is much more effective in transmitting information useful in assembling a kit than is a faithful photographic reproduction. The line drawing indicates at a glance the important features involved in wiring while the photograph requires careful study before the essential features can be sorted out from irrelevant features produced by shadows and shading. The commentary in many films is necessary only to help the viewer sort out the relevant from the irrelevant in the video presentation. Perhaps the study of the geometry of the circle should not begin with round plates, wheels, and tables, but with the circle itself, which establishes a category into which these various objects can be placed. The circle also includes that aspect of each of the objects named which is likely to transmit much of the information to the perceiver, for boundaries tend to be major information carriers.

Third, the perceptual model on which most audiovisual materials are based is already well recognized within the audiovisual area as being a thoroughly unsatisfactory one. Information is not satisfactorily stored when a passive learner is passively exposed to inputs though some learning may occur under such circumstances. While various attempts have been made to introduce activities as a part of the procedure involved in the use of audiovisual materials, the equipment involved does not appear to be particularly suited to the incorporation of learner activity. A part of the difficulty of incorporating such activity is that not much is known about the kinds of activity that results in effective retention and transfer.

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APPENDIX

INFORMATION THEORY: A REVIEW OF IMPORTANT CONCEPTS

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INFORMATION THEORY: AN OVERVIEW

Implications for the Design of Audiovisual Devices

The discussion of problems of audiovisual education is often interwoven with the language of information theory which, at least on the surface, should have some application to problems of transmitting information in educational situations. While the latter is a sufficient reason for the inclusion of this appendix, a still more compelling reason is that much of the research to be discussed in the book uses the language of information theory to formulate the problem involved and to discuss the findings. The vocabulary of information theory is important for understanding much technical literature related to the psychology and physiology of information transmission and, indeed, such literature would be quite incomprehensible without an understanding of this vocabulary. In addition, the understanding of the learning process which has evolved through the study of concept learning -- an area with important implications for the design of audiovisual materials -- is tied to information theory not only by vocabulary, but also by the mathematics which it uses.

Thus, in a sense, this appendix represents an attempt to introduce the reader to a language. Many of the chapters make extensive use of the material covered here. Of particular mention is the chapter on concept learning which reviews research deeply influenced by information theory. The chapter on the physiology of information transmission and the chapter on the information capacity of the senses also covers material which has been exposed to a similar influence. In addition, the chapter on the single channel nature of the perceptual system derives many of its important concepts from information theory.

A Brief History

C. E. Shannon's paper, "A Mathematical Theory of Communication", published in 1948, started a mushrooming of interest among scientists of diverse disciplines in information theory. This initial interest continues to be evidenced in many fields. In 1949 Miller and Frick introduced some of Shannon's general concepts into psychological literature. The name of this article was "Statistical Behavioristics and Sequences of Responses", and its main discussion is about an area known today as sequential dependencies. Two years after the publication of this paper, a conference was held at Harvard University, followed by a report of it published by Quastler in 1955. Since then, many journals have devoted extensive space to the description and use of information theory in psychology, particularly in the areas of perception and communication.

All of this activity in psychology did not just happen, but was preceded by many years of work in other areas. These background areas are classified into two major groups: (1) communication engineering and (2) statistics and experimental design.

For a short exposition of each of these separate histories, the reader is referred to Garner (1962).

Some Basic Concepts in Information Theory

Since information theory has its beginnings in the fields of engineering and statistics, one can well imagine that it is predominantly a mathematical theory. It was originally meant to handle the measurement of information transmission in well-known communication systems, and, consequently, was formulated in the framework of the engineer and mathematician, using a language largely unfamiliar, at first, to the psychologist.

Quantification of Information

The basic unit of information in the mathematical system is the bit, an abbreviation for binary digit. The bit is defined as the amount of information needed to designate which of two equally likely alternatives is, in fact, correct. Consider the situation where a coin is tossed with the two possible outcomes of heads or tails: prior to this event, the amount of uncertainty regarding its outcome is exactly one bit, which in turn is the amount of information derived from the act itself.

Suppose that we had a situation in which there were eight possible outcomes -- the simultaneous toss of three coins. By asking questions that could be answered yes or no, that is, binary questions, we could determine just which one of the outcomes occurred. What would be the least number of questions needed to find out in each instance which had occurred? We might ask the questions: "Was it alternative number one e.g., all three coins with heads?", or "Was it alternative number two?", and so on, and eventually find the right one.

This type of questioning is not the most efficient way to find out which alternative it was because it might require a total of eight questions to find out which of the eight alternatives it was. It would be much more efficient on the average to ask questions in such a way that they reduced the number of possible alternatives by one-half each time. We might ask, for instance, "Is it one of the first four?". Regardless of what the answer is, we have cut the number of possible alternatives in half. We have reduced the uncertainty in the situation by fifty per cent. One bit of information has been transmitted. To further reduce the possible alternatives by one-half, we ask the same sort of question, e.g., "Is it one of the first two?". After only one more such reduction in the number of alternatives using this questioning technique, a total of three questions, we will have our answer. In every case with eight equally probable alternatives the total number of questions needed to find out which one occurred was three. Whereas, in a randomly selected set of alternatives in three out of eight cases one could guess the right answer in less than three tries, but in five out of eight cases, it would take more than three tries to find the right answer. The savings in effort is obvious.

When one coin was tossed, there were 2^1 alternatives, that is, two. The amount of information transmitted, the amount of uncertainty dispelled, was one bit. In the next situation considered there were three coins tossed simultaneously, and the number of alternatives was 2^3, or eight. The amount of information transmitted by this event was three bits. Garner (1962) states the matter in this way: "Thus it seems intuitively obvious that we cannot use simply the number of possible outcomes of an event as our measure of uncertainty and information, but must find some measure which satisfies the two conditions that (a) it is monotonically related to the number of possible outcomes and, (b) each successive event adds the same amount of uncertainty and thus makes available the same amount of information."

"The measure which satisfies these conditions is a logarithmic one, of the form

$$U = c \log k,$$

where U is the required measure of uncertainty, k is the number of categories or possible outcomes, and c is a proportionality constant whose only function is to establish the particular unit of measurement" (p. 4). Because information measures are ordinarily involved in dichotomous situations, the measure is usually taken to the base two, and the proportionality constant c is one.

Now, if a die were thrown, one would have a situation in which the amount of uncertainty involved was more than one bit since there would be more than just two possible outcomes of the act. There are, of course, six possible outcomes. What would be the amount of information transmitted by the throw of the die? It would be found from the formula

$$U = I \times \log_2 6$$

or 2.449 bits.

The bit is the basic unit of information within this theory, but there are other concepts that are also basic. It would be profitable to list a few of them here and briefly explain their use in information theory.

Alphabet: The alphabet is the set of alternatives with which the recipient is concerned and from which the source chooses when constructing a message. It is selected *a priori*, and must be the same at both ends of the system, the source end and the receiver end. Any discrete set of sign-types such as letters, numbers, words, morse code, etc. will do.

Message: The chain of selections from the alphabet.

Channel: A channel designates the media which carry the transmission of information from the source to the receiver. Some of these media are: air (for sound waves and light waves), wire (for electrical impulses), and the human organism.

Channel Capacity or Limiting Capacity: Channel capacity is defined as the largest number of discrete signs that can be transmitted per unit time with any arbitrarily set, but of course small, number of errors.

Code: This is an agreed set of rules or a system through which messages are converted from one form to another. We speak of the transformation of a thought to sound waves through speech as an encoding, and the transformation of sound waves received into verbal symbols in the brain as a decoding. More will be said about this later.

Ensemble: "A collection (e.g., of possible signs, signals, messages, from a specified SOURCE, with a set of estimated probabilities of occurrence)" (Cherry, 1957, p. 304)

Noise: Random disturbances which do not represent any part of the messages from a specific source.

Redundancy: (of a source) "Unity minus the ratio of the information rate of the source to its hypothetical maximum rate, when encoded in the same set of signs. Broadly, a property given to a source by virtue of an excess of rules (syntax) whereby it becomes increasingly likely that mistakes in reception will be avoided" (Cherry, 1957, p. 305).

Other terms used in information theory will be defined later. The above definitions are to be considered as indicative of those used, but they are not necessarily the definitions universally accepted. There are no universally accepted definitions in cases, although there is a great amount of agreement on the usage of the terms.

The General Model of Information Theory

We must not confuse the lay usage of the term "information" with that of the scientist. To the theorist, information has only to have certain physical properties and does not necessarily have "meaning". In the usual lay usage of the term "information" there is the implication that the signal being sent or received "signifies" something, or that we can somehow attach a value or measure of truth to it. This is not necessary in information theory. We are concerned with the statistical rarity of an event, and the information sent is measured in terms of this statistical rarity. Information is that property which describes the potential of signals. There is some relation between it and the concepts of selection and discrimination, e.g., with respect to selection, we are interested in the probability of any given signal or sign being selected from our alphabet at the source, and further, the probability that the identical sign will be selected at the receiver because of the signal sent. We are also interested in the problem of the ability of our system to discriminate between the signals sent and the other possible selections in our alphabet.

As can be seen from Figure 6, the same alphabet must exist at both ends of the system. If the source were to use a different alphabet from the receiver, the source and the receiver would be confronted with a situation such as would exist if a visitor arrived from another planet, and he had no knowledge of our language while we had no knowledge of his. The resulting difficulty in communication is obvious. Such a situation would be much more difficult to surmount than the wartime situation in which an enemy message is intercepted and the code must be broken in order to find out what was said. In the latter situation, the alphabet would at least be known, and the rules of usage (syntax) and the probabilities of occurrence of the different alphabet members would provide additional clues.

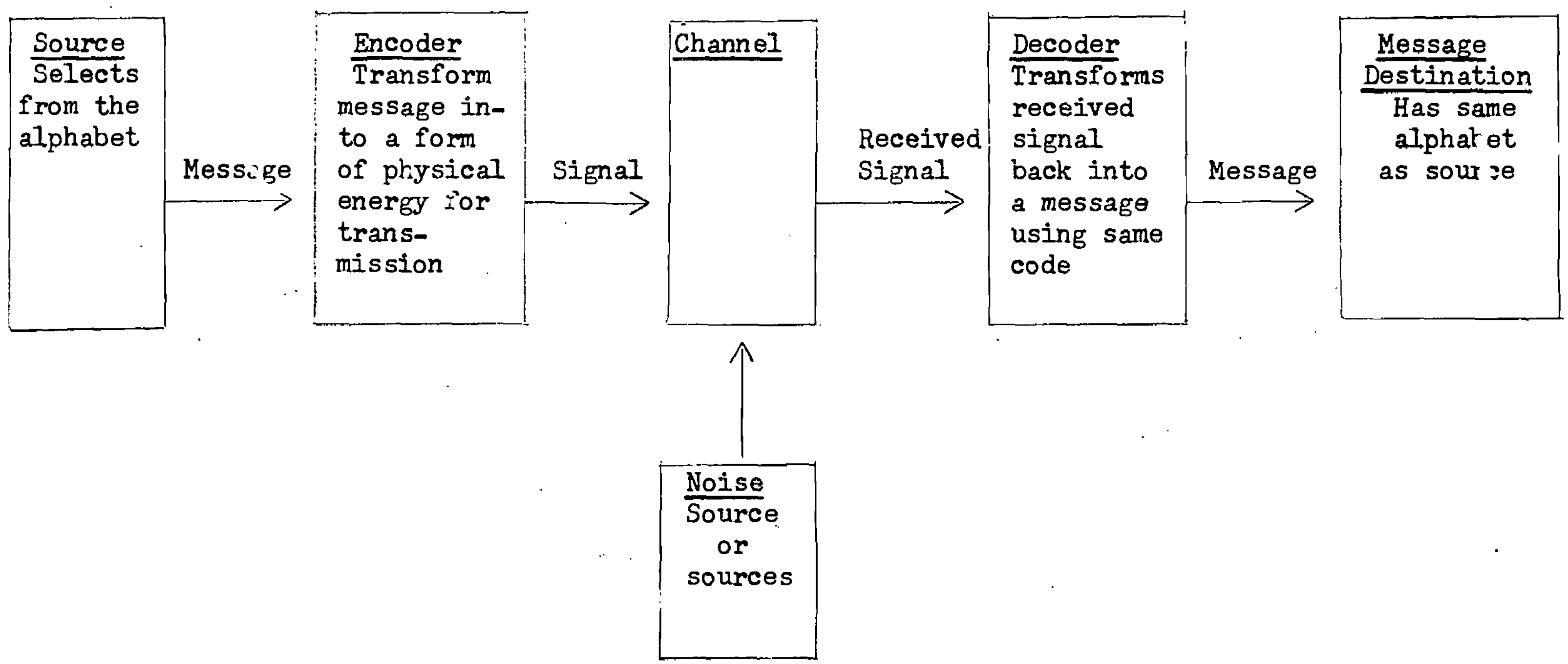

Figure 6. An Information Transmission System

As was made explicit in the earlier definition of alphabet, any discrete sign-set is a possible alphabet. Letters, words, discrete concepts, and propositions could be an alphabet.

The source scans its alphabet and from these discrete signs constructs a chain of signs which we call a message. One might, for purposes of illustration, use a telegraph system. The alphabet consists of different combinations of dots and dashes which are used to represent the letters of our alphabet. The source, or sender, draws from his messages, that is, words and sentences. Each letter of our alphabet[1] is represented by a discrete sign from our set. Each word is a separate string of letters and so on.

The transformation from the letters of the Roman alphabet to the "letters" of the morse code represents an encoding process. The process of coding, encoding at the transmitter end and decoding at the receiver end, must follow a set of unambiguous rules, and these rules must be the same at both ends of the system.

After the initial encoding into Morse code from the Roman alphabet, still another encoding takes place. This is the encoding of the sign-set into some form of physical energy for transmission. In the case of a telegraph system it would be the transformation of the Morse code alphabet into electrical impulses. It is these electrical impulses which are actually transmitted. With respect to this transformation into physical energy, the same rules apply. These must be a set of discrete physical events which, according to some set of coding rules, have a one to one relationship to the letters of our alphabet, or more correctly said, with the signs of our alphabet.

The encoded message is then sent via a medium to the receiver. Using our example of a telegraph system, the electrical impulses are sent along a wire from the transmitter to the receiver. The wire is the channel. As mentioned in our definition, any medium that will function to transmit energy from one point to another will serve as a channel. In the case of sight, the most common medium is air, but if a person were to be swimming under water and have his eyes open, the water would also serve as a medium for sight.

When talking about channels, it might be profitable to differentiate between external and internal channels. This differentiation will be carried out in the rest of this monograph. By an external channel, we mean the transmitting medium exterior to the body. By an internal channel, we mean the transmitting organs within the body. The different nerve channels are internal channels.

While the message is in the channel, the possibility exists that it may become distorted or mixed with noise. Noise clouds and masks information transmission in varying degrees, ranging from almost no effect to complete interference. Such interference always leads to an irreversible loss of relevant information in the message.

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[1]This ambiguous use of the term "alphabet" was intended to show the relationship of our alphabet, i.e., a, b, ...z, to the universe of possible alphabets of which our alphabet is only one.

Noise can take many forms, but the different forms of noise can profitably be grouped under two headings: patterned and unpatterned. Patterned noise would include cross-talking, irrelevant information sent on the same channel, and in short, any type of signals with an arrangement in which probabilities are assigned by some set of rules to the occurrence of the different signals in the system.

Unpatterned noise includes Gaussian noise and Prownian noise, with other types of noise such as electrical interference and atmospherics that defy the assignment of probabilities in a microscopic situation, but can only be dealt with over a long period of time (microscopically) by taking the average.

The engineers working with communication systems consider it a fact that a noiseless communication system does not exist. If this be so, then there must be two or more resultant conditions: (1) there must be redundancy in the transmission in order to counteract the results of this noise in information loss, or (2) there must be an increase of energy expended at the receiver in order to discriminate between the message and the noise.

Miller showed that the ratio of noise to information desired (message) with respect to sound affected directly the amount of information received. That is, the more noise with respect to the message, the less the amount of information correctly received (Miller, 1957). However, no study was found that dealt directly with the problem of what type of noise was most damaging, if there was a difference. It does seem however, that the noise which is most similar to the message while still not adding any relevant information to the message, would be the most difficult to mask out or discriminate from the message.

The receiver has two main tasks: (1) to receive and decode the signals se , and (2) to discriminate between the message and the noise. Both of these requi. an expenditure of energy and entail several problems. The most important of th problems in terms of the type of study included in this monograph will be described in a later section.

Returning to our telegraph system for a moment. After the message has been encoded into electrical impulses and sent out into the wire, it can become intermingled with noise. The movement of the molecules in the wire, and the atmospheric c nditions affecting the magnetic field through which the message must flow, are p ssible sources of noise. This noise can block the reception of the message if conditions are severe enough. If the damage caused by the noise is not severe enough to block the reception of the message altogether, then there might still be distortion in the message to such a degree as to cause errors.

The receiver receives the electrical impulses and codes them into some other form of energy such as sound waves. The telegrapher at the reception end hears these beeps and decodes them into the familiar letters and words of a language system like ours. We would, in terms of information theory, have to say that the message had been received if the receiver had made beeps corresponding to the pattern of electrical impulses originally introduced into the channel. However, in a situation in which meaning is also important, such reproduction would not suffice, but rather, we would desire the further decoding from beeps to letters of our alphabet. The further work of stringing these letters together into words would also be desired. Before we could say the message had reached its destination some sort of indication would have to have been given that it had arrived. Such evidence is easily provided in many physical situations by the use of energy measuring instruments. But in the human receiver, one cannot always measure the reception of messages beyond the mere determination of whether there has been an impingement upon the nerve endings, in a given organ or not. If one accepts this as sufficient evidence of the reception of a message, then there is no problem, but if we wish to ask also the question of whether or not the meaning of the message has been received, we have a more severe problem for the subject's behavior may not provide a straight-forward indication of the reception of the message.

Let us now follow an information transmission of the common sort that occurs in every day.

Our source will be a teacher in a classroom situation. His alphabet will be the concepts and words, intonations, gestures, etc., that he use to communicate to others. For purposes of this example we will assume that the receiver, a student in the class, has an understanding of the words that the teacher uses, and that the meaning of these words in the context of the message sent is the one normally associated with these words. It is common to both the teacher and the student. (In reality it is almost certain that the understanding and usage of words is an individual matter and no two people have the exact same understanding, or attach the same values to the same words. It is, of course, true that there must of necessity exist much agreement between persons in the meaning of words, or in the concepts that are represented by words, but this does not preclude the existence of highly individualized meanings and values associated with these same words). The similarity between personal uses of a word and the general uses of that word is what makes communication possible.

We have now satisfied the condition that the source and the receiver have the same alphabet from which to select signs.

The teacher wishes to have the student open his book to a given page. He now uses the different muscles utilized in speech and from his alphabet of words and gestures and intonations he selects those that are appropriate for the message he wishes to communicate. His throat and mouth, larynx and tongue, and so on, now expand and contract and shift to vibrate the air that is flowing past from the lungs and diaphragm. The message has been encoded into sound waves. Activity has gone on in the brain where the message was encoded into nerve impulses and sent down to the different sets of muscles in order to cause the characteristic vibrations of speech. The different muscles have responded. The message has been sent.

This seemingly simple occurrence has already opened several areas into which we might briefly glance. The selection by the source of a chain of signs with which we will communicate his message is an interesting phenomenon. It is contingent upon the speech habits of the source, the rules of syntax of the language into which the thought was encoded, the present situation, and a multitude of other things. The encoding of a message into different types of actions is indeed one area of extreme complexity. With respect to language, the redundancy inherent in languages allows for a great deal of flexibility and variability in

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the choice of alphabet members to communicate a single message.

Our source, the teacher, has selected from his alphabet those signs which are appropriate to communicate to the student that he should open his book to a given page. This has been encoded in the brain into nerve impulses, which in turn have been encoded by the actions of different muscles and organs into sound waves.

These sound waves are transmitted by the channel to the student. In this case the channel is the air. While in the channel it is possible to add noise to the message. This noise might be likened to what would happen if, at just the moment that the teacher started to speak beside the open classroom window, the traffic light turned green, a multitude of cars raced their engines and started off, a trolley car rang its bell, and an ambulance went streaking by with its siren blaring.

All of these "extra" sound waves are noise. They are not relevant to the message that the teacher wants to communicate. Some of them are patterned, while others, especially the indistinct background noises, are unpatterned. The noise might have prevented the reception of the message by the student. Each one of these different noise sources would affect him in a different way, or to a different degree. Noises (noise-sources) have certain weights or salliences or attention-getting values which are difficult to estimate within information theory. We might be able to do this by looking at the behavior of the receiver under noisy versus non-noisy conditions. The student had many extra clues as to what the teacher might have said, such as: the fact that the teacher looked at his book. He saw that the other students had their books open to a given page. The teacher motioned with his hand as if he were opening a book, etc. So, even though the student might not have received the verbal message the other redundant information could well have been received. The pantomined message might have gotten through.

This illustrates the usage of redundancy to insure the reception of a message when there is noise in a channel. One needs only to receive one of several redundant bits of information in order to reduce the uncertainty in the situation by one bit.

Also illustrated here is the possibility that multi-channel presentation of the same information might also be advantageous. The noise that blocked one would not necessarily block the other.

The student did miss the verbal message because of the noise, so he asks, "What did you say?"

The teacher repeats his message, and the student receives the signals (sound waves) this time with a minimum of interference. The sound waves impinge upon the ear of the student and cause characteristic changes to take place within the ear. These vibrations cause different sensory nerve endings to fire, and the signals are once again transformed into words in the brain of the student. When the student opens his book to the correct page or reacts in some other characteristic manner one may infer that the message has been received.

If the words had been misunderstood, then there would have been a loss of information in the system. There might have been a loss of information in the above mentioned example when the cars, trolley bell, etc., made so much noise. Noise may cause irreversible loss of information in a transmission system.

Some Applications of the Information Theory Measures to Psychology

The previous section was only a brief and incomplete description of an information theory model. Such mathematical measures as channel capacity, redundancy, and rate of flow of information, and others were not derived. The interested reader should consult works such as those by Attneave (1959), Garner (1962), and Khinchin (1957) for a more complete description of these measures.

The next sections of this chapter are intended to review some of the applications of information theory measures and/or concepts to different fields of psychology, and the problems associated with these applications. Particular attention will be paid only to those studies or groups of studies that have direct relevance to the purpose of this monograph. The following review will not be very wide or deep, but is meant to satisfy a very narrow purpose.

Just a year or two after the publication of Shannon's paper on information theory, Miller and Frick (1949) wrote a paper on the future importance of information theory to psychology in which they point out that "...psychologist's experiments usually generate a sequence of symbols; right and wrong, conditioned and unconditioned, left and right, slow and fast, abient and adient, etc." (p. 314). The dichotomous nature of the variables and the relation between the stimulus array and the response array permit them to be used as binary bits of information within the framework of information theory. A further hope was seen in information theory because in the methodology formerly used to handle these situations, the effects of sequential dependencies rather than being included in the analysis were removed by randomization processes, and in information theory these effects could be included in the analysis. If these sequential dependencies are ignored, it is the same as assuming that the events are independent of each other. This is not always a reasonable assumption.

Klemmer and Frick (1953) made the following statement about the use of information theory measures: "The [information] measure may be applied without logical difficulty to any situation in which one is willing to identify the members of the stimulus and response classes and make some statements about their probability distributions. Whether or not the measure is useful in the analysis of human behavior remains to be proven. Early results from its applications are, however, encouraging..." (p. 15). The use of the information theory measures requires the *a priori* identification of the stimulus and response elements and the assignment to them of probabilities of occurrence. These two conditions give rise to others, two of which were pointed out by Miller and Frick (1949). These are: (1) that changes in the probabilities associated with the sequential dependencies of the stimulus elements in a learning situation, and the requirement of designating *a priori* the probabilities of any given stimulus element occurring are incompatible, and (2) the estimation of the probabilities of stimulus elements occurring in any situation increases in difficulty as the length of the sequential dependencies considered increases, and becomes unfeasible beyond three step dependencies.

These conditions and limitations do limit somewhat the kinds of studies that can be done within an information theory framework, using the mathematical measures thereof. Let us now look at some of the studies that have been done within this framework.

Borrowing Concepts From Information Theory

Of great importance to the type of experimentation in which we are mainly interested, is the idea that we can profitably borrow the concepts from information theory that we feel we can use and not have to worry about all of the restrictions that are inherent in the mathematical theorems. This does not mean that we are free to do whatever we might choose, but rather, that we can have considerable flexibility in the problems we consider if we use the concepts, i.e., coding, transmission, rate, channel, etc., while not using them in a highly quantified manner.

One example of the advantages of such an approach is provided by Broadbent (1956, 1958). He points out that in many attempts to establish one or another theory about a given field in psychology the experimenter usually attempts to postulate a highly detailed and quantified model, and then conduct experiments that will prove that model as being the one that is true. There are two dangers in this type of procedure according to Broadbent, (1) that the experiments completed might fit more than just one model, and (2) if the specific model that the experimenter has postulated is disproved, it does not really narrow the field of possible models to any great extent.

He then suggests that a more profitable use of research time might be to first attempt to delineate the possible general models that will account for the phenomenon already studied in that field. After these general models have been delineated, the experimenter might then use the language of information theory to formulate more exactly these general models and make them amenable to experimentation.

In speaking of the contributions of information theory to the study of audiovisual aids and other new media in the education field, one is confronted with the fact that the knowledge in the field is often of a very general type, and does not lend itself easily to testing by highly quantitative models. It is for this reason that the first concern in this field should be with the formulation of general models that account for the known behavior characteristics in terms of information theory and the testing of the hypotheses that flow from these models through the use of any and all quantitative techniques that can be rationally applied.

Some Problems in the Application of Information Theory

Now that we have reviewed the general model of information theory and some of its applications, it would be in order to touch upon some of its problems and restrictions.

Cronbach (1955) criticized some of the studies done using information theory measures on the ground that the experimenters do not offer sufficient rationale for the use of information theory measures. While it is true that many of these studies have shown results that are indicative of trends in learning with respect to different variables suggested by information theory, there are certain restrictions of information theory that require that these results be looked at closely so that mistakes are not made by taking them at face value. There are some types of studies for which information theory is not appropriate, or in which the use of information theory measures actually deplete from the study some of the important sources of information about the phenomenon being studied. Let us look at some of these problems.

The first problem mentioned by Cronbach (p. 25) is that Shannon's measure is concerned with message space rather than certainty. Certainty here would be defined as the probability of the subjects selecting the correct message from his ensemble before the message was sent to him. Shannon's H or log uncertainty is a measure of message space in bits. What Shannon is essentially measuring with this measure is: "How long a message over a standard channel would be required to attain the same increase in certainty, using the ideal code?" (Cronbach, 1955, p. 18). "(The standard channel is a noise-free channel which transmits independent binary digits each with probability .50. Message space is of interest in studies of messages and channel capacities, but not necessarily in all perceptual problems and reasoning)" (p. 19).

The second problem mentioned by Cronbach is the fact that the sender's ensemble is not always the same as the receiver's ensemble. The receiver usually has only a vague knowledge of the sender's ensemble of signs. It can be shown that when the receiver does not know the alphabet and probabilities of the sender then his a priori certainty is lower. This means that when the receiver does not know the ensemble of the sender a message sent to him actually contains more information than the Shannon measure of uncertainty would describe because of the added information in the message concerning the ensemble of the source.

How easy is it to determine the ensemble of the source? The first problem would be that of determining the alphabet to be used and the members of the alphabet. We might use our own alphabet as an example. We have twenty-seven different alphabet members, that is, twenty-six letters and the blank space. Various types of punctuation are omitted here for simplicity. If all of the letters appeared with equal probability then we would have an alphabet in which the occurrence of each member would carry $\log_2 27$ or 4.75 bits of information. But our language does not use all of the members of our alphabet an equal number of times so that they do not have an equal chance of occurring. Morse, in devising his code, used the distribution of letters in a printer's office as an indication of the distribution of letters in our language. This led to the assignment of shorter code representations to the more frequently used letters. With unequal probabilities of occurrence, the occurrence of one letter might entail more information than the occurrence of others. This type of difficulty is quite feasible to overcome, but difficulties less easy to overcome are those produced by individual differences in speech habits, and by the situational and personal differences in any given situation and at any given time.

Sequential dependencies would further complicate the problem. For example, the letter "q" does not occur too often, but when it does the letter "u" is used in conjunction with it. One could be very certain that if a "q" appeared in English script a "u" would be almost certainly associated with it. Therefore, there would be no information in the "u" when occurring in conjunction with a "q" as the "u" would be totally redundant. When considering the letters "q" and "u" separately we would receive more information from their occurrence than when inter-relations are considered. The Shannon position considers all of the events as being independent, and the relations which are considered are the relations between a single input and a single output. The effects of inter-relatedness of inputs and/or outputs are lost.

An important point to mention here is the fact that constant errors are overlooked by information theory measures. Random errors are handled adequately by the theoretical structure, but they are handled as if they were independent of each other. This independence that is assumed is not always the case. If we were to present a subject with a series of stimuli, and he were to reverse the responses and do this in a constant manner, information measures would not see this as a mistake. The constancy of it makes it correct since one can tell the input from the output. Such behavior is seen actually as a recoding of the input information. In some situations it is exactly these constant errors at which you wish to look. For such studies, information theory measures are damaging.

A further thought might be mentioned here. Even after the initial work of constructing probability tables for letters, or even words, we would be confronted with the fact that with every letter or word used the nature of the probabilities of the following letters or words would change. As with the example using the letters "q" and "u", the same type of restrictive mechanism works with other letters and with words. For example, if we were to see an article such as a, an, or the, we would not expect the next word to be a verb. In fact, one might be tempted to say that the probability that a verb would follow would be essentially zero. A language is non-stationary in the sense that the probability of its units depends both on item context and general syntatical rules.

As we can see from the above, the application of the theorems of information theory is restricted because of the necessary condition that we first be able to assign the probabilities of the different alphabet members before we begin experimentation. To skirt this problem, the experimenters are forced to restrict their experimental materials to those to which they could assign probabilities, or else they assign probabilities and have the subjects learn them before starting the experiment. Such restrictions placed upon the stimuli could lead to a great deal of artificiality. If just some of the concepts from information theory are borrowed, as was suggested by Broadbent and others, we will avoid this restriction to some extent while still being able to study problems with less artificiality. The experimenter must decide if he wants to increase the control and quantification of the problem or if he wants to increase the generality. At this stage in the development of audiovisual aids, it would probably be best to concentrate on the more general advancement of the field until increased quantification of the studies becomes both profitable and feasible.

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Another source of difficulty in the use of the mathematical concepts of information theory, with respect to an area such as the one with which we are concerned in this volume, is that of assigning or determining the number of bits of information in a given stimulus. MacKay (1950, 1952) writes of two different kinds of information which he labeled "logon content" and "metron content". "Logon content" refers to the structural and means essentially dimensionality or degrees of freedom. "Metron content" refers to the metrical and is some function of the number of discriminable steps or categories on each dimension. A further consideration here would be the grain of the stimulus, that is, are we looking at the amount of information represented by the individual letters of a word, at the amount of information represented by the different words in a phrase, or the amount of information represented by a phrase? The same sort of differences can be shown to exist in other types of stimuli as evidenced by the experiment of Fitts, et al., (1956) although Attneave (1959) found that in one type of experiment at least, grain had no measurable effect.

If one were to look at a picture of a red ball, how would one determine how much information is contained in this presentation? The first and foremost consideration would be: "Of what alphabet is this 'term' a member?" Or the question might be phrased: "Under what term in the alphabet should it be classified?" This would limit the aspects of the red ball to which attention is to be paid. For example, one might be considering size, shape, color, saturation, etc., and only after having looked at the alphabet involved would one see just what determines the category under which one can classify any given stimulus. This is "logon" content.

One might be further interested in which of four size categories the ball fits, or which of eight color categories, or how much grey there was in the red, etc. The number of different categories of this type that one would have to consider also determines the amount of information contained in a single presentation of the ball. This is "metron content".

If one were to rule the picture into several squares of equal size and consider the picture of the ball as the sum total of the responses to each of these squares, then one would be considering the effects of grain on information content. It is possible that one might increase the time needed to determine what had been sent if one were required to state whether or not any part of the ball had been present in one square if that square were one of twenty or if it were one of two hundred. This has not always been born out in experimental evidence, but under different circumstances or using different materials, grain might well have an effect on the amount of information present in a stimulus.

After determining the aspects of a display to which attention is to be paid, and after defining the number of members in the alphabet with their different probabilities, one is ready to state how much information is present in a given stimulus under present conditions. All of the restrictions operative under these conditions limit the use to which the mathematical theorems of information theory can be put. Once again, some, if not most of these restrictions can be overcome by using concepts borrowed from information theory in describing and structuring such questions, rather than in quantitatively manipulating them.

It might be mentioned here that in artificially generated situations the grain of a stimulus can be controlled, but in the usual "real" situations, where the stimulus is something like a motion picture or a classroom situation, the control and quantification of grain is almost an insurmountable problem. "Logon content" does not depend upon grain, and so might be a plausible solution to the problem. More work needs to be done in this area.

Another requisite for the application of information theory measures is that the receiver not only should have the same alphabet of signs as the sender, but the same probabilities associated with their occurrence. Now, in a learning situation this is certainly not the case. The student is expected instead to alter his alphabet and/or probabilities to conform more nearly to those of the teacher. This is one definition of what the learning process entails. As this transformation occurs, the student becomes better able to communicate accurately with the teacher. The materials presented by the teacher can become, through these transformations, assimilated by the student, and learning has taken place. By relaxing the restrictions of the strict application of information-theory measures but by borrowing concepts from information, one can describe to some extent certain common learning situations within the convenient theoretical and linguistic model of information theory.

A further assumption which offers some difficulty in the real situation is that the rules by which the source encodes a given bit of information into some type of energy for transmission are the same as the rules by which the receiver decodes what it receives. That something as complex as a picture intended by the source to transmit a given set of information would actually provide this information to the receiver is not usually a tenable assumption. It is doubtful that a given picture would ever mean the same to all people involved. The learner, by receiving all of the information presented by the teacher, and utilizing past information in many instances and with the aid of redundancy, approximates the original message. By interaction with the teacher he learns to refine his approximations until they are acceptable to the teacher. Such interaction is possible under the conceptual model of information theory through the introduction of a servo mechanism (feedback system) by which the source knows if the receiver has received the message and how correctly he has received it. Once again, the more fruitful approach for the time being would seem to be the more general approach.

A third problem raised by Cronbach is the fact that under the system of information theory all errors and all discriminations are equally important. If one is looking at a situation in which this is the case, then of course this offers no serious drawback, but in many cases the difficulty of the discrimination is one of the variables in the experiment. This type of data compression which removes the possibility of studying an important variable is not usually desirable.

One could continue at great length in mentioning the possible problems associated with the use of information theory measures and concepts. However, let us move on and briefly mention only one or two more problems of a general nature.

One more area worthy of mention is the role of redundancy. Because information theory began in the fields of communication engineering, and statistics, its aims were quite circumscribed. One of the primary aims was to provide a model for the description and implementation of efficient communication systems. A desirable characteristic of such a system would be to have a code in which messages could be transformed with as few signs needed as possible and with as little energy as possible. Redundancy in such a system would be a hindrance to efficiency except where it would be needed to combat the effects of noise, assuming that one could not deal with noise in some other less expensive way. However, in the learning situation a certain amount of redundancy is not only necessary, but desirable. It not only combats the effects of noise, but it helps to "fix" the messages in the mind of the receiver. Redundancy also has the effect of slowing the message to a more manageable rate. The facilitation of perception per se is another role of redundancy. Therefore, systems that are efficient in the communications engineering framework, would not necessarily be efficient in the framework of the learning theorist. Redundancy plays several different roles depending on the situation.

Finally, the basic system in information theory is a static system. Any loss of energy is considered a factor in expense. Any loss or change of the input that cannot be compensated for by the source without a further expenditure of energy is not desirable, and any coding that is not built into the system becomes error. In the static system of basic information theory the human plays the role of a transducer. He is to decode the message sent and arrive at a set of signals identical to or approximating those selected by the source. But a human being is more than just a transducer. He can translate word for word and rearrange the translation according to the laws of syntax of another language, (which can also be done conceivably by a machine). He can store information and give it back at a later time, verbatim. A human can reduce information into a more easily handled subset of the former set, retaining the meaning of the former. And, he can expand upon the information given by adding to the former set and creating a larger set of information that is complimentary to the first but more explicit, or more general.

That the human may act as more than a transducer in the framework of concepts borrowed and modified from information theory, is an advantage that is not to be overlooked.

Many of the processes talked about in information theory have analogous or nearly analogous processes in learning. The scanning of the alphabet at the source might be likened to the process of thinking before speaking or writing. The different encodings and decodings are analogous in both situations. The concept of noise can be used to advantage when speaking about the learning process because one would like to know how much of what we try to teach is interfered with by the other things going on in the environment. The redundancy in any given situation is of concern because we would wish to be efficient in teaching, i.e., in the choise of the words we use and other materials selected to transmit the information.

In summary one can say the information theory does offer one more tool in the battery of statistical methods of data processing. It also provides a language that is especially beneficial because it allows people in different disciplines to talk about the same or different phenomenon in the same way, thereby facilitating the interchange of information among these different disciplines. One must be aware however, that information theory is not the answer to all problems of information transmission and, further, that it is entirely possible that other older methods might still provide a better way of looking at the data in many situations where attempts have been made to use information theory. Prudent use of its measures and the rational use of its concepts does promise progress.

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