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STUDIES RELATED TO THE DESIGN OF AUDIOVISUAL TEACHING MATERIALS.

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DESCRIPTORS- *EXPERIMENTS, *AUDIOVISUAL AIDS, REDUNDANCY, *LEARNING THEORIES, *TIME FACTORS (LEARNING), VISUAL STIMULI, PAIRED ASSOCIATE LEARNING, COMPREHENSION, STATISTICAL ANALYSIS, UNIVERSITY OF UTAH

AN INFORMATION TRANSMISSION MODEL THAT ADVOCATES LEARNING VIA ONLY ONE SENSE MODALITY (E.G. VISUAL) IS THE BASIS FOR SEVERAL SERIES OF EXPERIMENTS, EACH SUBJECTED TO RIGOROUS STATISTICAL ANALYSIS. CONCLUSIONS ARE--LEARNING IS NOT FACILITATED BY REDUNDANT INFORMATION PRESENTED SIMULTANEOUSLY THROUGH THE AUDITORY AND VISUAL SENSE MODALITIES, IT IS IMPORTANT TO LINK VISUAL INFORMATION WITH PREVIOUSLY STORED INFORMATION BY USE OF VERBAL SYMBOLS, SIMULTANEOUS NON-REDUNDANT USE OF TWO SENSORY CHANNELS IS HIGHLY EFFICIENT IN PAIRED-ASSOCIATE LEARNING, INDIVIDUALS DIFFER WIDELY IN SPEED WITH WHICH SENSORY MATERIAL IS PROCESSED, A DECREMENT IN LEARNING RESULTS FROM SWITCHING SENSORY CHANNELS DURING THE COURSE OF A PRESENTATION, AS INFORMATION IS RECEIVED THROUGH ONE CHANNEL THERE IS A BUILD-UP OF THE DISRUPTION INVOLVED IN SWITCHING SENSE MODALITY, USE OF COMPRESSED VISUAL INFORMATION (ELIMINATION OF REDUNDANT OR IRRELEVANT INFORMATION) PROVES TO BE AN INEFFECTIVE TEACHING METHOD WITH A GIVEN AGE GROUP, AND THERE IS HIGH VARIABILITY IN RELATIONSHIPS BETWEEN SPEED OF PRESENTATION, COMPREHENSION, AND COMPRESSION. MOST OF THESE STUDIES HAVE APPEARED IN JOURNALS, OR ARE EXCERPTS FROM DOCTORAL DISSERTATIONS ON FILE AT THE UNIVERSITY OF UTAH. (LH)

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With the assistance of:

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PREFACE

In 1962 the principal investigator was approached by the U. S. Office of Education and asked whether he would be interested in developing a major research project in the new educational media area. At the time of this contact, the principal investigator had been studying the research and writing of Donald E. Broadbent and had been pondering the implications of his ideas for the design of teaching materials. The ideas of the latter research worker and the ingenious model of information processing he had developed appeared to provide the foundation to a new approach to studies of the design of audiovisual materials. The Broadbent studies appeared to open up a new approach to experimentation in the audiovisual area and a project was worked out with the Office of Education which would permit research along these lines to be undertaken.

Fine support from the University of Utah must be acknowledged during the experimental phases of the project. The extensive time required for the writing of this report was provided by a year free of most other academic duties at Western Michigan University. These institutional contributions made it possible to extend the research far beyond the confines originally envisaged. Special acknowledgement must be made to the University Research Committee of the University of Utah which purchases and made available the speech compressor used in the studies reported in Chapter VIII.

Previous attempts to develop principles which could be applied to the design of audiovisual materials typically have involved experimentation with actual materials designed for classroom instruction. The studies reported here have abandoned the latter approach in favor of a procedure more similar to that pursued by the experimental psychologist. But there are still differences in what the experimental psychologist of today does and the kind of studies pursued here. The experimental psychologist tends to use simpler verbal materials than those which we have used. For example, the studies on the compression of visual information involved the teaching of the principle of refraction and the learning of relatively complex ideas. Most experimental psychologists would not have worked with materials at that level of complexity. The advantage of the use of complex materials lies in their close relationship to classroom learning. Similarity between the materials used in the experiments and classroom materials gives one some confidence in generalizing the findings to classroom situations. On the other hand, simple materials permit the experimenter to specify, in fairly precise terms, the characteristics of the materials. We have attempted here to strike a point somewhere between the simple materials used in classic psychological experimentation and the complex materials of the classroom.

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CHAPTER 1

INTRODUCTION

In a previous volume (Travers et al., 1965) an attempt was made to bring together available knowledge concerning the transmission of information to human receivers and to organize that information into a relatively simple model which could be used in the design of audiovisual materials. The knowledge which appeared to have the greatest relevance was derived from physiology, the psychology of perception, and classical communication theory. The most significant contribution came from the work of Broadbent (1958) and his associates who had already developed a model of human perception and communication which could be adapted for the purpose of designing audiovisual materials. While the model presented in the previous volume took gross liberties with that developed by Broadbent, it was referred to as a "modified Broadbent model" in order to give recognition to the main sources of the ideas that it incorporated.

The model is an information-processing model and is an attempt to represent the operations which appear to be performed on incoming information from the time of entry through the receptor organs to the time when the information fades from the system or is used to make a decision relative to action, or is relegated to storage.

A representation of the information-processing model is shown in Figure 1.01. The point must be stressed that, despite the fact that some of the information on which the model is based is derived from physiology, none of the components of the model can be considered to represent anatomical components of the nervous system and the relationship to established physiological events is indirect. Despite the fact that the model does not represent phenomena with the veridicality which a theory should possess, it does nevertheless represent a formulation of knowledge derived from a large body of information. This knowledge could, undoubtedly, have been condensed and represented in other ways and the particular representation selected inevitably represents the personal preference of those who undertake the formulation. The value of the model must be judged in terms of the research that follows. A major criterion of the worth of a model is the extent to which it generates productive research. Alternative representations of knowledge might have been more useful to others. For ourselves, the model presented both here and in the previous publication was found to be a rich source of ideas for scientific enquiry.

A few general comments about the representation provided are in order at this point to prevent misunderstandings that are likely to occur.

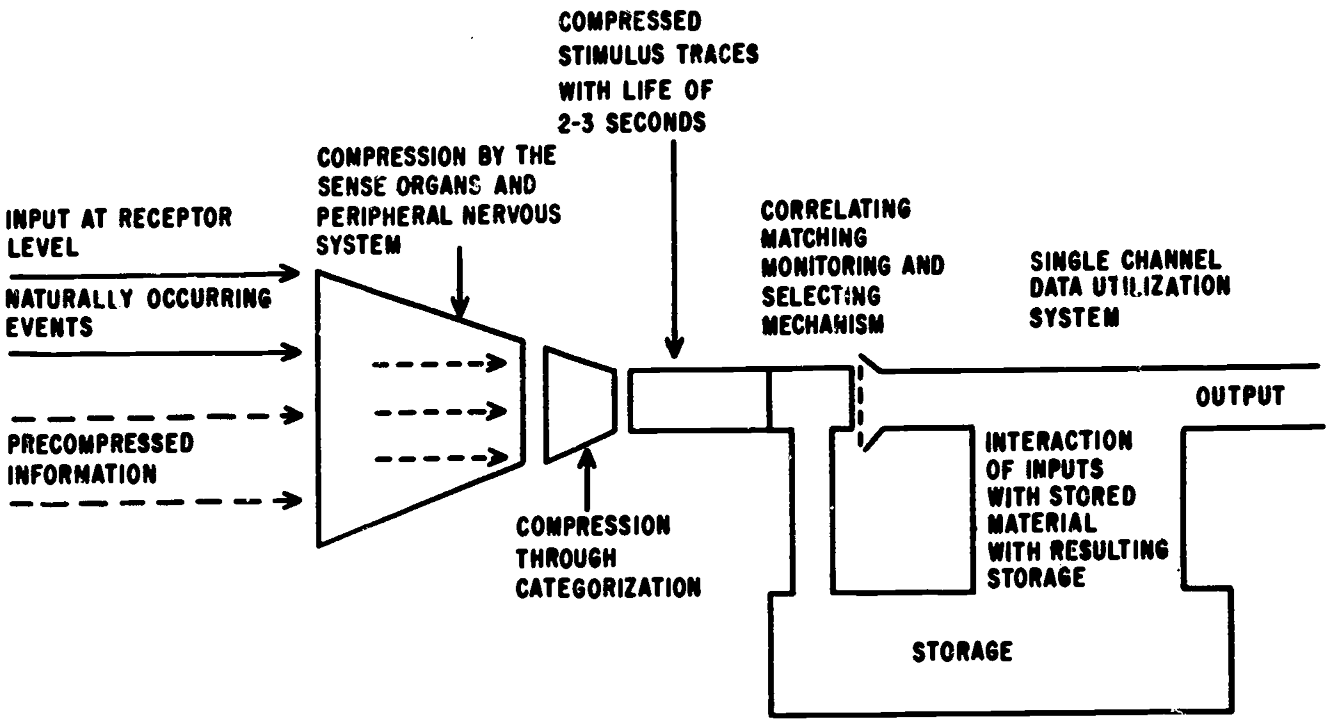

Figure 1.01. Information processing model derived from a model developed by Broadbent (1958).

First, the diagram 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.

Second, the constructs represented are often sketchy, largely because they are derived from limited and very incomplete information, but 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 presented in the earlier work of Travers et al. (1965) and avoid the repetition of evidence which has already been cited.

The Incoming Information

The information arriving at the receptors in typical educational situations may be in a naturally occurring form as it is in a realistic presentation. It may also be information derived from a real and naturally occurring situation but which has been subjected to a compression process. The compression process involves the retention of that information which is the more critical to the receiver and the discarding of the less critical information: it is exemplified by the use of black-and white line drawings representing full-colored natural phenomena which have a wealth of detail which the line drawing omits. Very little is known about the effect of precompressing information either on the learning process itself or upon the ability to transfer what is learned to subsequent situations which involve a large number of irrelevant cues. While the virtues of teaching in realistic situations have long been extolled by audiovisual specialists, the precise nature of these virtues need to be identified. While one may assume that the process of compressing information for transmission may resemble the process of internal compression, differences may well exist in the perceptual processes which result. Research on the precompression of information needs to be undertaken in order to gain some understanding of the effects this may have on the learning process. One problem is whether learning in the absence of large numbers of irrelevant cues, as occurs when information is precompressed, places a limit on subsequent performance in the presence of such irrelevant cues.

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 this 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 by the nervous system 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 being 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 begin to take place at the level of the first sensory nucleus, but it must be of a primitive nature and involve 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 perservative trace which lasts a few seconds but declines rapidly to zero. Hebb (1958) has also proposed that the nervous system is equipped with mechanisms for the temporary storage of information. These he calls "holding mechanisms." A very similar construct has been introduced by Broadbent (1958) who has postulated the existence of a temporary storage device which holds signals for a few seconds. The data on which Hull based his construct was 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 which is the final information processing system.

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 function of correlating, matching, monitoring and selecting. The mechanism postulated here has an outlet to the information utilization system which functions as a single channel.

Licklider (1952) has introduced the concept that incoming information is correlated or matched with previously stored information. When the inputs are scanned to determine whether the inputs of information are identical with stored information, the two sets of information are said to be correlated. The correlating process appears to be of great importance in all organisms that have complex nervous systems, for these organisms all show a high degree of responsiveness to any novel objects, that is to say objects which differ in some way from those previously encountered. An organism that heeds anything novel or unusual in the environment is more likely to survive than one which does not give such items priority of attention. Teachers have long made use of the fact that novel objects and events attract the attention of humans as they do that of rats.

The continuous checking 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 audio-visual material, for the response to the unusual often involves an emotional response which may not provide a favorable condition for learning.

The second process to be considered is that which Licklider (1952) refers to as matching. While the process of correlating is analogous to finding out whether two door keys are the same or different, the process of matching is analogous to that of determing whether there is a lock to fit a particular key. Searching for a screw to fit a particular nut is a simple example of the matching process. Another example is that of looking for an envelope into which a particular document will fit. In such cases the environment is scanned for the relevant object. Matching, as Licklider describes it, is more complex than correlating and may involve functions other than those undertaken at the level of the monitoring system.

A third 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 receiver's name or statements directly related to his needs, such as "Here is the money I owe you," are likely to be transmitted further. The selecter 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 the daily newspaper is highly responsive to white objects or parts of white objects projecting from underneath other subjects. 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.

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 mechanism 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.

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 of limited capacity. Broadbent refers to this system as the P-system. Others have used such terms as the perceptual 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, another restriction in the case of auditory transmissions is placed on the transmission of information; the information transmitted is 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 also 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 model at the level of 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 by wire, 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 expectancies. 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. This is 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 also 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 time between inputs permits a greater number of operations to be performed on the information, 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. While various attempts have been made to estimate the information handling capacity of the utilization channel of the human receiver, no satisfactory technique has as yet been evolved for this purpose.

The utilization system is generally protected from becoming overloaded by some such mechanism as Broadbent postulates in his filter system. Another protective device is afforded by the fact that when significant information is coming in through one sense modality, then there is likely to be a partial blocking of information coming in through other modalities. Under some conditions the higher centers can become overloaded with information with a resulting breakdown of the orderly process of information utilization. Broadbent (1958) has referred to the latter state of affairs as one in which the information channel becomes "jammed." The studies which follow provide some illustrations of cases in which the information-handling system becomes overloaded with a resulting disorganization of behavior or failure to learn.

The System for Permanent Storage

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 hypothesis. 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 being reconstructed in such a way that something approximating the original stimulus inputs can be generated. The fact that electronic processes can be used to reconstruct fragmentary visual information into good representations of the original, as has been demonstrated by Cherry (1962), suggests that much less may be stored of the visual inputs than is commonly supposed. An analogy is that electronic computers do not have to store logarithm tables in order to be able to produce the logarithm of any given number. All they have to store is a method of calculating logarithms. The visual storage system in the brain may use an analogous system storing fragmentary pieces of visual information and what are essentially rules for reconstructing the original information.

While the coded inputs may be stored as such, there is another very important relational property of inputs which has to be stored for behavior to be the way it is. This is the probability that sequences of categories of events will occur; that is to say 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 statements of principles for the design and utilization of audiovisual materials found in typical textbooks on the subject.

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 auditory 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 god who may not be too helpful to the faithful. While one cannot deny that educational materials must help the learner to perform transactions with a real world, the conclusion does not follow that teaching displays should necessarily be realistic. 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 he is 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 from the irrelevant within the context of a realistic situation, though the internally occurring compression process may eliminate the need for some of these discriminations. 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 one 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.

The Studies Which Follow

A major purpose of constructing a model of learning in a particular area is that it suggests numerous problems for research. A model that does not perform this function might as well be discarded. A model is conceived to be a guide to research rather than a guide to action, for action should be guided by theories which emerge from the resulting research.

The first problem suggested by the model is the question whether the perceptual system does function as a single channel transmitter of information. While most textbooks on problems of audiovisual communication have taken the position that multimodality communications result in the reception of more information than do single modality communications, this position is inconsistent with the model. Research cited to support the position of writers of audiovisual texts goes back over half a century. This leaves us in the position of questioning the research which has been previously undertaken and assigns us the task of attempting to duplicate previous findings. The early studies which are presented in the chapters that follow are attempts to either reproduce the results of previous work or to develop a case for rejecting that work.

Even if the single channel model presented here is essentially correct, it does not dispose of problems of the interrelationship of the different modalities in situations involving learning. Information is transmitted through the senses and the information received through the different modalities has to be related. A common relationship is that between names and objects. Some of these problems were studied as a part of the chapters that follow.

Another set of problems related to the development of cross-modality relationships concerns the discovery of optimum time relationships. For example, in learning to associate foreign words with objects, should the word and the object be presented simultaneously or sequentially? At first glance the model suggests that advantage may be gained by the sequential presentation, but this is not necessarily so. The simultaneous form of presentation may ensure a more rapid transfer of information into the perceptual system.

A final group of problems pertains to the compression of information. The model suggests that there may be advantages in compressing information prior to transmission in view of the possibility that the nervous system may compress away features that should be retained. This is the concept underlying the use of simplified diagrams in textbooks. Experiments on the value of the precompression of information should provide knowledge needed for the design of audiovisual displays. Since much is already known about the system through which the nervous system compresses visual information, one can readily precompress visual information in a manner compatible with that utilized by the nervous system. On the other hand, the process of auditory compression is hardly understood at all and no well-established and acceptable methods of precompressing auditory information have been developed. For this reason, research on the effective transmission of speech in compressed form cannot be guided by a set of well-developed neurological principles but must explore the various forms that speech compression can take. Some of our studies have undertaken such explorations.

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CHAPTER 11

TECHNICAL NOTE

The purposes of the brief technical introduction presented here are twofold. First, it provides an account of some of the details of the techniques used so that other research workers will be able to replicate the various studies if they so wish. Such a technical introduction also eliminates much repetition in the chapters which follow. Second, some of the details of techniques given here may well save future research workers weeks or even months of time. Our experience has been that the selection and assembly of suitable experimental equipment often occupies much more time than the experiment itself, particularly in an area such as the present one where very few experimental studies have been undertaken. There have, of course, been many studies using actual audiovisual instructional materials, but the purpose here has been to undertake a series of experimental laboratory studies using relatively simple materials. The techniques described in the pages that follow are not claimed to represent the best techniques that could be developed, and not even the best techniques that could be produced for the money available, but they did provide satisfactory experimental conditons and met the requirements of the experiments involved. They also provided a certain degree of flexibility so that experimental procedures could be readily modified after a preliminary trial run and without having to rework the entire set of materials.

Research Techniques

In the early stages of the researches presented in this report techniques had to be developed for the audiovisual presentation of material. While the projected studies might have involved phenomena involving motion, the decision was made to conduct only those enquiries which involved still presentations. Displays involving motion are technically more difficult to produce than stationary displays.

Since sequences of still presentations were to be studied, the obvious equipment to use was a slide projector or film strip projector and a two-track recorder. For this reason our initial studies were conducted with the Maestro II La Belle synchronized slide projector and tape recorder. This piece of equipment has merits for certain kinds of research, but it also has severe limitations. On the positive side, it was found to be highly reliable so long as a rigid maintenance schedule was followed. It was found necessary to replace all tubes at regular intervals and to make sure that the tape transport and slide changing mechanism were kept clean and well-oiled.

For slow presentations, careful equipment maintenance resulted in a high reliability of performance through many experiments. On the negative side, the lower limit of performance of the equipment is about 1 change of frame per second. When this lower limit is used, the screen presentation is for 0.6 second and the shutter is closed for 0.4 second. The latter speed can be achieved only when there are certain modifications to the equipment. One of these involves the use of triggering "blips" on the tape which are of minimum length. These can be placed on the tape by means of a battery of Hunter timers which measure out the exact length of the 1,000 cps tones so that the triggering mechanism would operate. The modification of the Maestro II La Belle circuitry which enables this to be done is not as simple as it might seem, for the switching circuit has to be introduced after the oscillator signal has been amplified. The unamplified signal was found to be lost in the auxilliary signalling mechanism and hence could not be readily turned on or off.

The tape triggering mechanism was found to lack the dependability which one might desire for experimental purposes. While it works well when the triggering of the slide projector occurs rather infrequently, that is to say not more often than once every five seconds, the frequent triggering required for our purposes resulted sometimes in the failure of the mechanism to trigger. This could be avoided to some extent by allowing for a thorough warmup of the equipment prior to the running of subjects.

While the La Belle Maestro II with tape-slide synchronizer mechanism was used as the basic piece of equipment for most of the early studies, the sluggish nature of this equipment required that a better means be found for producing audiovisual presentations of material. Two difficulties were clearly the cause of this sluggishness. One of these is the fact that the slides in this particular piece of equipment are slow to drop when they are triggered, and another is that the triggering mechanism requires rather long signals. The remedy for the first of these is to replace the slide projection mechanism with a filmstrip projector. The particular piece of equipment used for this purpose was the Victor Soundview PS 65 manufactured by Kalart. This is a filmstrip and slide projector with a remote control for moving the filmstrip forward. The forward movement of the filmstrip is very rapid and decisive and can be made at rates above 5 per second. The film is advanced by means of a solenoid which draws power from a very large capacitor which in turn is charged through a rectifier.

While the use of the Victor Soundview provided an excellent means of changing the visual presentation rapidly, a substitute for the La Belle mechanism that triggered the changing from a signal on one channel of a recording tape could not be so readily found. Eventually, a standard mechanism was experimented with and modified. The circuit for this mechanism is shown in Figure 2.04. The capacitance across the relay coil may be varied, but the larger the capacitor the more sluggish the mechanism becomes. A very fine adjustment of the relay was found to be necessary for performance to meet the requirements of the experiments. If such an adjustment was not properly made, there was a tendency for the relay to "chatter." In some experimental situations a 0.02 microfarad condenser was connected across the relay points in the output circuit to prevent chattering.

Slide and filmstrip triggering mechanisms which depend upon the presence of magnetic signals recorded on tape are not satisfactory if the signals occur more frequently than about 2 per second. When higher speeds of triggering the visual system are involved, a different system has to be used.

One alternative system is to apply a conducting tape to the back of the regular tape-recorder tape and to use this as a triggering device. However, the contact on the tape cannot be used to trigger directly the projector since the latter generally operates on 110 volts and such a high voltage applied to the sensing tape would be likely to burn a hole in it after a single passage over the contacts. In order to circumvent this difficulty a device was developed so that the sensing tape operated a relay in a 6.3 volt circuit which, in turn, operated the projector mechanism. The delay introduced by the intervening relay is negligible for all practical purposes in our series of experiments.

The main difficulty encountered in the use of sensing tape was that of locating it in the exact position in relation to the sound-track where the visual display is to be changed or is to appear. This generally has to be done after the auditory material has been recorded. The particular item of auditory material is located by moving the tape over the pickup head until the signal is heard. A mark is then made on the tape with a felt pen and the sensing tape is then placed on the back of the tape in the proper position.

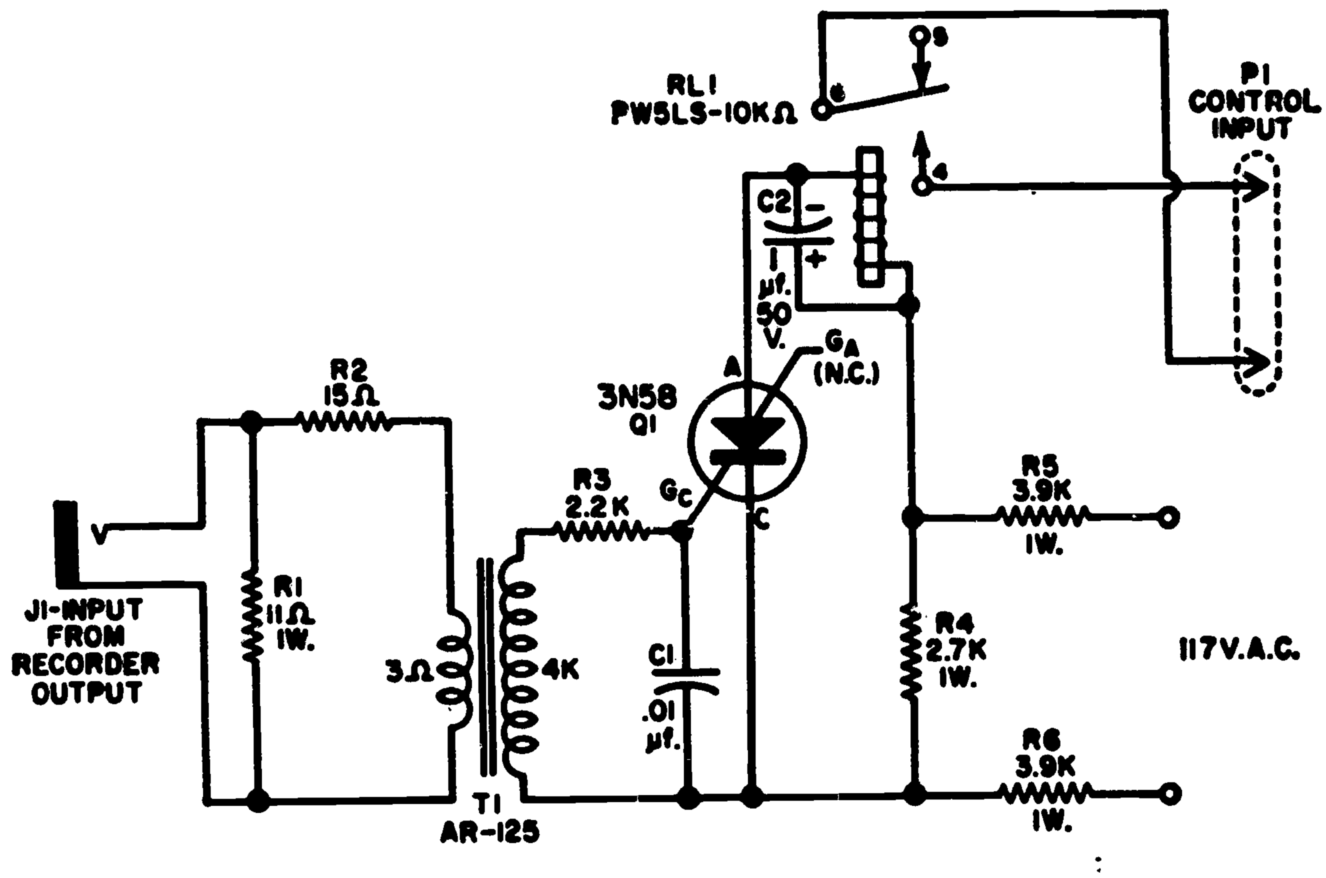

Figure 2. 01. Schematic for a tape-slide synchronizing mechanism.

The difficulty of locating the correct position for the sensing tape, when there are a number of equally spaced trials can be overcome by using an alternative system. The initial sensing mark still has to be located, but is not used to trigger the slide projector. The contacts which are shorted by the sensing tape trigger a pair of Hunter timers. The latter are devices used to make or break circuits at regular intervals. A pair of the timers connected in sequence can be used to close or open circuits at regular intervals. In the present case, the closing of a circuit through the sensing tape was used to start the operation of a pair of timers. These timers were set so that they activated the film-strip projector at regular intervals. For the purpose of the research reported here the frequency of activating the film-strip projector was never above three per second.

When this technique was used, the auditory material was generally spliced into the tape. The splicing operation was necessary for one or the other of two reasons. First, when words or syllables were used which had to be fitted into a 0.5 sec. time interval, many trials had to be made to ennunciate the word or syllable so that it would be of sufficiently short duration and still be intelligible. Second, in some experiments it was found desirable to trim the auditory stimuli so they were all of comparable length. Syllables or words can often be cut substantially, without any loss of information, mainly through cutting either the initial or final phonemes or both. Intelligibility does not appear to be affected by this cutting process. Although, for example, a digit may take as long as 0.5 seconds to ennunciate in the normal course of everyday conversation, a tape recording of the digit may be cut so that only less than half remains and the recording still remains intelligible. If the subject knows, in advance, that the recording consists of digits rather than other material then even more cutting can be undertaken.

When slower speeds of presentation are involved, the words or other material can be recorded directly from the tape through a microphone. Under these conditions, the clicking of the timers will provide a satisfactory cue for ennunciating the words at the correct times.

Visual displays were prepared on film through the use of an Exacta XVI camera mounted on a stand. For the making of black-and-white slides of filmstrips best results were obtained with Kodak M417 high contrast film.

The exposure time was 0.5 second at F=16 with the light provided by two 150 watt bulbs mounted in 3-pound coffee cans. The lamps were located 18 inches from the surface photographed. The film was processed with D-19 developer for 7 minutes at 68° F. For color presentations Kodachrome 11 Professional Color Film A gave excellent results when used in conjunction with two photoflood lamps placed 24 inches from the surface to be photographed and mounted inside 3-pound coffee cans. The exposure was 1/ 250 th. second at F=30.

The films thus photographed were either left intact, when they were to be used as filmstrips, or were cut and mounted on slides. The particular film products noted here were found to be satisfactory for repeated use through Victor Soundview projector. Other films which were tried out in the early stages of the research were found to be much less satisfactory since they lacked the durability required for repeated presentations and tended to tear at the perforations.

Perhaps a final word has to be said on the matter of why sound film was not used for our studies of audiovisual learning. The answer is that the production of a finished sound film occupies, at the best, many days. Since we found that most of the experimental materials were unsatisfactory until they had been reworked several times, procedures had to be developed which permitted the production and trial of an entire set of materials within a 24-hour period and the production of a revised set of the same materials within the next 24 hours. The procedures described here permitted us to do this while the production of sound-motion film material would probably have taken 10 times as long.

CHAPTER III

LEARNING OF REDUNDANT AND NONREDUNDANT MATERIAL PRESENTED THROUGH TWO SENSORY MODALITIES

The details of the materials used in Experiment I and Experiment II are given, in full, in the thesis of Adrian P. Van Mondfrans on which the chapter is based. The thesis entitled "An Investigation of the Interaction Between the Level of Meaningfulness and Redundancy in the Content of the Stimulus Material, and Mode of Presentation of the Stimulus Material" is on file in the library of the University of Utah, The results of these experiments have also been reported in the following article: Van Mondfrans, A. P. and Travers, R. M. W. Learning of redundant material presented through two sensory modalities. Perceptual and Motor Skills, 1964, 19, 743-751.

The third experiment has been reported in the following article: Chan, A., Travers, R. M. W., and Van Mondfrans, A. P. The effect of colored embellishment of a visual array on a simultaneously presented auditory array. Audiovisual Communications Review, 1965, 13, 159-164.

The fourth experiment has been reported in the thesis of Danielle Haygood entitled "Visual and Auditory Redundancy in Concept Formation" which is on file at the University of Utah. The substance of the thesis is also reported in the following article: Haygood, D. H. Audiovisual concept formation. Journal of Educational Psychology, 1965, 56, 126-132.

INTRODUCTION

Textbooks on the use of audiovisual devices have long claimed the superiority of presenting redundant information through two sense modalities as opposed to one. The concept underlying this claim seems to be that bombarding subject with redundant stimuli ensures a greater amount of learning since subject receives more instances of the same material, each one of which might be conceived as a separate learning trial. For example, an audiovisual presentation, provides redundant auditory and visual information, and this can be conceived to be an auditory presentation and a visual presentation, thus providing subject with the equivalent of two learning trials. This would lead one to expect more learning from an audiovisual presentation than from a presentation using only the auditory or visual channel.

Day and Beach (1950) reviewed 10 studies which compared the relative efficiency of an audiovisual presentation of redundant information with the efficiencies of the auditory and visual channels alone. Of these studies, those by Munsterberg and Bigham (1894), Quantz (1897), Smedley (1900-1901), Kemsies (1900), von Sybel (1909), Henmon (1912), Koch (1930), and Elliott (1936) provided evidence which was reported as supporting the position that a combined audiovisual mode of presentation was superior over the auditory or the opposite position. O'Brien's data showed no consistent trend. No more recent studies of this problem could be found although extensive research has been produced on the problem of transfer from one sensory channel to another. Research on the latter problem has been well reviewed by Asher (1964) in an introduction to a series of studies of transfer effects on vocabulary items in several languages. While the studies comparing a redundant audiovisual mode of presentation with a nonredundant single channel presentation appear, on the surface, to support the claimed advantages of the two-channel presentation, a closer examination of them shows that none reported levels of significance and many of the observed differences were slight.

When weaknesses of the earlier studies in this area are considered together with the implications of Broadbent's (1958) theoretical model of the perceptual system as a single channel system, a different picture emerges.

Broadbent's theoretical model implies that only the informational inputs entering one sensory channel have access to the higher centers of the brain at any one time. The other inputs entering through other sensory channels are stored for a short time(a matter of only seconds) until the channel into the higher centers is free, and only then can they pass through. Inputs which do not gain access fade and are lost. One would not expect multiple-channel inputs of redundant information to facilitate learning. The possible exception to this is the situation in which information is transmitted at such a slow rate that the learner can switch from channel to channel and hence, perhaps can increase his learning by having what amounts to an additional trial.

This position suggests that the essential features of the previous experiments need to be incorporated into a sound experimental design to provide more valid information than is at present available.

The first experiment reported here is an attempt to rest the central hypothesis involved in the studies reviewed by Day and Beach (1950). The hypothesis is that, when redundant information is transmitted simultaneously through two sense modalities, more information is retained than when only one modality is involved. The modalities used are those of vision and hearing. In the first experiment relatively long exposure times were used to allow subjects to switch channels if they desired.

The second experiment involved shorter stimulus presentation times, and in terms of the Broadbent model one would predict that there would be no advantage in using multiple sensory channels. Indeed, Broadbent suggests that simultaneous inputs through multiple sensory channels occurring at a rapid rate could cause perceptual jamming, that is to say, an interference of one input with another input and a resulting inability of subject to use or store the information. The second experiment which involved higher speeds of information transmission was an attempt to test the hypothesis that perceptual jamming might occur.

An interaction was expected between the mode of presentation and the level of meaningfulness and redundancy of the stimulus material such that, as the level of meaningfulness and redundancy increased in the stimulus material, the auditory mode of presentation would become relatively more efficient and the audiovisual and visual modes of presentation would remain relatively constant.

The third experiment represents an attempt to find out what happens when an effort is made to draw attention to the input of information through one sense modality in a learning situation involving auditory and visual transmissions of nonredundant information. Does this increase the overall information learned or does an increase in the information learned through one modality take place at the expense of the information learned through the other modality? The model previously outlined suggests the latter hypothesis.

The fourth experiment involves a different approach to the same set of problems investigated in the first three studies. While the previous studies involved rote learning tasks, the last study in the series involves a concept learning task. This final study in the series also permits the investigation of the problem of the effect of redundancy of information when redundant information is transmitted through two different sense modalities.

EXPERIMENT I

The central purpose of the first experiment was to determine whether redundant information transmitted through two sense modalities resulted in the acquisition of more information than when a single modality is used. The experiment was essentially similar to those that had been conducted previously, but care was taken to control the conditions of learning and to introduce a range of materials to be learned.

Method

Subjects.—Subjects were 72 male and female undergraduate students at the University of Utah. They were assigned at random to experimental conditions.

Materials.—The stimulus materials were nonsense syllables in one learning condition, words in a second learning condition, and words with constraint in the third learning condition. The nonsense syllables were selected from the Krueger list (cf. Underwood & Schulz, 1960) such that they all had a meaningfulness rating between .50 and .60, and were pronounceable. They were assigned randomly to three lists of 16 nonsense syllables each. Each list of nonsense syllables was presented by each mode of presentation so that the effects of inter- and intralist similarity were counterbalanced.

The words were selected from the Lorge-Thorndike list of the 501 to 1,000 most common words. Each word was six or seven letters long, and not the name of a number or person. The words with constraint were generated, using the lists of words previously compiled, but with the added stipulations that they be arranged in sequences of four in the order--adverb or adjective, noun, verb, noun--and such that each sequence could be found in an English sentence with only the addition of connectives. These added stipulations generated constraint; that is, they limited the number of possible choices. For example, suppose the adjective "modern" had been randomly selected from the list of words, then the next word selected from our list would no longer be random, but would have two constraints placed upon it. It would have to be a noun, and one that would "make sense" with the word "modern." A possible example would be "kitchen." The third word and the fourth word would also be subject to similar constraints.

Procedure.--Half of the subjects participated under conditions of a stimulus presentation each 4 sec. and for the rest of the subjects stimuli were exposed at a 2-sec. rate. Each subject was assigned to a learning condition (nonsense syllables, words, or words with constraint), to an order of lists (there were three different lists in each learning condition), and to a sequence of treatments, auditory (A), visual (V) and both (AV); for example, A, V, AV, or A, AV, V, etc.

The auditory presentation was tape recorded. The visual presentation was effected by using a film strip, and the combined audiovisual presentation utilized a synchronized combination of the tape recording and the film strip. In the auditory presentation each syllable or word was pronounced only once. Since the visual presentation of a stimulus lasted for the full period of time between successive stimuli (4 or 2 sec.) less the time it took the film strip to advance (approximately .1 sec.), it is recognized that the visual and auditory presentations were not equivalent. However, the use of other procedures such as repeating the auditory stimulus or lengthening the duration of the auditory stimulus also would not ensure equivalence to the visual presentation. Therefore, it was considered that a single presentation of the auditory stimulus was the best choice. The possible effects of the duration of the auditory vs. the duration of the visual stimuli could partially be observed across the four times since at the shorter time the advantage of the visual presentation would be greatly reduced.

Each list included 16 syllables or words. After each complete presentation of a list, using one of the three different presentation modes, the subject was allowed 1-1/2 min. in which to write down as many of the nonsense syllables or words as he could remember. A new response sheet was used after each trial, and used sheets were removed from the subject at the end of each trial.

Subjects scores were the number of errors made in learning the lists to the criterion of two consecutive correct trials or until 10 trials had been presented for a given list.

The statistical design of this study was one of repeated measures on subjects in a counterbalanced 3 x 3 x 2 factorial design.

Results

The means and standard deviations used in the analysis of variance for this experiment and the one which follows are found in Table 3.01.

An analysis of variance presented in Table 3.02 showed that the effects of time ($p < .01$), material ($p < .001$), treatment ($p < .001$), order ($p < .001$), and the interaction between treatment and the stimulus material ($p < .001$) were all significant. Of the significant effects listed, three are of incidental importance only. These are time, material, and order. When these effects were further analyzed, using an individual degrees of freedom test for orthogonal comparisons (Walker & Lev, 1953, pp. 356-358), it was found that more was learned at the 4-sec. exposure rate than at the 2-sec. rate ($p < .01$), but there was no interaction between the exposure time and the mode of presentation (treatment). The nonsense syllables appeared to be more difficult than the words with constraint, but the difference was not significant ($.05 < p < .06$). The first list presented was more difficult to learn than the second ($p < .01$), and the second was more difficult to learn than the third ($p < .05$).

Of primary importance, however, are the findings with respect to the relative efficiency of the three different treatments (A, V, and AV), and the interaction between treatment and stimulus material.

TABLE 3.01

MEAN ERRORS AND SDs OF ERROR SCORES TO CRITERION IN THREE TYPES OF STIMULUS MATERIAL BY PRESENTATION MODE AND ORDER

	Time Between Successive Stimulus Exposures							
	Experiment I				Experiment II			
	4 sec.		2 sec.		1 sec.		.6 sec.	
	M	SD	M	SD	M	SD	M	SD
	Presentation Mode							
Words with Constraint								
Auditory	11.7	6.2	15.8	12.7	23.8	12.0	38.2	13.0
Visual	11.2	6.9	16.2	14.0	25.4	15.5	37.5	21.0
Audiovisual	12.5	10.7	12.9	7.3	29.3	15.5	37.2	21.7
Words								
Auditory	13.2	9.4	25.3	13.1	26.0	16.7	41.8	23.6
Visual	13.2	8.7	21.8	15.5	26.7	18.2	37.5	19.3
Audiovisual	12.6	11.3	23.5	12.7	29.2	20.0	38.1	18.0
Nonsense Syllables								
Auditory	93.2	33.4	102.3	25.9	115.8	34.2	131.8	12.1
Visual	55.9	26.1	69.2	26.3	83.6	20.4	121.8	15.8
Audiovisual	60.8	29.4	68.3	26.6	94.9	34.0	119.8	16.9

TABLE 3.01 (con't)

	Time Between Successive Stimulus Exposures							
	Experiment I				Experiment II			
	4 sec.		2 sec.		1 sec.		.6 sec.	
	M	SD	M	SD	M	SD	M	SD
	Presentation Order							
Words with Constraint								
First	17.6	8.3	21.0	6.9	34.6	15.3	45.2	14.7
Second	9.4	6.3	13.5	14.4	22.9	12.3	37.8	22.2
Third	8.3	5.7	10.4	9.9	19.8	13.5	29.9	15.7
Words								
First	16.2	11.8	25.8	11.6	31.4	22.7	43.2	19.8
Second	11.8	5.7	25.8	13.7	26.2	13.6	36.6	19.2
Third	10.8	9.2	19.0	15.0	24.2	17.3	37.5	21.8
Nonsense Syllables								
First	79.0	29.7	89.5	27.2	92.8	31.1	120.7	14.7
Second	65.3	37.2	75.6	31.1	100.2	33.1	123.9	13.7
Third	65.6	33.7	75.2	32.1	101.4	34.1	128.7	18.2

Note.—N = 12 for each mean

TABLE 3.02

ANALYSIS OF VARIANCE FOR SEQUENCE, MATERIAL, TIME, ORDER AND TREATMENT EFFECTS FOR DATA FROM EXP. I (N = 72)

Source	df	MS	F	p
Sequence (S)	5	59,431	1.54	---
Material (M)	2	5,458,247	141.49	<.001
S x M	10	54,637	1.42	---
Time (T)	1	330,176	8.56	<.01
S x T	5	60,722	1.57	---
M x T	2	35,062	---	---
S x T x M	10	47,848	---	---
Ss/Grpups	36	38,578	---	---
Order	2	191,732	22.76	<.001
Treatments (Tr)	2	131,066	15.56	<.001
Plot	8	6,713	---	---
O x M	4	11,824	1.40	---
O x T	2	5,854	---	---
O x M x T	4	689	---	---
Tr x M	4	92,204	10.95	<.001
Tr x T	2	24	---	---
Tr x M x T	4	4,500	---	---
Residual	112	8,423	---	---

The major hypothesis for this part of the study was that there would be significant differences among the three modes of presentation with respect to the amount of learning. When the effect of treatment was broken apart, using the individual degrees of freedom test for orthogonal comparisons (Walker & Lev, 1953, pp. 356-358), it was found that the auditory presentation was significantly less efficient than the other two ($p = .001$), and there was no significant difference between the visual presentation and the audiovisual presentation. The relative inefficiency of the auditory mode of presentation must be interpreted in the light of the interaction between the mode of presentation and the level of meaningfulness and redundancy of the stimulus material. The only significant interaction was the nonsense syllable learning condition with the auditory mode of presentation ($P = .001$). There were no significant differences between the visual and audiovisual modes of presentation across all three types of stimulus materials at these longer stimulus exposure times. There were no significant differences between the auditory mode of presentation and the other two across words and words with constraint.

EXPERIMENT II

The first experiment provided no evidence of facilitation of learning through the use of two modalities nor was there evidence that the simultaneous inputs of redundant information through the two modalities resulted in any interference phenomenon. The possibility existed that, if more rapid transmissions of information had been involved, the audiovisual transmission would have been inferior to the visual transmission alone as a result of interference. For this reason a second experiment was undertaken which involved more rapid rates of transmission of information.

Method

Subjects.--Seventy-two male and female undergraduate students at the University of Utah were assigned at random to treatments.

Procedure.--Materials were the same as those in Exp. I, as was the procedure, but the two exposure rates were 1- and .6-sec. While the design could be regarded as a 3 x 3 x 2 factorial design involving repeated measures, it was considered preferable to analyze the data from each learning condition separately in a 3 x 2 factorial design with repeated measures so that possible jamming effects would appear as a two-way interaction, rather than as a three-way interaction.

Results

Nonsense syllables.--The significant effects in the nonsense-syllable learning condition were time ($p < .05$), and treatment ($p < .001$), as shown in Table 3.03. More was learned at the 1-sec. exposure time than at the .6-sec. exposure time. When the treatment effect was analyzed, using an individual degrees of freedom test (Walker & Lev. 1958, pp. 356-358), the auditory presentation was significantly inferior ($p < .001$) to the visual and audiovisual modes. There was no significant difference between the visual mode and the audiovisual mode, although the audiovisual mode of presentation was slightly inferior to the visual mode.

Words.--The analysis of variance of error scores when words were learned is also shown in Table 3.03. There were no significant main effects. The failure of the treatment effects to approach significance is of interest. Although there were no significant differences among the three modes of presentation when the stimulus materials were common words, there were slight differences, with the audiovisual mode being slightly inferior to the visual and aural modes.

Words With Constraint.--The significant effects in the words-with constraint learning condition shown in Table 3.03 were time ($p < .05$), the time by sequence interaction ($p < .05$) and order ($p < .001$). More was learned at the 1-sec. exposure rate than the .6-sec. rate. The order effect was the usual practice effect, i.e., more difficulty in learning the first list than the second ($p < .001$) and more difficulty with the second list than the third ($p < .01$).

Once again the effects of treatment were not significant. Although the visual mode was slightly superior to the audiovisual mode, this difference was not significant at the .6-sec. rate, but it was at the 1-sec. rate ($p < .05$).

TABLE 3.03

ANALYSIS OF VARIANCE FOR SEQUENCE, TIME, ORDER AND TREATMENT EFFECTS FOR NONSENSE SYLLABLES, WORDS, AND WORDS WITH CONSTRAINT (N = 24)

Source	Nonsense Syllables			
	df	MS	F	p
Sequence (S)	5	27,281	---	---
Time (T)	1	359,294	5.13	<.05
T x S	5	11,810	---	---
Ss/Groups	12	70,097	---	---
Treatment (Tr)	2	68,183	11.43	<.001
Order (O)	2	10,367	1.74	---
Within	44	5,965	---	---

Source	Words			
	df	MS	F	p
Sequence (S)	5	61,360	---	---
Time (T)	1	215,168	2.41	---
T x S	5	59,777	---	---
Ss/Groups	12	89,440	---	---
Treatment (Tr)	2	1,464	---	---
Order (O)	2	14,368	2.65	---
Within	44	5,423	---	---

Source	Words with Constraint			
	df	MS	F	p
Sequence (S)	5	42,254	1.57	
Time (T)	1	206,296	7.66	<.05
T x S	5	100,879	4.04	<.05
Ss/Groups	12	26,925		
Treatment (Tr)	2	2,550		
Order (O)	2	114,460	23.55	<.001
Within	44	4,860		

Discussion and Conclusions of Experiments I and II

Of primary importance was the finding in both experiments that there were no significant differences among the amounts learned using the three different presentation modes, except when the stimulus materials had little redundancy or meaning. For nonsense syllables the auditory mode of presentation was significantly inferior ($p < .001$) to the other two, and there were no significant differences between the visual mode and the audiovisual mode.

These findings do not agree with the earlier findings, but the failure to use tests of significance and the characteristically small differences for small Ns make the interpretation of these earlier studies tenuous. In the light of the greater controls used in this design and tests of significance, it is concluded that the use of two sensory modalities has no advantage over one in the learning of material which is redundant across modalities. Indeed, there are indications that the simultaneous presentation of redundant stimuli at high rates of presentation could result in a decrement in learning as compared to the presentation of the same material using only one sense modality. However, the differences between the audiovisual mode and the other two were not significant, except in the words-with-constraint learning condition at the 1-sec. exposure rate, and perceptual jamming was not conclusively demonstrated. One reason for the lack of more general evidence of perceptual jamming could be the relatively slow presentation rate of the stimulus elements, even in the second part of the study. The rate of one stimulus element every .5 sec. is still relatively slow.

The inferiority of performance under the auditory mode of presentation of nonsense syllables is considered to be due to the highly ambiguous nature of the stimulus material although several subjects were able to write them correctly at the longer exposure times. Underconditions in which meaningful, organized materials were used as stimulus materials the auditory mode of presentation was not inferior.

EXPERIMENT III

This experiment was designed to study the effect on learning of the embellishment of the visual information with color in a task involving the simultaneous learning of nonredundant information through both the auditory and visual sense modalities. In the task selected the embellishment provided no relevant information but was designed only to draw attention to the visual channel. The purpose of this study was to find out whether embellishment, designed to attract attention, would or would not increase learning through the modality involving the embellishment, though any increase in learning might be at the expense of learning through the second modality. The experiment also permitted the exploration of the possibility that such embellishment might increase the overall amount of learning through raising the level of arousal of the subject.

Mowbray (1952, 1953 and 1954) looked at the problem of simultaneous learning through both vision and audition. In the 1953 study the subjects were presented with prose passages of varying difficulty. The passages were presented both aurally and visually at the same time, and at the same rate in terms of words per minute. The learning was measured by a ten-item test which was designed to measure both comprehension of the paragraph and retention of discrete facts. The scores from the simultaneous trials were compared with scores from control groups that performed the same tasks non-simultaneously. One of the conclusions drawn was that "the auditory channel showed significantly greater disruption of performance than the visual for the simultaneous operation" (p. 317). That is, when different passages of the same difficulty were presented at the same rate simultaneously through the auditory and visual channels the audio channel suffers the greatest loss of efficiency.

This same finding was substantiated in the 1954 study even though vastly different stimulus materials were used. The subjects were provided with outline maps which they were to complete. Brief, simultaneous, visual and auditory instructions were presented to the subjects for completing some of the missing details. All of the relevant auditory and visual information was presented simultaneously in every case. It was found that when the information needed for completing the maps was presented simultaneously through the audio and visual channels more correct completions were made using the visually presented information than using the audio information.

When the data from the 1953 study was reanalyzed by Travers et al. (1963) the findings were strongly suggestive of the position that the amount of information transmitted by the two simultaneous nonredundant sources involving two modalities was equal to the amount of information transmitted by either source alone.

It is hypothesized that the presentation of colored-embellished nonsense syllables will interfere with the reception of auditory syllables more than would black and white visual syllables. It is further hypothesized that more will be learned from the visual messages than from the audio syllables. The model under consideration in this report leads us to expect that any increase in learning through the visual modality resulting from color embellishment will result in a reduced amount of learning through the auditory modality.

Method

Material.—Two different lists of nonsense syllables (eight in each list) were chosen from Krueger's list such that they all had a meaningfulness rating of from .50 to .60. One list of nonsense syllables was made into both (a) a colored and embellished filmstrip and (b) a black-and-white filmstrip. The second list was recorded on magnetic tape. The two lists are to be found in Table 3.04. The colored and embellished filmstrip was composed of nonsense syllables with novel and colored letters on unusual colored backgrounds consisting of wallpaper. The black-and-white filmstrip used the same nonsense syllables on an off-white background in plain black letter.

TABLE 3.04

LISTS OF NONSENSE SYLLABLES USED SIMULTANEOUSLY IN THE EXPERIMENT

Visual nonsense syllables (either colored and embellished or black and white)	Auditory nonsense syllables
1. JEB	1. ZAS
2. YOG	2. POF
3. BIP	3. NID
4. YOZ	4. WUB
5, KEX	5, TEF
6. VUT	6. PAB
7. BIV	7. MIF
8. YAB	8. GAX

Subjects.—The subjects were all from the introductory psychology class at the University of Utah. One hundred and sixty-six subjects participated. They signed up for the experiment in groups of four to six. Each group was assigned at random to one of the two experimental conditions.

Procedure.—After the random assignment of a given group of subjects to one of the two experimental conditions they were seated in a room with a one-way window at one end to which a screen had been affixed. The subjects were instructed that they would be presented with two sets of nonsense syllables at the same time. The one set would be visually presented and the other set aurally presented. It should be noted that each subject was looking at one nonsense syllable at a time, and at this same time he heard a different nonsense syllable. Their task was to remember as many of both sets of nonsense syllables as they could. After a complete presentation of the eight pairs of nonsense syllables the subjects were allowed ninety seconds in which to write down as many nonsense syllables as they could remember. The answer sheets used had places for two lists of eight nonsense syllables each, one headed with the word "visual" and the other headed with the word "audio." A correct response was made when the subject wrote a nonsense syllable under the heading which represented the mode by which it had been presented, and when the nonsense syllable was correctly spelled. It was not necessary that the nonsense syllables be in order. Each subject received ten presentations of the eight pairs.

The syllables were presented at the rate of one each 2-sec., and were exposed for 0.6 sec. The visual presentations involved the projection of an image through one-way glass onto the back of the screen in the experimental room. The letters in the nonsense syllables were about two inches high. The exposure time of 0.6-sec. for each simultaneous presentation was selected because it gave the subject approximately the same amount of time to attend to the visual presentation and the auditory presentation, since each auditory presentation lasted about 0.6-sec.

The equipment used for presenting the displays consisted of a Victor Soundview PS 65 filmstrip projector through which the filmstrip containing the visual displays was run. The forward movement of the filmstrip was controlled by a bank of Hunter timers which also controlled a shutter placed in the path of the light beam.

The sound transmission was provided by means of tape run through an Ampex 1260 tape recorder. The auditory and visual displays were synchronized by means of a short length of sensing tape placed on the back of the magnetic tape. The sensing tape was used to trigger the Hunter timers. Thus, when the apparatus was ready for presenting material to a subject, the tape transport would be turned on; when the tape carrying the metallic sensing tape passed over a set of contacts the timers would be started and the first visual display would appear at the same time as the first auditory display. From then on, the timers would take over and trigger both the filmstrip advance mechanism and the shutter while the tape provided the auditory material, also at regular intervals. The auditory and the visual displays had to remain synchronized for only 16 seconds and the apparatus was fully capable of doing this.

Results

The experimental design consisted of a 2 x 2 fixed-model factorial design with repeated measures. Groups of subjects were assigned randomly to either condition BW (where subjects were presented two different sets of nonsense syllables at the same time, one visually using black letters and a white background, and the other aurally), or to condition CE (where subjects were presented simultaneously with the same two lists of nonsense syllables as in condition BW, but the visual presentation involved novel colored letters on unusual backgrounds). Table 3.05 presents the means and SDs for each condition.

TABLE 3.05

MEANS AND SDs OF SCORES IN THE TWO EXPERIMENTAL CONDITIONS

Learning Condition	Total no. correct	N	Mean	Std. Dev.
Condition CE				
Visual	3234	83	38.96	+ 10.24
Simultaneous Audio	1417	83	17.07	± 9.75
Total	4651			
Condition BW				
Visual	2875	83	34.63	± 11.39
Simultaneous Audio	1727	83	20.81	± 12.22
Total	4602			

In Table 3.06 the summary of the analysis of variance is presented. The total amount learned through both modalities in the CE condition was not different from the total amount learned in the BW condition.

The amount learned via the auditory channel was significantly less than that learned via the visual channel (p less than .001). This substantiates the second hypothesis and fits the data from the Mowbray studies.

TABLE 3.06

ANALYSIS OF VARIANCE FOR EXPERIMENTAL CONDITION AND PRESENTATION MODE

Source	Sum of Squares	Df	Mean Squares	F	p
Between Ss Total	32,269.93	165	---	---	---
CE Condition vs. BW Condition	7.23	1	7.23	---	n.s.
Between Ss Error	32,262.70	164	196.72	---	---
Within Ss Total	49,612.50	166	---	---	---
Audio vs. Visual	26,479.59	1	26,479.59	198.47	.001
Interaction	1,348.08	1	1,348.08	10.10	.001
Residual	21,784.83	164	133.42	---	---
Grand Total	81,881.43	331			

Of special interest to this study is the finding that the interaction between the mode of presentation (auditory or visual) and the experimental conditions (CE or BW) was significant (p less than .001). To break apart this effect a Duncan's Multiple Range test was used. The results are reported in Table 3.07.

As can be seen from the table, there were fewer nonsense syllables learned via the auditory channel when the auditory was paired with the CE visual presentation than when the auditory channel was paired with the BW visual presentation (p less than .05). It is also important to note that there were more nonsense syllables learned via the CE visual presentation than in the BW visual presentation (p less than .05). These two findings indicate that although there is the same total amount of learning taking place under these two experimental conditions the relative effectiveness of the auditory channel when paired with the CE visual presentation is significantly less than when it is paired with the BW visual. Thus, under the CE condition more is learned via the visual channel than under the BW condition, but less is learned via the audio channel. It is therefore concluded that a CE (colored-embellished) visual presentation disrupts the processing of the auditory information more than does a BW (black and white) visual presentation.

TABLE 3.07

SUMMARY OF DUNCAN MULTIPLE RANGE TEST ON THE NUMBER OF CORRECT RESPONSES

		CE Audio	BW Audio	BW Visual	CE Visual
		1417	1727	2875	3234
CE Audio	1417	---	310*	1458**	1817**
BW Audio	1727		---	1148**	1507**
BW Visual	2875			---	359*
CE Visual	3234				---

* The difference is significant at the .05 level.

** The difference is significant at the .01 level.

Discussion

The data supported the hypothesis that there would be more learned via the visual channel than through the auditory channel when nonredundant information was presented simultaneously through both channels. This finding is in line with the findings of the Mowbray studies (1953, 1954).

Of primary importance is the substantiation of the hypothesis which stated that a colored-embellished visual presentation would disrupt the audio channel more than a black and white visual presentation. This was found to be the case. Not only was less learned via the audio channel under the CE condition (p less than .05), but more was learned via the visual channel under the CE condition (p less than .05). Of particular importance in the present context was the finding that the overall amount learned under the CE condition did not differ significantly from the amount learned under the BW condition. Thus, the increment in learning via the visual channel due to the addition of colored-embellishment does not result in an increase in the overall amount learned since it occurs at the expense of the learning through the auditory channel.

The data are consistent with the general position that the factor limiting the amount of data which can be received by a learner is the central perceptual process rather than the input provided the senses. The use of attention attracting devices does not appear to increase the overall amount of information transmitted but merely increases the information taken in through one channel at the expense of another channel. The finding is consistent with Broadbent's hypothesis (1958) of a limited capacity P system.

EXPERIMENT IV

The vast majority of studies of concept learning have utilized visual concepts such as color. Even when the stimulus characteristics have had the capability of being transmitted by other means (e.g., by shape, touch), they have, with few exceptions (e.g., Fenn & Goss, 1957), been presented visually. In contrast, few studies have dealt with the processes by which the subjects acquire concepts based on auditory characteristics. However, two such studies have appeared in recent psychological literature. The first of these, by Lordahl (1961), used a combination of auditory and visual stimuli and explored the effects of irrelevant information.

Lordahl found that as irrelevant visual information increased, performance decreased. However, increasing the amount of irrelevant auditory information had no significant effect. When the types of errors were analyzed, it was found that the tendency to ignore irrelevant auditory information was greater than the tendency to ignore irrelevant visual information.

The finding that increasing the amount of irrelevant visual information increased the difficulty of the task was consistent with those of previous "visual-only" concept learning studies (e.g., Walker & Bourne, 1961), in which this relationship was firmly established. The lack of significant effect when the amount of irrelevant auditory information was increased was contrary to what would be expected from such studies. To explain the finding that the subjects tend to ignore auditory information, Lordahl suggested that the subjects enter the experiment with a bias toward the use of visual information, though he offers no explanation as to why this may be so.

The second study of auditory concept learning, by Bulgarella and Archer (1962), used only auditory stimuli, and explored the effects of both relevant and irrelevant information. They found that increasing the number of relevant dimensions increased problem difficulty significantly. Similarly, increasing the amount of irrelevant information degraded performance significantly. These results were the same as those found in visual concept learning studies (e.g., Walker & Bourne, 1961). Bulgarella and Archer suggested, as did Lordahl, that when used in combination with visual stimuli, auditory stimuli may tend to be ignored by the subjects; however, when auditory stimuli are used exclusively, variations in relevant and irrelevant information have the same effect as when visual stimuli are used exclusively.

Little work appears to have been done concerning concept learning through presentation of redundant auditory and visual information. However, provision of auditory cues or "auditory coding" is almost universally assumed to be beneficial in practical applications. For example, human engineering guides suggest auditory coding as a way of "enhancing" the utilization of information transmitted primarily through the visual mode, particularly "critical" information (e.g., Morgan, Chapanis, Cook, & Lund, 1963). However, lack of information in this area appears to be a continuing problem; examination of both the text and bibliographies of several human engineering books (e.g., McCormick, 1957, Morgan et al, 1963) disclosed little empirical research concerning auditory coding, and none at all concerning use of redundant auditory signals.

A similar acceptance of the use of redundant audiovisual information seems widespread in the field of education. It is commonly held in audiovisual education texts that more learning accrues from the use of material which is presented both visually and aurally (DeKieffer & Cochran, 1955; Wittich & Scholler, 1963). However, here again, there is little experimental research to support such statements.

Although redundancy of auditory and visual information on concept formation has not been studied experimentally, the effect of adding redundant information within the visual mode has been studied extensively in several different settings (Bourne & Haygood, 1959, 1961; Bricker, 1955, Rappaport, 1957). These studies suggest that adding redundant relevant information is uniformly helpful in a concept learning task.

If redundant relevant information is uniformly helpful, and if the assumptions of human engineers and educators are correct, then the addition of redundant auditory information to visual, and vice versa, should improve performance. On the other hand, if the conclusion of Lordahl and Bulgarella and Archer--that the subjects tend to ignore auditory information when both auditory and visual information are present--is correct, then the addition of redundant auditory information to visual would not improve performance over that found when visual presentation is used alone. Thus it seems worthwhile to study visual, auditory, and auditory plus visual concept learning within the same experiment.

The purpose of the experiment reported here was to provide this comparison by presenting the subjects with problems in which the solutions required auditory information only, visual information only, auditory information redundant with visual information (either would suffice), and a fourth condition, used by Lordahl, in which both auditory and visual information were required for problem solution.

Method

Subjects.—Seventy students from educational psychology and sociology classes at the University of Utah served as the subjects. They were assigned randomly to one of the seven experimental conditions, and each was paid for participation. Since no sex differences have been noted in similar experimentation (e.g., Pishkin, 1960), no effort was made to control the composition of the groups by sex.

Task.—The task was similar to those used in previous concept-learning studies (e.g., Bourne, 1957), with the main exception that both visual and auditory stimulus characteristics were used. The subject was required to sort, or classify, a series of audiovisually presented stimuli into two categories. The visual aspect of the stimuli consisted of geometric patterns which varied along three binary stimulus dimensions: color (red, blue), form (triangle, square), and size (large, small). The auditory aspect of the stimuli, presented through earphones, consisted of tones which also varied along three binary dimensions: pitch (high, low), volume (loud, soft), and continuity (continuous, interrupted). The visual and auditory aspects of the stimuli occurred simultaneously, so that each stimulus consisted of a combination of six dimensions, three visual and three auditory.

A dimension was considered to be relevant if it could be used to classify correctly each complete, bimodal stimulus combination. If both levels of a dimension appeared, but it could not be used for correct classification, it was irrelevant. If, in a given problem, a dimension did not vary, it was considered not to exist. This is the usual method of treating such dimensions (Bourne & Restle, 1959).

The pattern and tone programs were constructed so that when any dimension was redundant with any other, the levels within each were perfectly correlated. For example, if size and pitch were redundant, large patterns always had high pitch and small patterns always had low pitch. All dimensions not redundant during a problem varied randomly and independently of all other dimensions.

A total of seven conditions was studied. Three of these conditions consisted of one-dimensional problems: one with a visual solution (1-V), one with an auditory solution (1-A), and one with a visual solution redundant with an auditory solution (1-VrA). A second set of conditions consisted of two-dimensional problems: one with a complete visual solution (2-V), one with a complete auditory solution (2-A), one with a complete two-dimensional visual solution redundant with a complete two-dimensional auditory solution (2-VrA), and one with a cross-modality solution--one dimension drawn from the visual and one drawn from the auditory mode of presentation (1V +1A). All two-dimensional conditions required conjunction of the relevant characteristics for solution.

Apparatus.—The visual portion of the stimuli was presented by filmstrips projected on a small screen about 5 feet in front of the subject with a Dunning Animatic 16-millimeter stripfilm projector. The auditory portion of the stimulus consisted of tones produced by a Grason-Stadler twin oscillator, transmitted through a Heathkit amplifier, and received through a Koss stereophonic headset used monaurally (single phone only). Relative volume of tones was controlled by the use of a resistor, and interruption of tones by a cam recycling timer. All filmstrips and sound programs were constructed so that positive instances made up 50 percent of the total stimuli.

Presentation of the auditory stimuli, correct responses for the feedback signal, and timing of presentation were controlled by punched tape fed through a Western Union tape reader which was connected to the oscillator, the response panel, a multiple-delay timer unit, and an Esterline-Angus operations recorder. Both the correct responses and the responses made by the subject were recorded by the operations recorder. The response panel contains two pushbuttons, labeled Yes and No, each with a red feedback signal light above it.

Procedure.—During the reading of instructions for all groups, the visual and the auditory stimuli were presented and described. In this way the experimenter was able to insure that the subjects could hear and could discriminate between all dimensions and characteristics of the stimuli. Each subject was told that his task was to learn to classify the sound and pattern combinations into two groups, that each button on the control panel represented one of the groups, and that he was to find the particular characteristics that made a combination stimulus a member of one group or the other.

Subjects in the conditions having one relevant dimension were told they would need to pay attention to only one of the six characteristics, and that the correct classification could be either visual or auditory. Subjects in the conditions having two relevant dimensions were told they would need to pay attention to two of the six characteristics, and that the correct combination could be two characteristics of the patterns, or two characteristics of the tones, or a combination of one pattern characteristic and one tone characteristic. Subjects in the redundant conditions were given essentially the same directions as those in the respective one- or two-dimensional groups. Those in the group requiring use of auditory and visual information were given the same instructions as those in the two relevant dimension conditions. Instructions stressed accuracy, rather than speed.

During each trial, the following sequence of operations took place: (a) the visual and auditory aspects of the stimulus were presented simultaneously - the geometric pattern on the screen and the tone in the earphone - and remained on until the subject pushed one of the two response buttons; (b) as this was done, the filmstrip was advanced one frame to a blank position, the tone stopped, the subject's response was recorded on the operations recorder, and the timing unit was activated; (c) after .75 second the correct signal lamp was illuminated and the correct response recorded; (d) after another 1.0 second the filmstrip was advanced another frame, projecting the next visual pattern, while simultaneously the next auditory combination was presented.

All conditions were self-paced, in that the subjects were allowed as much time as desired to make responses. When the subject had classified the stimuli correctly for 16 consecutive presentations, he had reached criterion. The equipment was then turned off, and the subjects in the redundant-solution groups were asked to verbalize the solutions they had been using.

Experimental Design.--The total experimental design was made up of three subdesigns. The first of these subdesigns consisted of the three one-dimensional problems: 1-V, 1-A, and 1-VrA. The second of the subdesigns consisted of the four two-dimensional problems: 2-V, 2-A, 2-VrA, and 1V + 1A. The presence of both one and two dimensions and both visual and auditory modes provided a third set of conditions which may be analyzed as a 2 x 2 factorial design.

Because irrelevant information was not at issue, the number of irrelevant dimensions was held constant in all problems, with one auditory and one visual irrelevant dimension.

Results

Errors to criterion was used as the main dependent variable for the analysis. Number of trials to criterion gave essentially the same results.

Analysis of the one-dimensional problem groups (1-A, 1-V, and 1-VrA) showed no significant differences in error scores. Analysis of the two-dimensional problem groups (2-V, 2-A, 2-VrA, and 1V + 1A) showed a significant effect ($F = 3.39$, $df = 3/36$, $p < .05$).

A summary of this analysis is shown in Table 3.08. A Duncan range test of the two-dimensional problems showed that the cross-modality group (1A + 1V) differed significantly from all the other two-dimensional groups (df = 36, $p < .05$); none of the other groups differed significantly.

TABLE 3.08

SUMMARY OF ANALYSIS OF VARIANCE
OF ERRORS 2-V, 2-A, 2-VrA,
and 1V + 1A

Source	df	MS	F
Modality	3	792.76	3.39*
Residual	36	233.96	

*$p < .05$.

In the analysis of variance of the third (2 x 2) subdesign, it was found that neither main effect (number of relevant dimensions, mode of presentation) was significant. This finding contradicted results of previous research (Bourne & Restle, 1959), which has consistently shown that the number of relevant dimensions is a powerful variable in concept learning. Therefore, separate *t* tests of the difference between means were computed for the auditory and visual modes. The comparison of the visual problems (1-V versus 2-V) yielded a significant difference (*t* = 5.01, *df* = 18, $p < .01$); the comparison of the two auditory conditions (1-A versus 2-A) failed to show a significant difference (*t* = 0.47, *df* = 18).

Consideration of the two t tests suggested that the failure to find a significant main effect in the 2 x 2 design (and in the one-dimensional analysis as well) resulted from inflated variance in the auditory groups. Therefore, the variance for each group was computed. These variances are shown in Table 3.09, along with the respective mean errors.

TABLE 3.09

MEAN ERRORS AND VARIANCES
WITHIN GROUPS

	Modality			
	V	VrA	A	V + A
One dimension:				
Mean errors	3.80	5.20	9.90	--
Variance	5.96	16.16	130.69	--
Two dimensions:				
Mean errors	11.00	8.20	13.00	28.10
Variance	12.60	29.56	235.20	565.89

Note.—Each group contained 10 subjects.

A comparison of the variances within groups, using an F test, showed that the variance in the auditory groups was significantly higher than the variance in the visual groups. The variance in the cross-modality group also was higher than that in the visual group.

Discussion

Although the main purpose of the present experiment was to explore the effect of adding redundant auditory information to visual information, and vice versa, the failure to find any significant differences precludes any discussion of the effects of redundancy.

There are several possible explanations for this result. The most obvious is that Lordahl (1961) and Bulgarella and Archer (1962) are correct in concluding that the subjects tend to ignore auditory information when both auditory and visual information are present. Under such conditions a finding of no differences between problems with auditory, visual, and auditory redundant with visual solutions would not be surprising—provided the auditory and visual solutions were roughly comparable in difficulty. However, this explanation is unconvincing, because in both one- and two-dimensional redundancy problems as many subjects chose auditory as chose visual solutions; in fact, several stated cross-modality solutions.

A more satisfactory explanation is that such differences as exist were obscured by the inflated variance of groups presented with relevant auditory information. This is particularly apparent in the 2 x 2 subdesign where the one-and-two-relevant visual groups differed significantly, while the auditory groups did not. The net effect was that the 2 x 2 design failed to show any significant differences.

The increased variance in auditory problems might be the result of several factors. First, the subjects may have had wide differences in experience with auditory classification. There appears to be a lesser emphasis on training in the use of auditory information in our culture; whereas almost everyone has extended training in use of visual coding (e.g., sorting, playing cards, learning alphabetic letters and numerals), little training takes place in auditory coding or classification outside of music classes or bird-watching clubs. Thus, it might be expected that there would be great uniformity in a simple visual concept learning task, but that the subjects' scores would spread out in a task requiring auditory classification. If this interpretation is correct, it would indicate that future studies in audiovisual concept learning should employ procedures which partial out individual differences in using audiovisual information, including perhaps repeated-measures designs or extensive pretraining schemes.

Turning to consideration of the cross-modality problem, the finding that it was more difficult than other two-dimensional problems cannot be attributed simply to the presence of both auditory and visual relevant information, since both were present in the 2-VrA condition also. Rather, it must result from the nature of the cross-modality solution, in that some relevant information is necessarily taken from each modality. This explanation would attribute the difficulty of the cross-modality problem to the subjects' lack of experience and training in forming compound concepts which are part auditory and part visual. There appear to be few conjunctive concepts which necessarily include both auditory and visual components, although it is easy to think of concepts which may be identified either by being seen or by being heard. If this finding can be shown to have generality, it will indicate that simultaneously presenting a portion of the relevant information in the visual mode and another portion in the auditory mode is an inefficient method of teaching. A complete presentation in either the visual or auditory mode is superior, as is a fully redundant audiovisual presentation.

CONCLUSIONS AND IMPLICATIONS OF THE EXPERIMENTS REPORTED IN THE CHAPTER

The studies reported here, taken either collectively or individually, provide findings consistent with the model of information transmission presented in the first chapter of this report. They also provide results which are wholly in contrast with the traditional position cited in textbooks in the audiovisual area which is alleged to be supported by a number of studies. A careful examination of these studies shows that they all manifest gross deficiencies and that they can hardly be used as a basis for educational practice. If we could offer here only a single experiment on which to take the stand that the conclusions of previous research are faulty, then our position would be a weak one, but such is not the case. The evidence comes from several different studies which have approached the problem in different contexts involving different tasks.

The first two experiments involving a serial learning task showed clearly that a single modality presentation of material resulted in as much learning as when the same information was provided through two sense modalities. In examining the data, care was taken to avoid the pitfall of averaging learning in the two single-modality conditions and then comparing the average with learning in the bimodality condition. The studies in which the latter fallacy has been committed will not be cited here to avoid embarrassing anyone. Even the best researchers will, at times, commit boners. If the latter procedure had been followed in the present study, the incorrect conclusion would also have been derived to the effect that bimodality presentations of redundant information result in more effective learning than single modality presentations. However, the latter conclusion is not correct and does not follow from the data.

The conclusions drawn from the first two experiments are greatly strengthened by the findings of the fourth. The latter experiment used an entirely different category of task from the first two but it also explored the advantages of providing redundant information through two sense modalities in contrast to one. The results were essentially the same. No advantage was found in providing redundant information through the visual and auditory modalities as compared with the transmission of information through the visual modality alone. Our suspicion is that other investigators are unlikely to discover tasks in which an advantage is gained in learning by transmitting redundant information through two modalities.

The third study in the series presents evidence of a different nature relevant to the concept that the mechanism of information processing at the higher levels can be represented as a single channel system which has a limited capacity. In this study nonredundant information was transmitted simultaneously through the eye and the ear at a rate presumed to be greater than the learner could utilize. Then an attempt was made to draw the attention of the learner to the visual source of information. The result of this was that more visual information was learned, but at the expense of the learning of the auditory information. The total amount of information learned remained unchanged. When this finding is taken together with the finding derived from the Mowbray (1953) study that the acquisition of information through a single sense modality was equal to the amount of information acquired through two modalities used simultaneously, the conclusion must be reached that we are dealing with a limited capacity system for processing information. In the Mowbray study, as in Experiment III reported here, the information transmitted through the two modalities was nonredundant.

Thus the general picture which emerges is that learning is not facilitated by the presentation of redundant information simultaneously through the auditory and the visual sense modalities. This generalization holds only when information is transmitted at a rate equal to or in excess of the maximum rate at which the receiver can utilize the information. At slower rates of presentation one might expect that more information would be learned through bimodality presentations than through single modality presentations. In terms of the rates of transmission of information typically observed in classrooms the latter rates, where the use of two sense modalities becomes more effective than one, would represent very slow rates of transmission.

The evidence presented supports the model for the design of audio-visual materials presented here rather than the traditional model.

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CHAPTER IV

SOME CONDITIONS RELATED TO THE ESTABLISHMENT OF OBJECT-NAME ASSOCIATIONS ACROSS SENSE MODALITIES*

*The first experiment reported in this series is based on a dissertation by Adrian Chan entitled "The Effect on Retention of Labeling Visual Displays," which is on file in the library of the University of Utah. The second experiment has been reported in an article by Adrian P. Van Mondfrans and Robert M. W. Travers entitled "Paired Associate Learning Within and Across Sense Modalities and Involving Simultaneous and Sequential Presentations," which appeared in the American Educational Research Journal, 1965, 2, 89-99. The third experiment was conducted by Donald J. Mueller, Adrian Van Mondfrans, Adrian Chan and Robert M.W. Travers. The fourth experiment appears as a part of a doctoral dissertation by Donald J. Mueller entitled "Explorations of Variables Related to Paired Associate Learning," which is on file in the library of the University of Utah.

An examination of audiovisual teaching materials reveals that one of their many uses is that of teaching the names of unfamiliar objects. Such materials can be used with even the youngest of children, for the name of the object can be spoken and, under such conditions, does not call for reading skill on the part of the learner. With older children the name of the particular object presented through the visual channel may be either spoken or printed. This process of learning object-word associations presents many unexplored facets, some of which are explored in the studies reported in this chapter.

The first study presented is an exploration of the advantages to be achieved in the retention of visual information through providing labels for the visual displays involved. One may suppose that some visual information is retained through being translated into verbal symbols which then represent a coded form of the visual information. If one looks at the outside of a house and says to oneself "This is a modern type of house," one has coded the visual information in verbal terms. Such coded information may be more readily retained than the uncoded information. The first study reported throws some light on this problem by exploring the value of providing through the auditory channel information which serves to code the information transmitted through the visual channel.

The second and third studies are concerned with other related problems pertaining to the development of associations between names and objects. These two studies provide findings concerning the relative advantage of the simultaneous presentation vs. the sequential presentation of the two items to be associated. The findings in this regard represent some of the more significant of those reported here.

The fourth experiment in the series introduces a new problem, namely the advantage or disadvantage of placing the more meaningful item first in the development of associations between pairs of elements. This particular study ran into some unexpected difficulties which resulted in problems in interpreting the data. Despite these difficulties the study is reported here since it may be of some help to future research workers in the area.

EXPERIMENT 1

Although teaching devices commonly transmit concrete information through the visual channel and symbolic information through the auditory channel, many different relationships may exist between the two transmissions of information. One common relationship is that of redundancy. For example, a visual display shows a farmhouse and the narrator announces "This is a farmhouse." The purpose of this paper is to study the effect of such redundant information on the ability of the subjects to recognize later the visual displays.

Research has been undertaken on a number of phenomena related to this problem. Carmichael, Hogan and Walter (1932) and later Hall (1950) investigated the effect of labeling a visual display on subsequent changes in the stored trace. Ambiguous figures were given meaningful labels and, on later attempts of the subjects to reproduce the figures, the subjects were found to produce figures that fitted the labels better than the original figures. However, these studies are only indirectly related to the study presented here. More directly related is that of Pyles (1932) who, with young children aged 2 to 7, found that the learning of form discrimination was improved by attaching verbal labels to forms even though the labels were meaningless. Her results were consistent with both nonsense forms and forms representing common animals such as dogs and cats. However, much more than the labeling of the form was involved, for the child was required to say, "The name of that shape is ________," after the experimenter had given the name. It is hardly surprising that increasing the activity of the child in relation to the object facilitated form recognition. A study related to the present problem, but with certain important differences, was undertaken by Kurtz and Hovland (1953). These research workers presented children of elementary-school age with 16 objects. One group of children was required to circle the name of the object while another group circled a picture of the object. Later, on a recognition test, those who had circled the name of the object showed better retention than those who had circled the picture. The focus in the latter study was on the nature of the activity performed by the learner, for two different activities were involved, and not on the redundancy of the information transmitted. A study by Campbell and Freeman (1955) involving a very complicated design found no effect on the retention of a visual form of verbal labels provided as redundant information, but in this study the research workers were not concerned with the direct effect of labeling on retention but with the effect on the association between two visual displays.

Thus, none of the studies reviewed here have provided any direct test of the effect of redundant verbal information on the retention of visual information, the problem considered in this study.

In this study, subjects are shown ambiguous visual displays simultaneously presented with labels that are either descriptive of the displays or that are irrelevant. It is hypothesized that: (1) the descriptive (relevant) labeling will facilitate retention of the information provided by the visual displays more than will nonsense (irrelevant) labeling; (2) no labeling will be superior to nonsense labeling since under the no-labeling condition a subject can just learn the shape or can more readily invent his own label to associate the display to previous knowledge; and (3) the use of a single sense modality during the acquisition will facilitate learning more than will the use of two modalities. It is further hypothesized that the use of relevant labels will facilitate the later recognition of the visual displays even when the labels are not used in the recognition task.

Method

The experimental procedure involved the presentation of visual displays to subjects with different types of verbal labels or with no labels presented simultaneously. Later, subjects were tested for their ability to recognize the shapes with the aid of different kinds of labels or no labels in a multiple-choice recognition test.

Choice of Shapes.--The visual displays consisted of abstract angular representations of objects drawn as black-and-white silhouettes. Some examples are shown in Figure 4.01. These abstract shapes were drawn with a particular object in mind and were deliberately made to be poor representations of it. The drawings were such that at least 50 percent of the subjects similar to those involved in the experiment were able to recognize the object represented.

Choice of Labels.--A nonsense name or the name of the object that the shape approximated was used as a label. The labels for the objects were presented either through the auditory or visual channel.

The meaningful-relevant labels were the names of the objects chosen by E which the abstract figures approximated. These labels were: CAN OPENER, GUITAR, JET, CAT, SAILBOAT, SUNGLASSES, COOLIE, SHIP, CONVERTIBLE, NAPOLEON, HYDRANT, WATER FAUCET, FIST, WRENCH, STAPLER, SKYSCRAPER, MEXICAN, KEY, SHOE, SCISSORS, AIRCRAFT CARRIER, SHARK, CHAIR, and DUCK.

In order to prepare the nonsense names, twelve nonsense monosyllables were chosen arbitrarily from Krueger's list of nonsense syllables with association values of 50-60 and twelve nonsense dissyllables were

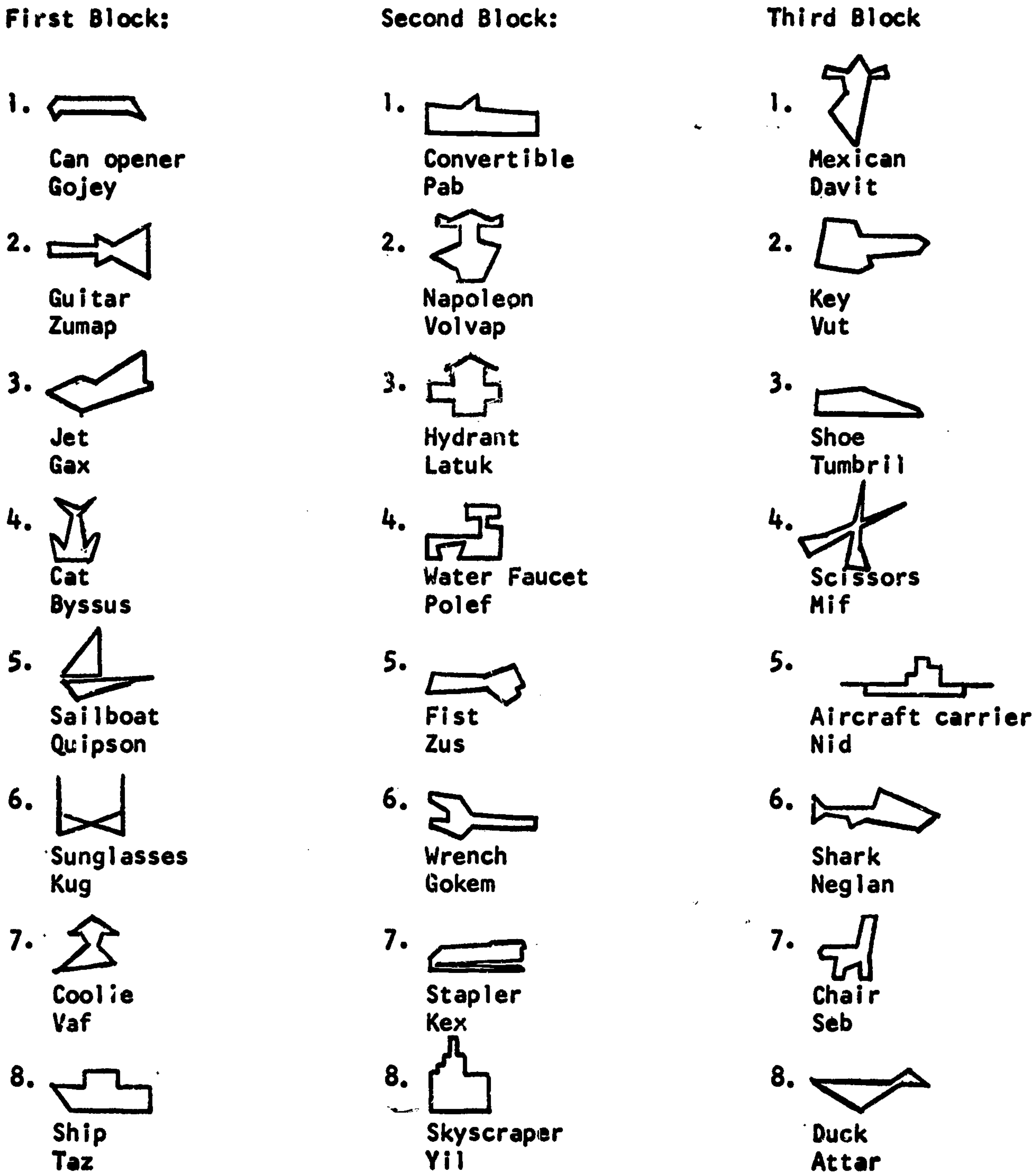

Figure 4.01. Blocks of semi-meaningful shapes with corresponding meaningful-relevant labels and nonsense labels.

chosen arbitrarily from Noble's list of nonsense syllables with association values between .99 and 1.84 (number of associations in sixty seconds). Both of the source lists of nonsense syllables are given in Underwood and Schulz (1960). The syllables and dissyllables were used as nonsense labels for the 24 visual shapes. These syllables were: GOJEY, ZUMAP, GAX, BYSSUS, QUIPSON, KUG, VAF, TAZ, PAB, VOLVAP, LATUK, POLEF, ZUS, GOKEM, KEX, YIL, DAVIT, VUT, TUMBRIL, MIF, NID, NEGLAN, SEB, ATTAR. These were then divided into three blocks of eight nonsense labels each in such a way that four monosyllables and four dissyllables were in each list.

Counterbalancing Shapes and Labels.--So that no group of shapes could be more easily identified than another, a procedure was used to determine which shapes were more closely associated with each label. In this procedure a group of 30 University students were shown the 24 figures one at a time at 20-second intervals and were instructed to write down on a sheet of paper three suggestions concerning what each drawing looked like. Subjects were instructed to write down their best choice first, their next-best choice last. A total score was obtained for each shape, indicating the extent to which it was given the same label as that assigned to it by the instructor. A total score for each label assigned by the experimenter to each shape was obtained from the responses of the 30 subjects. Scores of three points were given when the subjects' first choices were the same as the experimenter's predetermined label, two points for the second choices, and one point for the third choices. On the basis of these data, the shapes were evenly distributed into three counterbalanced blocks of eight shapes each.

In order to provide alternative shapes for the five-choice format of the recognition task, the alternative shapes were designed that resembled the stimulus shape but differed slightly in angular contour. Examples are shown in Figure 4.02. Some alternatives were drawn to fit or to correspond with the subjects' other labels which differed from those of the experimenter for a particular stimulus shape. For example, one particular shape was labeled KEY by the experimenter, but other labels given by the subjects in the preliminary study were GUN, CANNON, or AXE. It was with these alternative labels in mind that E drew some alternative shapes that looked somewhat like a gun, cannon, or an axe.

Preparing Three Sequences of 24 Shapes.--Each of the 24 shapes that had been drawn could be assigned a meaningful-relevant label, a nonsense label, or no label. (This is the "Label" treatment in subsequent analysis of variance.) The 24 visual displays were divided into three sets or sequences of 24 shapes. Each set of 24 shapes contained a block of eight shapes with meaningful-relevant labels, another block with nonsense labels,

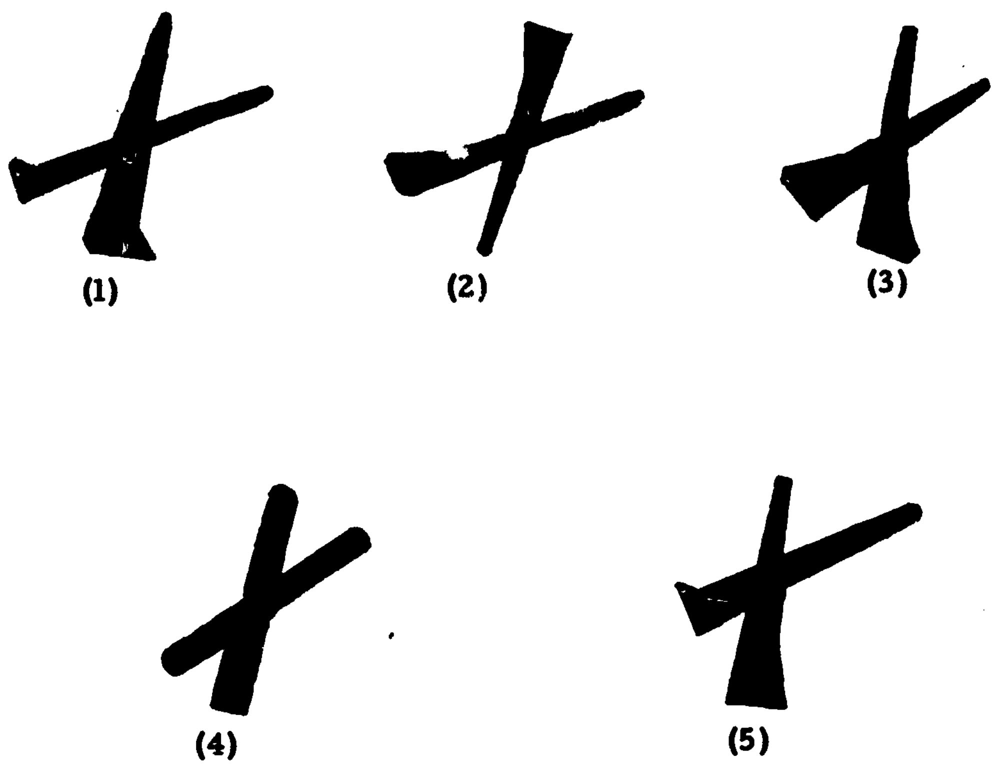

Figure 4. 02. Example of multiple-choice form recognition item used for measuring retention.

and a third block with no labels. The arrangement of the three sets of 24 shapes is presented in Table 4.01. For example, the first block of eight shapes appeared in the first set of 24 shapes with meaningful-relevant labels, but it appeared in the second set of 24 shapes with nonsense labels and in the third set of 24 shapes with no labels. The second and third blocks of eight shapes each also appeared in the three sets of 24 shapes with meaningful-relevant, nonsense, or no labels as shown in Table 4.01. Thus, three sets of 24 shapes were produced with each set appearing with a different labeling treatment. In addition, all the shapes within each of the sets of 24 were placed in random order.

TABLE 4.01

DIFFERENT SETS OF 24 SHAPES PRESENT IN THE EXPERIMENT

Set	Meaningful Label	Nonsense Label	No Label
Set 1	1st Block	2nd Block	3rd Block
Set 2	3rd Block	1st Block	2nd Block
Set 3	2nd Block	3rd Block	1st Block

The visual displays were flashed on a screen located about 10 feet from the subject and the black silhouette of the object was about 12 inches in length.

The visual label was a printed word that appeared together with the representation of the object and immediately below it.

The auditory labels were produced by means of a tape recorder synchronized with the LaBelle Maestro II projector used to present the visual displays on the screen.

Thus, the materials provided three sets of visual materials each of which involved three different labels (meaningful, nonsense, and no labels), and each of the three sets of 24 visual displays could be used either with visually presented labels or with aurally presented materials. The materials provided the framework for a factorial repeated-measures design.

Subjects. -- One hundred and twenty-nine undergraduates served as subjects. Seventy-two of these subjects were randomly assigned to six groups of 12 subjects representing six conditions of learning, while the remaining 57 subjects represented the control groups.

Apparatus. -- The 24 stimulus figures on white background were reproduced on microfilm slides; three slides were made of each stimulus figure, one had a meaningful-relevant label, another had a nonsense label, and the third had no label. The experimental instructions were also reproduced on microfilm slides. The experimental facilities consisted of a room with a table and six chairs, a movie screen, a single-unit slide projector-tape recorder (La Belle Maestro II), recorded tapes of the experiment, and IBM scoring stencils.

Procedure. -- IBM sheets were given to subjects as they entered the experimental room and they were instructed to sit at a table facing the movie screen. The lights were dimmed and E started the slide projector-tape recorder. The instructions were given aurally or visually according to the subjects' assigned group. The visual shapes with their appropriate labels were presented at two-second intervals for two trials. In the recognition task the subjects had five seconds to pick out the correct shapes in each of 24 multiple-choice items.

All subjects were assigned to one of six learning conditions; within each group they were presented and tested with one of three sets of 24 shapes as shown in Table 4.02. The six different learning conditions were as follows:

(1) Experimental A-A (N = 12): All subjects were presented the 24 stimulus shapes with the labels given aurally by tape recorder (through a loud speaker), and were tested by a recognition task with the labels also given aurally; in other words, an auditory presentation of the labels both in the acquisition trials and in the recognition test (A-A). The subjects in this group were further assigned and given one of three sets of 24 shapes, four subjects in each set. In short, all 12 subjects were exposed to all kinds of labels (meaningful-relevant, nonsense, and no labels), with labels presented aurally and tested with labels given aurally (A-A), but each group of four subjects received a different sequence or set of 24 shapes

(sets 1, 2, or 3). The IBM sheets were hand-scored with a scoring stencil and the number of errors for each kind of label was obtained.

(2) Experimental V-V (N=12): All subjects received the same treatment as in Group A-A except that during the acquisition trials the labels were given visually (printed on the slides) and in the recognition task the labels were also given visually (V-V).

(3) Experimental A-V (N=12): All subjects received the same treatment as in Group A-A except that during the acquisition trials the labels were given aurally and in the recognition task the labels were given visually (A-V).

(4) Experimental V-A (N=12): All subjects received the same treatment as in Group A-A, except that during the acquisition trials the labels were given visually and in the recognition task the labels were given aurally (V-A).

(5) Experimental A-NL (N=12): All subjects received the same treatment as in Group A-A, except that during the acquisition trials the labels were given aurally and in the recognition task no labels were given.

(6) Experimental V-NL (N=12): All subjects received the same treatment as in Group A-A, except that during the presentation period the labels were given visually and in the recognition task no labels were given. In addition, the following control groups were in cluded:

All subjects in the control groups received the recognition task only and no presentation learning trials. In Controls 1 and 2 (N=20 each) subjects were instructed to select the shape among the five alternatives which best matched the label given. In Control 1, the labels used were meaningful-relevant; while in Control 2, the labels were nonsense-irrelevant. In Control 3 (N=17), subjects were just instructed to select the shape among five alternatives which looked best to them, without the aid of any labels.

Results

The mean number of errors and the standard deviations for the experimental and control groups are shown in Table 4.02; _t_ tests were calculated to compare the differences between the experimental label groups and the control groups. Significant differences were found when the meaningful-relevant, nonsense-irrelevant, and no label groups were compared with their respective control groups, 1, 2, and 3. The differences indicate that these three experimental label groups had far fewer errors than their corresponding control group; these differences were all significant at the .001 level. Comparisons using t tests were also calculated between the control groups and chance. The results indicate the following: (1) Control 1 (meaningful-relevant labels used in the recognition task) made, on the average, significantly fewer errors than would be expected by chance ($p < .001$); (2) Control 2 (nonsense-irrelevant labels used in the recognition tasks) did not perform on the average significantly different from chance; and (3) Control 3 (no labels used in the recognition task) made, on the average, significantly fewer errors than would be expected by chance ($p < .001$). All in all, it should be noted that the experimental groups made significantly fewer errors than the control groups and the control groups (except Control 2) made significantly fewer errors than would be expected if they had marked the answer sheets at random.

Table 4.02 presents the mean error and standard deviations for each type of label. In this respect, the meaningful-relevant labeling produced fewer mean errors than nonsense labeling and no labeling, while the no-labeling condition had fewer mean errors than the nonsense-labeling condition.

Analysis of Variance of Main Effects.--A fixed model with counterbalancing and repeated measures, 3 x 2 x 3 factorial design was used to analyze the data. The main effects pertained to: (a) labels (L)--relevant, nonsense, and no labels; (b) sets of 24 shapes (S)--sets, 1, 2, and 3; (c) presentation mode (P)-- audio or visual; and (d) recognition-test label mode (R)--audio, visual, or no label. The interaction of presentation and recognition (P x R) could also be assessed from the analysis of variance. Individual degree-of-freedom tests were computed for the significant results to determine what factors accounted for most of the variance(Li, 1957).

The significance of the effect of labeling can be determined from the analysis of variance presented in Table 4.03. The main effect of labeling and the interaction of presentation and recognition were found to be significant ($p < .001$ and $p < .05$, respectively). The other main effects of presentation, recognition, and sets of 24 shapes did not approach significance.

TABLE 4.02

MEAN ERRORS AND STANDARD DEVIATIONS PER 8 SHAPES COMMITTED BY EACH LEARNING GROUP AND EACH CONTROL GROUP ON EACH TYPE OF LABEL

Group	Sense Modality of Label in Learning and Testing Conditions	N	Meaningful M	Meaningful SD	Nonsense M	Nonsense SD	No Label M	No Label SD
Experimental A-A	Auditory-Auditory	12	1.42	0.75	3.75	0.93	3.58	1.13
Experimental V-V	Visual-Visual	12	1.50	1.37	3.33	1.80	3.17	2.15
Experimental A-V	Auditory-Visual	12	1.08	1.04	2.75	0.83	2.83	0.96
Experimental V-A	Visual-Auditory	12	1.00	1.00	3.08	1.26	2.83	1.19
Experimental A-NL	Auditory-No Label	12	1.75	0.83	3.08	1.56	2.83	1.35
Experimental V-NL	Visual-No Label	12	1.50	0.90	3.43	1.28	2.58	1.19
All Experimental Groups	Experimental	72	1.38	1.10	3.24	1.35	2.72	1.54
Control 1		20	4.28	1.76				
Control 2		20			6.50	1.07		
Control 3		17					5.82	2.25

TABLE 4.03

SUMMARY OF ANALYSIS OF VARIANCE OF ERROR DATA

Source	Sum of Squares	df	Mean Squares	F	p
Between S Total	238.63	71			
Presentation (P)	0.29	1	0.29	n. s.*	--
Recognition (R)	1.75	2	0.88	n. s.*	--
Presentation and Recognition (P x R)	21.79	2	10.89	3.27	.05
Sets of 24 Shapes (S)	1.86	2	0.93	n s.*	--
Ss/Groups	212.94	64	3.33	--	--
Within Ss Total	286.70	144			
Labels (L)	133.02	2	66.51	61.58	.001
Residual	153.68	142	1.08	--	--
Grand Total	525.33	215	--	--	--

*n. s.: Not Significant

Table 4.04 shows monorthogonal individual degrees-of-freedom tests that indicate the following: (a) the difference between meaningful-relevant label and nonsense label was significant at the .001 level; (b) difference between meaningful-relevant label and no label was significant at the .001 level; and (c) the difference between nonsense label and no label was significant at the .001 level. In short, the meaningful-relevant label condition had significantly fewer errors than the nonsense-label or the no-label condition, and the no-label condition had significantly fewer errors than the nonsense-label condition.

TABLE 4.04

SUMMARY OF INDIVIDUAL DEGREE-OF-FREEDOM TEST

Source of variation	*F*	*p*
Meaningful-relevant labeling vs. nonsense labeling	115.45	.001
Meaningful-relevant labeling vs. no labeling	60.50	.001
No labeling vs. nonsense labeling	8.81	.001
Groups Audio-Audio and Visual-Visual vs. Groups Audio-Visual, Visual-Audio, Audio-No Label, and Visual-No Label	6.54	.05

Analysis of Variance of Interaction.--The significant interaction of the modality of the label during acquisition and the modality of the label on the recognition test is represented in Figure 4.03. The interaction does not appear to be meaningful, but such is typically the case with complex factorial designs. The results presented up to this point have been concerned with the over-all effects of labeling irrespective of whether the label did or did not appear on the recognition test. Of special interest is the effect of labeling when the labels do not appear on the recognition test. This problem must now be considered.

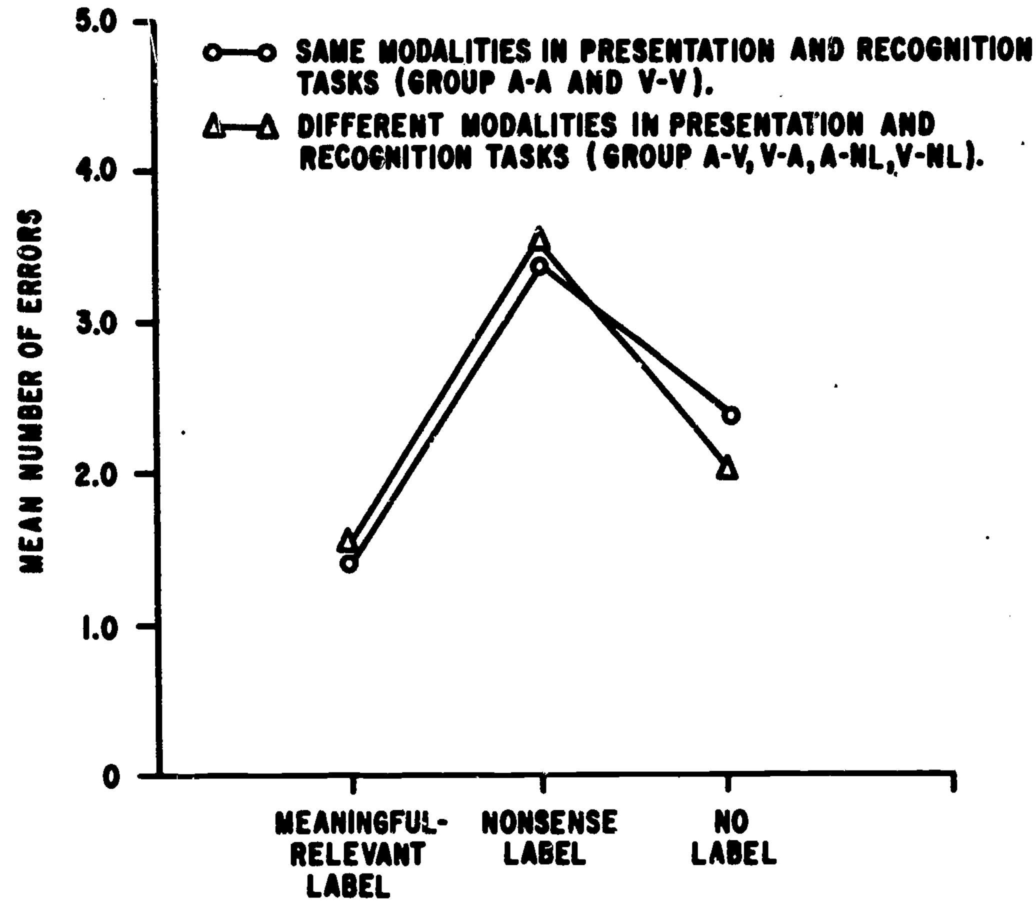

Figure 4.03. Representation of the interaction effect of the modality of the label during acquisition and the modality of the label during the recognition test.

Effects of Labeling in the Learning Task when No Labels are Included on the Recognition Test.--Table 4.05 shows the analysis of variance for the data of Group A-NL and Group V-NL. There was no significant difference between the errors made by Group A-NL and Group V-NL, but the main effect of labeling was found to be significant across the two groups. Individual degree-of-freedom tests on Table 4.06 indicated: (a) the difference between meaningful-relevant label and nonsense label was significant at the .001 level; (b) the difference between meaningful-relevant label and no label was significant at the .001 level; and (c) the difference between nonsense labeling and no labeling was significant at the .10 level. It should be noted that these three experimental conditions were also significantly superior to the control conditions at the .001 level as previously stated. In short, the meaningful-relevant label condition of learning resulted in significantly fewer errors than the nonsense label or the no-label conditions, even when no labels were provided in the recognition test. This finding is consistent with the over-all analysis of variance in Table 4.03 and the individual degrees-of-freedom results in Table 4.04. The label that associated the visual display to previous experience in the presentation trials facilitated the retention of information related to the shape.

TABLE 4.05

SUMMARY OF ANALYSIS OF VARIANCE BETWEEN GROUP AUDIO-NO LABEL AND GROUP VISUAL-NO LABEL

Source	Sum of Squares	df	Mean Squares	F	p
Groups A-NL and V-NL	0.05	1	0.05	ns*	----
Between subjects error term	63.89	22	2.90	----	----
Labels	32.86	2	16.43	13.92	.001
Residual	54.14	46	1.18	----	----
Grand Total	150.94	71	----	----	----

*ns: Not Significant

TABLE 4.06

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE INDIVIDUAL DEGREE-OF-FREEDOM TESTS FOR SIGNIFICANT LABELS IN GROUPS AUDIO-NO-LABEL AND VISUAL-NO-LABEL

Source of variation	F	P
Meaningful-relevant labeling vs. nonsense labeling	26.85	.001
Meaningful-relevant labeling vs. no labeling	11.93	.001
Nonsense labeling vs. no labeling	2.98	.10

Discussion

The analysis of the results indicates support for the first two hypotheses, but not for the third hypothesis. The first hypothesis stated that meaningful-relevant labeling will be significantly superior to nonsense labeling and no labeling. The findings that the meaningful-relevant label condition has significantly fewer errors than the nonsense-label condition and the no-label condition ($p < .001$) indicates support for the first hypothesis (Tables 4.02, 4.03, 4.04). It appears from the study that this result is consistent with the conclusion drawn by Campbell and Freeman (1955) that meaningfulness and relevancy or appropriateness of the label attached to the stimulus may be a factor facilitating perceptual learning. The implication of this result could be expanded to a perceptual learning experiment using more complex visual displays, such as are found in audio-visual teaching materials.

The second hypothesis stated that the no-labeling condition will be significantly superior to the nonsense-labeling condition. The assumption made in this hypothesis is that under the no-labeling condition the subject is just able to learn the shape or is able to invent his own meaningful and appropriate label, whereas, under the nonsense-labeling condition the subject is prevented from using a more appropriate label. The result indicates support for the second hypothesis. This finding is inconsistent with the results of the Pyles (1938) study in which she found that the nonsense-labeling group made fewer errors than the no-label group. It might be argued that the nonsense names used by Pyles such as MOBIE, KOLO, TITO, GAMIE, and BOKIE, were not strictly nonsense or irrelevant names at all, but might have had some association with the stimulus shapes for the children of that age group.

The third hypothesis stated that subjects given the labels in the presentation trials and the recognition tasks on the same sensory modality will make significantly fewer errors than those subjects who were given the labels in the presentation trials in one sensory modality and were tested with the labels given in another sensory modality. The result in Table 4.06 shows that learning groups, using the same sensory modalities for labels in both the learning and recognition task, made significantly more errors (rather than less errors) than groups using different sensory modalities for labels ($p < .05$). This finding does not support the hypothesis, nor does it make any sense. However, upon further analysis of the data (Figure 4.03), there seems to be very little difference in the mean errors between groups using the same modalities and the groups using different modalities in the presentation and recognition tasks.

The main purpose of using the conditions Audio-No-Label and Visual-No-Label was to determine the extent of association of a visual display with previous knowledge provided by a label.

If the same meaningful labels were given in the learning trials and in the recognition task, some facilitation would be expected. An important matter is whether the same facilitation would occur if no labels were introduced in the recognition task. Tables 4.05 and 4.06 indicate that under the no-label testing situations the meaningful-relevant labels that associated the visual shape with previous experience in the acquisition trials improves retention (more correct responses). This confirms the fourth hypothesis.

EXPERIMENT II

The purpose of the present study is to explore various combinations of sense modalities in presenting information and the relationship of these combinations to the learning of associations. The study is also concerned with the time conditions related to the forming of associations, particularly when these are formed across different sense modalities.

In paired-associate learning, the stimulus and response items are usually presented via the same sense modality, with the stimulus item occurring first and the response item following it. This study is designed to determine what the results would be if the presentation mode (sense modality) of the stimulus and response items and the time relationship between the stimulus and response items were varied.

Kale and Grosslight (1955) report a study in which the task was to write the correct Russian words when presented with their English equivalents. The presentation modes were the visual-print, the visual-pictorial, the visual-pictorial with motion (the object representing the word was shown in motion), the audio and the kinesthetic (the S's vocalization of the learning materials), and their combinations. It was found that the presentation mode did make a difference in the amount of Russian vocabulary learned, with the visual-pictorial-with-motion mode being superior to the visual-print, audio, kinesthetic, and visual-pictorial modes ($p < .01$). The audio mode was the least effective.

Otto (1961) also found that the presentation mode of the response items was an important variable in a paired-associate learning task. In his study, the stimulus items were geometric figures and were always presented visually. The subject responded with a nonsense-syllable "name" for each figure. After the subject's response, the correct syllable was presented aurally, audiovisually, or audiovisual-kinesthetically (the subject heard, saw, and pronounced the syllable). The young children did best when the respons- items were presented by the audiovisual-kinesthetic mode; the fourth and s... graders did best when the response items were presented by the audiovisual mode. The audio mode was uniformly the worst. Since the visual-only mode was not tested, its effectiveness could not be determined.

In the area of paired-associate learning, we have little information concerning rate of acquisition when the pairs of items are presented simultaneously compared with when they are presented sequentially. In most paired-associate studies, the learner either reads the two items sequentially or hears them sequentially. In classroom situations, on the other hand, the presentation of an object and its name may be either simultaneous or sequential. The relative effectiveness of the two procedures is unknown, although the design of every audiovisual aid requires that one of the two procedures be adopted in preference to the other. There are variations involved in making this comparison that can be summarized in the form of a question: Is the presentation of an object for a 1-second interval followed by the presentation of its name during a 1-second interval equal in effectiveness to the simultaneous exposure of the object and its name together for a 1-second interval followed by a 1-second interval with no display? Or is it more similar in effectiveness to the simultaneous exposure of the object and its name for 2 seconds?

Previous research suggests that time of exposure is unimportant when time per trial is held constant, but that variations in time per trial are important. Murdock (1960), using unrelated words as the stimulus materials, showed that the number of words remembered from lists of different length was a function of the total time of the presentation of the list rather than the time allotted for each stimulus item. Bugelski (1962) and Bugelski and Rickwood (1963) also presented evidence indicating that the important variable in a paired-associate task was the total presentation time, or the total time the subject has for learning the pairs, and not the time per exposure of the stimulus-response pair.

It is hypothesized here that there will be significant differences in the effectiveness of various combinations of presentation modes in learning object-name paired associates. Both the presentation mode of the stimulus item and the presentation mode of the response item will be varied. It is also hypothesized that those combinations involving multichannel presentations will not result in more learning than those involving only single-channel presentations. The auditory-only presentation will be inferior to all the others.

The study involves two simultaneous conditions, and these are both hypothesized to be superior to the sequential condition. Since the total time allowed for the presentation of one stimulus-response pair will be the same under the two simultaneous conditions, it is hypothesized that these two conditions will be equal in effectiveness.

Method

Subjects.--The subjects were 270 male and female undergraduate students at the University of Utah. Ninety participated under each of three time conditions: (a) the sequential (Seq.) condition involving a 1-second exposure of the stimulus element followed by a 1-second exposure of the response element; (b) the simultaneous condition with a 1-second exposure of the visual arrays (Sim. 1); and (c) the simultaneous condition with a 2-second exposure of the visual arrays (Sim. 2).

The subjects were assigned to a time condition and a presentation mode at random, and those in each time condition were evenly distributed across the nine different presentation-mode combinations.

Task.--A paired-associate task was used. The stimulus item for each pair was a diagram, or the word descriptive of the diagram transmitted through the auditory channel, or combinations of these presentations. The materials for the stimulus elements are shown in Figure 4.04. The response element of each pair was a verb presented either as a printed or as a spoken word, or presented in these two ways simultaneously. Learning was measured by a test in which each diagram was followed by a space for the subject to write the appropriate verb. The test was given after each complete presentation of the 10 paired associates.

The diagrams were familiar geometrical figures. They were administered to a pilot group of subjects similar to those used in the experiment in order to establish the fact that the figures and their names were highly familiar. It was recognized that the names did not completely and precisely specify the figures, but the correspondence between them was considered adequate. The diagrams themselves, rather than their printed names, were used in the visual presentations since this procedure corresponds to the object-name learning tasks found in audiovisual teaching devices.

All the response items were three-letter verbs chosen from the Lorge-Thorndike list of the 500 most-used words. The subjects in the pilot group used in selecting the stimulus materials were also presented with a trial list of verbs. Only those verbs that, when spoken, could be spelled and easily distinguished from one another by all members of the pilot group were used in the experiment. These verbs were: are, can, did, has, let, run, say, use, put, and was.

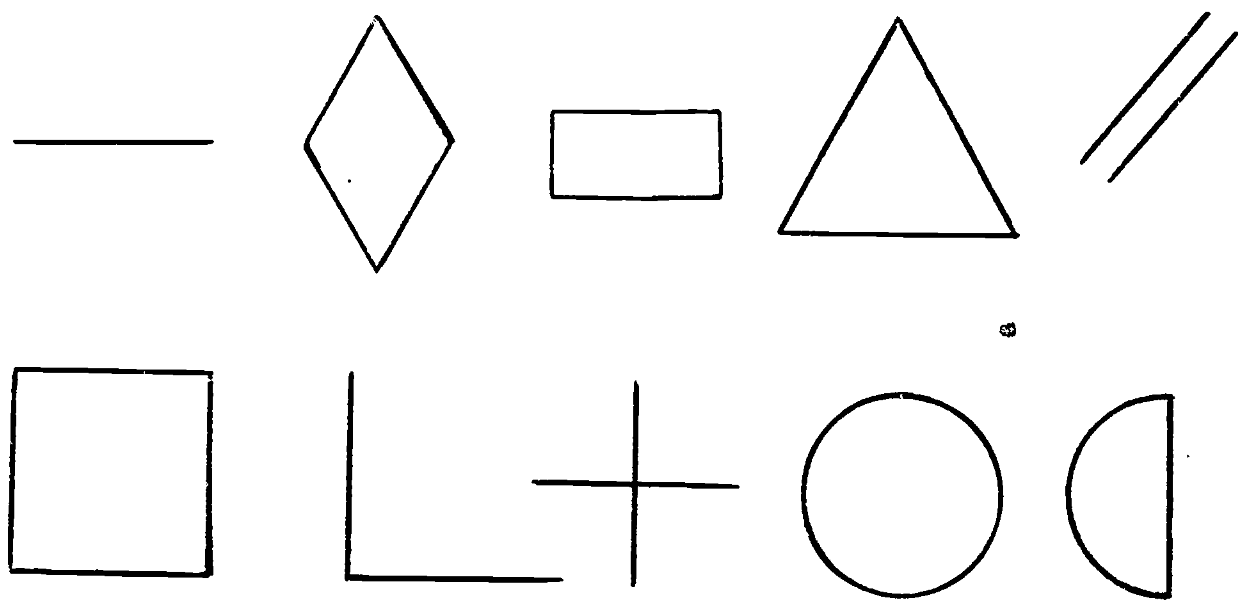

Figure 4.04. Stimulus Figures.

Presentation Procedure. --Using the combinations of presentation modes given in Table 4.07, the investigators presented the stimulus figures, or their names, and the response verbs. The audio presentations were by tape recorder, with a man's voice for the stimulus item of each pair and a woman's voice for the response item. This was done to aid the subjects in distinguishing between the name of a figure and the response verb when spoken simultaneously. Under these conditions subjects can readily separate the two. The visual presentations of the stimulus and response items were made via a slide projector.

The audiovisual presentation was a combination of the auditory and visual presentations, synchronized so as to have the stimulus and response items occur together in the simultaneous conditions and sequentially in the sequential condition. The equipment was a Labelle Maestro II slide-projector and tape recorder unit, which had a relay system that was tripped by high-frequency blips on the tape to trigger the slide-changing mechanism.

The total presentation time for a stimulus-response pair was 2 seconds in each of the three time conditions. In the sequential condition, the stimulus item was presented for 1 second and the response item was presented for 1 second. In the Sim. 1 condition, the stimulus and response items were presented for 1 second, with a 1-second pause between successive stimulus-response pairs. In the Sim. 2 condition, the stimulus and response items were presented for the entire 2 seconds. (A limitation was placed on the audio presentation of the stimulus and response items, however, since stretching out the pronunciation of a word for 2 seconds might seriously alter its character, and repeating a word several times during the 2 seconds would amount to several presentations of the stimulus or response item and would not be comparable to the other presentation conditions). It was decided to pronounce the stimulus and response items in the audio presentations only once.

After each complete presentation of the 10 stimulus-response pairs, the subjects were given response sheets containing the stimulus figures (the test mentioned previously) and allowed 45 seconds to write as many of the appropriate verbs opposite the corresponding figures as they could remember. The order of the figures was randomized from sheet to sheet to insure that the association between the stimulus and response items was being made rather than just the order of the response items memorized. Each subject received 10 trials with the particular materials to which he had been assigned; his score was the total number of correct responses on his 10 response sheets.

TABLE 4.07

COMBINATIONS OF STIMULUS AND RESPONSE PRESENTATION MODES USED IN THE STUDY

Simultaneous 1*		Simultaneous 2**		Sequential	
Stimulus	Response	Stimulus	Response	Stimulus	Response
A	A	A	A	A	A
A	V	A	V	A	V
A	AV	A	AV	A	AV
V	A	V	A	V	A
V	V	V	V	V	V
V	AV	V	AV	V	AV
AV	A	AV	A	AV	A
AV	V	AV	V	AV	V
AV	AV	AV	AV	AV	AV

*The simultaneous-1 condition involved a 1-second exposure of the visual array followed by a 1-second blank.

**The simultaneous-2 condition involved a 2-second exposure of the visual array with no blank period between the successive stimulus-response pairs.

Results

The means and the standard deviations of the subjects' scores (total number of correct responses) are shown in Table 4.08. To obtain meaningful and readily understood results, these data were analyzed as follows: Sim. 1 was compared with Sim. 2; Sim. 1 was compared with Seq.; and Sim. 2 was compared with Seq.

Analyses of Variance

Sim. 1 vs. Sim. 2.

The results of the analysis of variance for the Sim. 1 and Sim. 2 conditions are summarized in Table 4.09. The only significant effect was that of presentation mode ($p < .001$). Note that the difference between learning under Sim. 1 and Sim. 2 was not significant; that is, the total amount learned by the subjects in Sim. 1 was the same as that learned by the subjects in Sim. 2. This finding supports the hypothesis that it is the total time allotted for learning a stimulus-response pair that is crucial and not the time per exposure.

A Duncan Multiple-Range Test was used to break down the significant effect of presentation mode. The results are shown in Table 4.10. It is clear that the A-A and the AV-A presentation modes are inferior to all the others. There is also evidence of the inferiority of the A-V combination. The equivalence of the V-A, V-AV, AV-V, AV-AV, and V-V modes of presentation demonstrated that a multichannel presentation does not aid significantly in forming associations. This finding was substantiated by an individual degree-of-freedom test comparing the single-channel presentations (A-A, V-V, V-A, and A-V) with the multichannel presentations (AV-V, AV-A, A-AV, V-AV, and AV-AV), in which no significant difference appeared. Those presentation modes in which the A-channel was involved in both the stimulus and response presentations (A-A, AV-A, and A-AV) were inferior to the V-V group (V-V, V-AV, and AV-V) at the .001 level of significance.

Sim. 1 vs. Seq.

As can be seen in Table 4.11, the effect of time condition was significant ($p < .05$)--the Sim. 1 condition resulted in more learning than the Seq. condition. The effect of presentation mode was also significant ($p < .001$). A Duncan Multiple-Range Test was used to break down this effect, with the results shown in Table 4.12. Once again the A-A and the AV-A modes are the least effective. The A-V and the A-AV modes show some inferiority to the V-A, AV-V, AV-AV, and V-V modes.

TABLE 4.08

MEANS AND STANDARD DEVIATIONS OF THE AMOUNT LEARNED (TOTAL NUMBER OF CORRECT RESPONSES) BY TIME CONDITION AND MODE OF STIMULUS-AND-RESPONSE PRESENTATION*

Time Condition	Mode of Stimulus-and-Response Presentation								
	A-A	A-V	A-AV	V-A	V-V	V-AV	AV-A	AV-V	AV-AV
Sim. 1									
Mean	31.7**	49.9	54.3	64.2	79.0	65.4	39.3	73.4	72.2
SD	15.7	17.5	19.1	17.4	14.4	17.2	16.8	18.5	16.8
Sim. 2									
Mean	39.8	49.5	66.6	67.5	69.4	69.3	44.1	63.0	69.0
SD	12.1	7.6	14.5	12.9	25.6	20.9	10.7	26.1	13.7
Seq.									
Mean	45.5	53.7	46.2	56.6	57.4	49.0	48.1	55.1	59.6
SD	10.4	18.3	14.6	14.2	12.4	18.8	14.4	22.9	14.9

*N=10 in each cell.
**Perfect score=100.

TABLE 4.09

SIM. 1 VS. SIM. 2: ANALYSIS OF VARIANCE FOR TIME-CONDITION AND PRESENTATION-MODE EFFECTS

Source	df	Sum of Squares	Mean Square	F	p
Time Condition (TC)	1	64.8	64.8	....	....
Presentation Modes (PM)	8	30, 291.4	3, 786.4	13.67	.001
TC x PM	8	2, 331.0	291.4	....	....
Within	162	44, 857.6	276.9		
Total	179	77, 544.8			

TABLE 4.10

SIM. 1 VS. SIM. 2: LEVELS OF SIGNIFICANCE* REACHED BY DIFFERENCES BETWEEN THE EFFICIENCIES OF PRESENTATION MODES**

	A-A	AV-A	A-V	A-AV	V-A	V-AV	AV-V	AV-AV	V-V
A-A	...	N.S.	.05	.01	.01	.01	.01	.01	.01
AV-A		....	N.S.	.01	.01	.01	.01	.01	.01
A-V			....	.05	.01	.01	.01	.01	.01
A-AV				....	N.S.	N.S.	N.S.	N.S.	.05
V-A					. .	N.S.	N.S.	N.S.	N.S.
V-AV						....	N.S.	N.S.	N.S.
AV-V							....	N.S.	N.S.
AV-AV								....	N.S.
V-V									....

*Computed by Duncan Multiple-Range Test.
**Presentation modes arranged from least effective (at the left) to most effective (at the right).

TABLE 4.11

SIM 1 VS. SEQ.: ANALYSIS OF VARIANCE FOR TIME CONDITION AND PRESENTATION-MODE EFFECTS

Source	df	Sum of Squares	Mean Squares	F	p
Time Conditions (TC)	1	1,754.7	1,754.7	5.86	.05
Presentation Modes (PM)	8	16,948.2	2,118.5	7.08	.001
TC x PM	8	6,515.6	814.4	2.72	.01
Within	162	48,486.4	299.3		
Total	179	73,704.9			

TABLE 4.12

SIM. 1 VS. SEQ.: LEVELS OF SIGNIFICANCE* REACHED BY DIFFERENCES BETWEEN THE RELATIVE EFFICIENCIES OF PRESENTATION MODES***

	A-A	AV-A	A-AV	A-V	V-AV	V-A	AV-V	AV-AV	V-V
A-A	...	N.S.	.01	.01	.01	.01	.01	.01	.01
AV-A		...	N.S.	N.S.	.01	.01	.01	.01	.01
A-AV			...	N.S.	N.S.	.05	.01	.01	.01
A-V				...	N.S.	.05	.01	.01	.01
V-AV					...	N.S.	N.S.	.05	.05
V-A						...	N.S.	N.S.	N.S.
AV-V							...	N.S.	N.S.
AV-AV								...	N.S.
V-V									...

***Same as on Table 4.10

The comparison between the single-channel presentation modes and the multichannel presentation modes yielded no significant difference. The comparison between the A-A group and the V-V group showed the first to be inferior to the second, as in the previous analysis ($p < .001$).

The interaction between the time conditions and the presentation modes ($p < .01$) is best explained by looking at Figure 4.05. Most of the interaction would result from the relative positions of the A-A, the A-V, the A-AV, and the AV-A presentation modes. The difference in the relative merits of these modes in the Sim. 1 condition as compared with the Seq. condition results in the significant interaction.

<u>Sim. 2 vs. Seq.</u>

The analysis of variance of these data shows that the effects of time condition ($p < .01$) and presentation mode ($p < .001$) were significant, as shown in Table 4.13. The simultaneous condition facilitated learning significantly more than the sequential condition. A Duncan Multiple-Range Test was again used to break down the presentation-mode effect, with the results shown in Table 4.14.

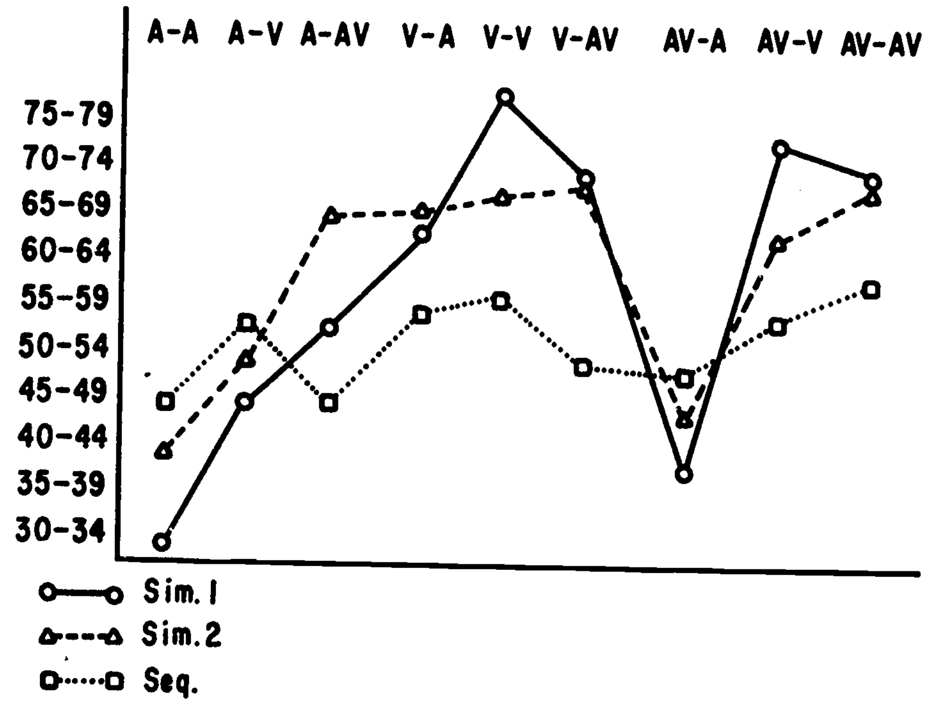

Figure 4.05. Mean number of correct responses for each presentation mode by time condition.

TABLE 4.13

SIM. 2 VS. SEQ.: ANALYSIS OF VARIANCE FOR TIME CONDITION AND PRESENTATION-MODE EFFECTS

Source	df	Sum of Squares	Mean Squares	F	p
Time Conditions (TC)	1	2,493.9	2,493.9	9.39	.01
Presentation Modes (PM)	8	9,503.5	1,187.9	4.48	.001
TC. x PM	8	3,943.9	493.0	1.86	....
Within	162	43,003.6	265..4		
Total	179	58,944.9			

TABLE 4.14

SIM. 2 VS. SEQ.: LEVELS OF SIGNIFICANCE* REACHED BY DIFFERENCES BETWEEN THE RELATIVE EFFICIENCIES OF PRESENTATION MODES***

	A-A	AV-A	A-V	A-AV	AV-V	V-AV	V-A	V-V	AV-AV
A-A	....	N.S.	.01	.01	.01	.01	.01	.01	.01
AV-V		....	N.S.	.01	.01	.01	.01	.01	.01
A-V			....	N.S.	.05	.05	.01	.01	.01
A-AV				....	N, S.	N.S.	N.S.	.05	.05
AV-V					....	N.S.	N.S.	N.S.	N.S.
V-AV						....	N.S.	N.S.	N.S.
V-A							....	N.S.	N.S.
V-V								....	N.S.
AV-AV									....

***Same as on Table 4.10

The efficiencies of the various modes of presentation were about the same as in the other two analyses. The A-A, AV-A, and A-V modes again were inferior to the rest. The AV-V, V-AV, V-A, V-V, and AV-AV modes were equal. When the A-A group was compared with the V-V group, the V-V group was found to be significantly superior ($p < .001$). When the multichannel presentations were compared with the single-channel presentations, there was no significant difference.

Correlations Between Order of Efficiency of Experimental Conditions

The order from least to most effective of the various presentation modes was determined for each time condition. Rank one was given to the least effective presentation mode in each time condition, rank two to the next, and so on. It was then possible to correlate the ranks of the presentation modes in one time condition with those in another time condition. A high correlation would show that the relative effectiveness of the presentation modes tested was quite constant. This would allow generalizations to be made about the presentation modes used.

The rank-order correlation coefficient obtained by comparing the ranks of the presentation modes in the Sim. 1 condition with those in the Sim. 2 condition was .82 ($p < .005$). Thus, the relative efficiencies of the presentation modes in these two conditions were highly correlated.

The correlation coefficient between the order of efficiency of the various presentation modes in the Sim. 1 condition and the Seq. condition was .78, which also differed significatnly from zero ($p < .01$). The correlation coefficient comparing the Sim. 2 condition with the Seq. condition was .67 ($p < .05$). It is clear from these data that the efficiencies of the presentation modes used were relatively constant across all three time conditions.

Discussion

It was hypothesized that there would be significant differences in effectiveness among the various presentation modes. This was substantiated in all the analyses of variance. The A-A presentation was significantly inferior to the others. The AV-A mode was the next most inferior and the A-V mode the next. At the other end of the scale were those modes using the visual channel for both the stimulus and response presentation. In this group were the V-V, AV-V, and V-AV modes, with the AV-AV mode also showing superiority over the A-A mode. It appears that in the case of the subjects tested, the visual channel was more efficient in transmitting information of the type used and in facilitating associations. Some of the superiority of the V-V group may be attributable to the fact that in the simultaneous time conditions the audio presentations interfered with each other more than did the visual presentations.

There were no demonstrable differences between the amounts recalled when the stimulus-response pairs were presented through a single channel and when they were presented through more than one channel. This finding is in agreement with the bulk of the data from the Kale and Grosslight study (1955) and the Otto study (1961).

The fact that the relative effectiveness of the presentation modes tested was constant across all three time conditions allows the generalizations in the two preceding paragraphs to be made. The amounts recalled under the two simultaneous conditions were not significantly different. This was so even though the actual viewing time of a visual array in the Sim. 2 condition was twice that in the Sim. 1 condition. The important variable was the total time allowed for each stimulus-response pair to be learned, which was held constant at 2 seconds in all three time conditions. This finding agrees with the data of the Murdock (1960), the Bugelski (1962), and the Bugelski and Rickwood (1963) studies, which all showed that the total time allowed for learning a simulus array was a more important variable than the time allotted for each stimulus member.

An especially interesting finding of the present experiment was that the simultaneous conditions produced more learning (as measured by recall) in a paired-associates task than did a sequential presentation of the same materials. Since the task was one of recall, in which one member of a stimulus-response pair was presented and the subject was to respond with the other member, this result may have been due to the contiguity of the stimulus-response pairs. In the sequential condition, each response item except the last was contiguous both to its stimulus and to the succeeding stimulus; whereas in the simultaneous conditions, the two members of each pair were linked only to each other.

EXPERIMENT III

The previous study investigated some of the time conditions related to the development of associations between a simple figure such as a square or a triangle and a three-letter word. The findings were that a simultaneous presentation resulted in the development of stronger associations than did the sequential presentation (figure followed by word). Since the figures could be presented either as two dimensional shapes or as words (square, triangle, etc.), a comparison could be made between the strength of the association developed through a given number of trials when the association was to be figure-word and when the association to be developed was that of word-word. The data were consistent with the position that cross-channel associations were as easily developed as were within-channel associations.

While the study dealt with materials which were highly meaningful to the subject, there is some interest in determining whether similar results would have been achieved if the task had involved the association of highly meaningful words to shapes which were only semi-meaningful. This is the problem of the present study. The task was similar to the task of learning names as it is commonly undertaken. In addition, in the present study, three time relationships conditions were included; namely, sequential object-word, sequential word-object, and the simultaneous presentation of both word and object. Two orders of measuring the associations developed were also included.

In paired-associate learning the custom has been to refer to the first word of each pair as the stimulus item and the second word as the response item. Such nomenclature is convenient when the task is clearly that of learning to give thesecond word (response) when the first (stimulus) is presented. In the present study, either one of the two stimuli may appear first or they may appear simultaneously during the acquisition trials. For this reason the two items in each pair will be referred to as the word item and the object item. These two items may be presented either sequentially or simultaneously.

Studies of paired-associate learning have not been concerned with time relationship which is a central variable in the present study. While some interest has been shown in paired-associate learning involving more than one modality, the emphasis has been either on the problem of cross-modality transfer, research which has been thoroughly reviewed by Asher (1964), or the emphasis has been on the problem of the extent to which learning can be facilitated by cross-modality redundancy. Studies related to the latter problem have been reviewed by Van Mondfrans and Travers (1964).

Method

Subjects.--The subjects were 72 University of Utah summer students from lower division educational psychology courses, who represented considerable heterogeneity with respect to age.

Design.--The plan of the study included a 3 x 2 x 2 design involving three time arrangements (sequential,object-word, sequential word-object, and simultaneous word and object), two transmission modalities for the word items (visual and auditory), and two methods of testing (given the word find the object, and given the object find the word). The general design of the study is shown in the first two columns of Table 4.15.

Materials and Apparatus.--A list of 12 word-object dyads was prepared. The dyad words were selected from the Thorndike-Lorge (1944) list and included words occurring with a frequency of once in one to four million times. The 12 words were all nouns of five and six letters and were selected for their dissimilarity and pronunciability. The 12 objects were selected from a list of semi-meaningful shapes developed by Chan (1964). The materials are shown in Figure 4.06.

TABLE 4.15

SUMMARY STATISTICS FOR CORRECT RESPONSES ON TOTAL TRIALS AND ON TRIAL 1.

Time Relationship and Transmission Mode	Test Order	N	Total trials M	Total trials SD	Trial 1 M	Trial 1 SD
Sequential Word-Object						
Aud Word, Vis Object	Word-Object	6	23.17	3.49	4.17	2.48
Vis Word, Vis Object	Word-Object	6	26.00	10.71	6.17	3.82
Aud Word, Vis Object	Object-Word	6	19.83	4.54	4.00	1.41
Vis Word, Vis Object	Object-Word	6	15.33	8.52	3.33	2.50
	Total	24	21.08	7.75	4.42	2.73
Sequential Object-Word						
Vis Object, Aud Word	Word-Object	6	13.83	8.18	2.67	1.86
Vis Object, Vis Word	Word-Object	6	20.17	6.52	3.33	1.97
Vis Object, Aud Word	Object-Word	6	17.67	4.63	2.33	1.82
Vis Object, Vis Word	Object-Word	6	14.83	3.49	2.17	1.33
	Total	24	16.62	5.78	2.62	1.53
Simultaneous						
Aud Word, Vis Object	Word-Object	6	23.83	3.06	4.17	1.17
Vis Word, Vis Object	Word-Object	6	17.67	4.59	3.50	1.64
Aud Word, Vis Object	Object-Word	6	23.83	5.53	4.83	2.32
Vis Word, Vis Object	Object-Word	6	26.17	5.31	6.17	2.03
	Total	24	22.62	5.46	4.67	2.03

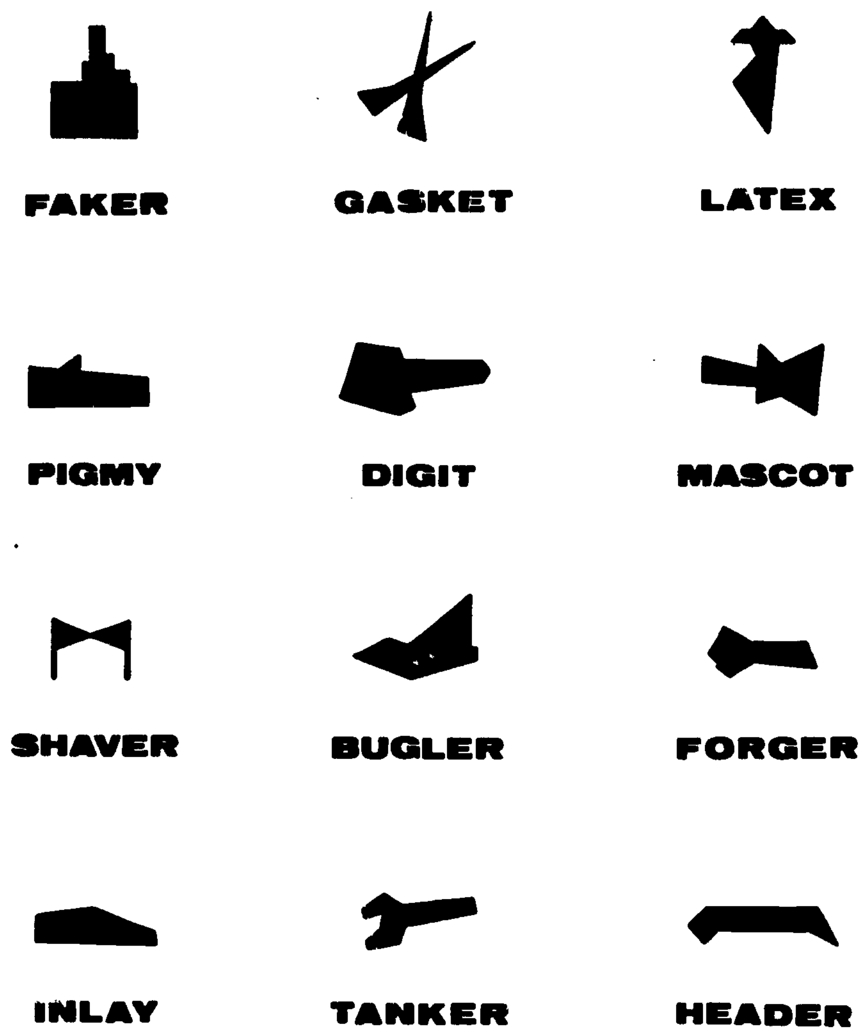

Figure 4.06. Dyads consisting of semi-meaningful objects and words.

A single-unit equipment system consisting of tape recorder and slide projector (LaBelle Maestro II), housed in a sound-proof room, was used to present the stimulus and response items. Stimulus and response items were flashed on a 4-ft. square standard bead projection screen placed about 10 feet in front of the subject. The projected images of the objects were on the average six inches in height and 12 inches in length. All objects were of comparable size. The projected images of of the words were 2-5 inches in height and 13 to 17.5 inches in length. Negative microfilm slides were prepared for the visual presentation of the words and objects. The speaker for the auditory presentation of the response words was located just below the projection screen, and the auditory transmission was amply loud and clear.

Acquisition and Test Trials.--On each of the three acquisition trials the list of 12 objects was presented visually, one at a time, and the 12-word associates were presented either auditorily or visually. With the simultaneous visual presentation of object and word, the word was presented below the object In order to understand the timing of the dyad items, it is necessary to understand that the auditory presentations were synchronized with the performance of a slide projector which presented slides in sequence. Each slide was presented for one second and was followed by a period of 0.4 seconds with no presentation on the screen during which time the slide was changed. All presentations of a set of stimuli involved the time occupied by three slides, 3 seconds, plus the time involved to change three slides, 1.2 seconds (3 x 0.4). In a simultaneous presentation, both the word and the object were presented during the second occupied by the first slide and two blank slides followed. For the sequential presentation, the word or object was presented either on, or at the same time as, the first slide and then the second word or object was presented either on, or at the same time as the second slide, and a blank slide followed. In each case the total time for the presentation of the pair of items plus the blank slide or slides plus the changing time was 4.2 seconds.

Although actual exposure time for each sequentially presented pair was longer (two seconds) than for the simultaneously presented pair (one second), evidence has been provided by other investigators (Bugelski, 1962; Bugelski & Rickwood, 1963; Murdock, 1960) which demonstrates that these exposure-time differences have little consequence on learning so long as total trial time is held constant among conditions. Total trial time under each condition was approximately 50.4 seconds.

The measurement of learning in a paired-associate study involving pairs of words is a simple matter. However, when one item of a pair is an object, rather than a word, the measurement problem is much more difficult. It would not be feasible to present a word and to ask the subject to reproduce the object although the presentation of the object and the requirement of the subject to reproduce the associated word presents no difficulties. This study was concerned with both forms of reproduction and, hence, a measure of learning had to be developed which would be administered either way. What was done was to develop two matched testing tasks. In one of these the objects occurring in the acquisition trials appeared in a column on the left side of the test form in random order and the words were given in a column on the right. The task for the subject was to consider each object and to match it with the appropriate word in the right column. The second test condition reversed the presentation so that the words appeared in the left column and the objects in the right column, and the subject was directed to consider each word and to find the object with which it had been paired.

Procedure. --The subjects were run in small groups of two to four individuals. They were given brief typed summaries of the experimental procedure, and were then asked to pay careful attention to the projection screen. Immediately following each of the three trials, the subject was tested for amount of learning. The total procedure took from 10 to 15 minutes.

Results

Table 4.15 reports the total number of response items correctly matched with the stimulus items for all five trials. Table 4.16 gives the results of the analysis of variance for the effects of time relationship, test order, and transmission mode. Only one main effect, time relationship, was found to be significant ($p < .01$). Further analysis of this effect with a Duncan Multiple Range Test (Table 4.17) showed that the simultaneous presentation was more effective than only one of the sequential orders, object-word ($p < .01$). The sequential object-word arrangement was also significantly less effective than the sequential word-object condition ($p < .01$). Learning under the simultaneous and the sequential word-object arrangements was equivalent, and no significance was achieved.

The interaction between time relationship and test order was also shown to be significant ($p < .01$). Closer inspection of this effect suggested, however, that no clear-cut interpretation could be assigned to it. When a t test was used to compare the efficiency of learning between similar and opposite presentation and test orders, the comparison of word-object and object-word presentation orders with word-object and object-word test orders yielded a non-significant t of 1.519.

In another analysis, the data from Trial 1 were also subjected to an analysis of variance. This analysis was prepared since there are many

TABLE 4.16

ANALYSES OF VARIANCE FOR NUMBER OF CORRECT RESPONSES ON TOTAL TRIALS AND ON TRIAL 1

Source	df	Total Trials' MS	Total Trials' F	Trial 1 MS	Trial 1 F
Time Relationship (T) (Sequential Word-Object & Object-Word, Simultaneous)	2	185.08	5.12**	30.26	6.83**
Transmission Modality (M) (Visual, Auditory)	1	8.00	<1.00	3.23	<1.00
Test Order (O)	1	12.50	<1.00	1.68	<1.00
T x M	2	81.14	2.24	1.00	<1.00
T x O	2	212.47	5.88**	16.43	3.71*
M x O	1	18.00	<1.00	2.80	<1.00
T x M x O	2	74.70	2.07	8.30	1.87
Residual	60	36.14		4.43	

*p<.05, **p<.01.

TABLE 4.17

DUNCAN MULTIPLE RANGE TEST SUMMARY TABLE OF SIGNIFICANCE BETWEEN THE RELATIVE EFFICIENCIES OF TIME RELATIONSHIP CONDITIONS[a,b]

	Sequential: Object-Word	Sequential: Word-Object	Simultaneous: Word Object
Object-Word	----	.01	.01
Word-Object		----	n.s.
Word Object			----

[a]The table is the same both for total trials and Trial 1. [b]Time conditions arranged from least (left and top) to most (right and bottom) effective.

learning situations in which learning is expected from a single presentation of two stimuli. Here again, the time relationship effect was significant ($p < .01$). A breakdown of this effect using a Duncan Multiple Range Test (Table 4.17) indicated that both the simultaneous and the sequential word-object arrangements produced significantly more learning than sequential object-word ($p < .01$), but were approximately equivalent to each other in effectiveness. The t test comparing congruent presentation and test orders was not significant ($t = 0.281$).

In general, correct responses over three trials as well as on the first trial led to virtually identical results. At no time did the effect of transmission modality (of word items) approach significance.

Discussion

In the previous study the observation was made that the simultaneous presentation of an object-word pair was more effective than the sequential presentation. When a second sequential order was added to the present study, that of word-object, it was not known what the final outcome of the comparisons of the simultaneous and sequential arrangements might be; however, there was no apparent reason to suspect that the simultaneous arrangement would not be more effective than sequential word-object.

A possible explanation for the observed effectiveness of the word-object sequential arrangement is found in the relative meaningfulness of the object and word items. In looking at the object-word sequential condition first, it will be recalled that the object was presented visually as stimulus for a 1-sec. duration, was followed by a 1-sec. presentation of the word as response, which in turn was followed by a 1-sec. rest period. This sequence required that the first-presented object had to be held in storage while the second-presented word was being transmitted visually or auditorily. Hence the task may be made more difficult when the semi-meaningful object comprises the information to be stored. It would seem, then, that the observed difference between the relative efficiencies of the word-object and object-word sequential arrangements and the simultaneous arrangement might in large part be a function of the relative meaningfulness of the item that is presented first.

It was predicted that the visual mode of presentation of the word item would lead to significantly greater learning than the auditory presentation. This prediction did not hold up, and the effects of the two transmission modes were equivalent. The inconsistency of these results with the findings of Van Mondfrans and Travers (1964) might be accounted for by differences in the two studies. In the present study only the transmission mode of the word items was varied, whereas in the previous study both the word and object items were varied with respect to modality. Furthermore, the present study contained a time relationship arrangement (sequential word-object) not included in the earlier experiment.

Despite these differences between the two studies, the modality data of the present experiment bear a resemblance to earlier research summarized by Day and Beach (1950). Day and Beach concluded that with increasing complexity of stimulus materials, the visual mode becomes a more efficient source of transmission, whereas with increasing simplicity and familiarity of the stimulus materials, the auditory mode becomes more effective. In the present study, the interaction effect between time relationship and transmission modality was only somewhat less than an acceptable level of significance. A closer inspection of the time relationship-transmission mode data suggests a resemblance of the present data to the observations of Day and Beach.

It is of interest that in the conditions where learning was facilitated most (simultaneous word and object), the means for the auditory mode were higher than for the visual mode. However, in the conditions where learning was facilitated least (object-word), the visual mode produced higher means than did the auditory mode. In other words, as task complexity increased the visual mode tended to facilitate learning more than did the auditory mode. Conversely, the auditory mode tended to facilitate learning when task complexity was least. It should be observed that although these are at best trends, nevertheless the consistency of these results with the conclusions of Day and Beach is noteworthy.

The expectation was that congruence between presentation and test orders would lead to more efficient learning than would non-congruence between these two order effects. In the sequential conditions *t* tests were used to compare the combined congruent conditions (i.e., word-object with word-object and object-word with object-word) with the combined non-congruent conditions (i.e., word-object with object-word and object-word with word-object), and the *t* for neither response measure was found to be significant. No ready explanation is available for the failure of the congruence hypothesis to hold up under test, although a closer look at the means for these four conditions suggests that the trend of the data points in the direction of the hypothesis when learning is most facilitated (word-object conditions), but is reversed when learning is least facilitated (object-word conditions). In other words, when both presentation and test orders were most facilitative (word-object order) learning was most efficient, and when both orders were least facilitative (object-word order), learning was least efficient.

Another point to make is that the test order factor implies that the task will be undertaken by the subject according to instruction. That is to say, the subject responds first to the stimulus in the left column of the test form and then finds the matching response on the right of the page. This order of examining the stimuli from left to right is the customary order in our culture for handling paper-and-pencil materials. However, some subjects may have used the reverse order and have examined the materials from right to left. Such a switch would have limited the value of the data for testing the congruence hypothesis.

EXPERIMENT IV

The purpose of the present study is to explore further some of the variables related to the acquisition of word-object associations.

In the previous study, it was found that when a semi-meaningful object was paired with a common 5-6 letter word, the sequential arrangement of word followed by object facilitated learning more than the sequential arrangement of object followed by word. Since the word item was always more meaningful than the object item, there was some question as to whether the greater effectiveness of the word-object arrangement occurred as a result of the word-first order of the dyad items or as a result of the presentation of the more meaningful word on the stimulus side of the dyad.

In the present study stimulus and response meaningfulness and presentation order were manipulated as separate experimental factors. The word-object and object-word orders were included, and high-low and low-high stimulus and response meaningfulness arrangements were also included. On the basis of the results derived from the previous study, it was expected that the word-object presentation order would be more facilitative of learning than the object-word order, and that the high-low meaningfulness arrangement would be more effective than the low-high arrangement.

Method

Subjects.--The subjects were 30 undergraduates drawn from introductory educational psychology courses and represented considerable homogeneity with respect to age and ability.

Design.--The experiment involved a 2 x 2 factorial design in which 15 subjects were nested within each of the two stimulus and response meaningfulness conditions (high-low and low-high). For each subject, two measures were obtained on the presentation order factor, i.e., on the word-object and object-word orders. Table 4.18 gives the basic experimental design which provided data for two separate analyses. In the second analysis, the presentation-order effect was again extracted, but the meaningfulness factor was not included.

Materials and Apparatus.--Ten word-object dyads were constructed. Five dyads each contained a high meaningful word taken from the Thorndike-Lorge (1944) word list. These five words were nouns of a consonant-vowel-consonant (CVC) trigram arrangement. Each contained a different vowel, and no consonant was used more than once. The remaining five dyads each contained a low meaningful CVC trigram taken from the Glaze (1928) and Krueger (1934) lists. The low meaningful trigrams averaged 26.80 per cent in meaningfulness value on the Glaze list and 62.60 per cent on the Kruger list. The same 15 letters appearing in the high meaningful words were included in the low meaningful items. No pair of letters occurring in the first (and last) position of the high meaningful words were placed in the last (and first) position of the high meaningful words. All ten items, shown in Figure 4.07, were selected for their pronunciability and dissimilarity.

The object items were constructed after the same method as were the word items. Each object consisted of three basic geometrical shapes. A total of 15 different shapes was used in making up the five object items. The low meaningful objects involved the same 15 shapes as the high meaningful objects. No two shapes appearing in a high meaningful object were again paired in a low meaningful object. Also,, the positioning of the shapes was arranged so that a shape appearing in a top position of a meaningful object was placed in a bottom position of the low meaningful object. The five meaningful objects were designed after a bird, man, candle, Christmas tree, and question mark. The low meaningful objects were judged to be quite unrepresentative of any meaningful material with which subjects were likely to have had much past experience.

The words and objects were paired so that a high meaningful word occurred with a low meaningful object (Set 1), and a low meaningful word occurred with a high meaningful object (Set 2). With this arrangement, both sets of dyads could be presented either in the word-object or object-word presentation orders as well as in the high-low and low-high meaningfulness orders. The two sets of dyads are shown in Figure 4.07.

High-contrast negative film slides were prepared for visual presentation of the dyads. Each word or object was centered on the film slides. The projected images of the word items were approximately two inches in height and eight inches in length, and of the object items, 8-15 inches in height and 3-8 inches in width.

A single-unit electronic system consisting of tape recorder and slide projector, housed in a sound-proof room, was used to present the stimulus materials. A 4-ft. square standard bead projection screen was located 10 feet in front of the subject.

Learning and Test Trials. --On the learning trials, the stimulus item (word or object) of the dyad was projected on the screen for one second. There followed a 0.4-sec. period for slide change. Following the presentation of each dyad, a blank slide was projected for one second, then another

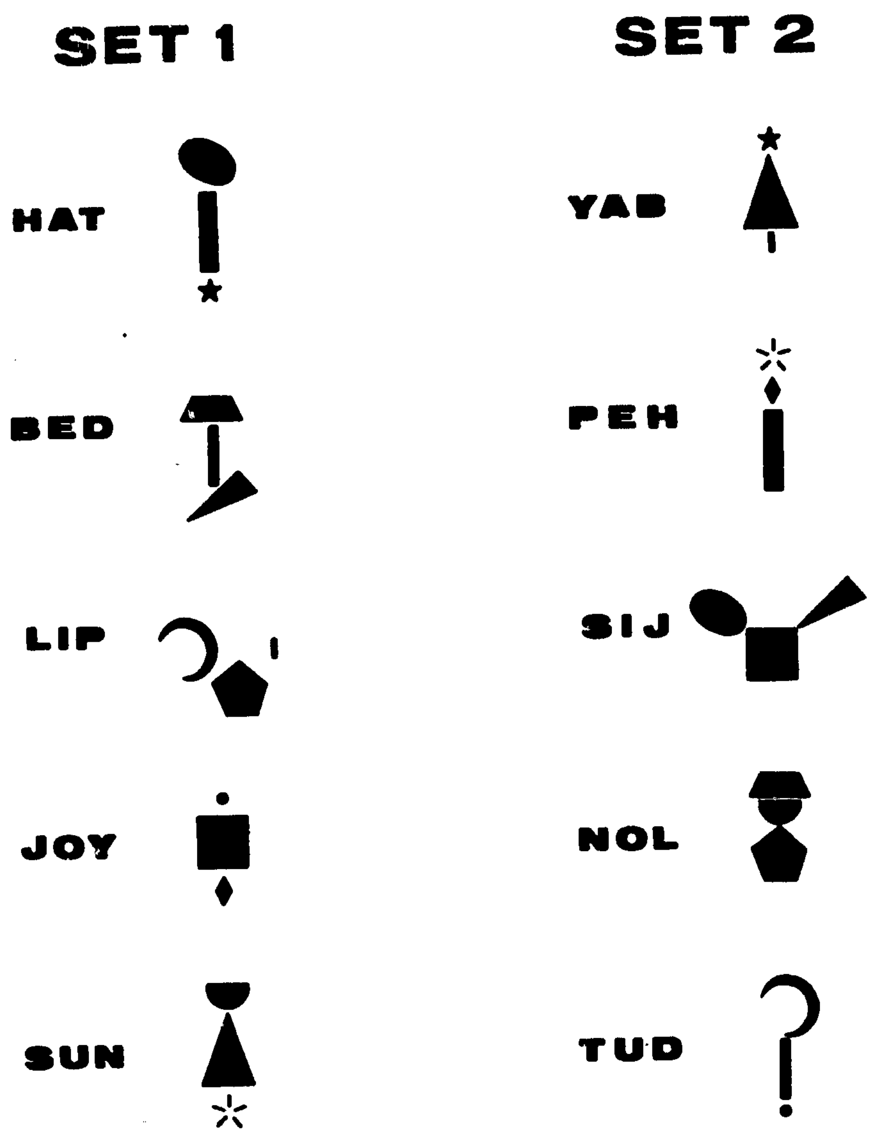

Figure 4.07. Dyads consisting of words and meaningless shapes on the left and nonsense syllables and meaningful shapes on the right.

0.4 seconds was consumed in the slide-change operation. The total time taken in the presentation sequence for each dyad was 4.2 seconds.

Learning was measured through the use of a multiple-choice test. On the test trial, the subject was presented with each of the five words and the five objects which served as stimulus members on the learning trials. The stimulus item of each pair, word or object, was presented for one second. The next slide, projected for a 5-sec. period, contained the response item with which the word or object had been paired together with three distractor items. Thus, each multiple-choice slide included the correct response member and three distractor items which were also response members occurring in the dyad list and which were of the same level of meaningfulness as the correct response item. A blank slide was then projected for five seconds, during which time the subject indicated his choice of answers on an IBM answer sheet. The multiple-choice method of measurement was used to avoid the difficulties which would be involved in scoring if the subject had had to draw the objects. Counterbalancing was achieved with respect to the positioning of the correct response item and with respect to the number of times each word or object was used as a distractor on the multiple-choice slides. This method of testing was used for both the word-object and the object-word orders of presentation.

The interval between each learning trial and test trial was 10 seconds, and between each test trial and learning trial, 20 seconds. Each learning trial required 42 seconds, and each test trial, 122 seconds.

The list of ten paired associates was presented three times, but in a different order on each acquisition trial. The same three orders were repeated for all subjects. The order was also different on each test trial, and the three test orders were repeated for all subjects. The entire procedure occupied about 15 minutes. The subjects were run in small groups of two to four individuals, and were randomly assigned to the various conditions of the experiment.

Results

The dependent measure was the number of correct responses on all three trials. Table 4.18 reports the summary statistics for this measure and the designs for two analyses of variance run on these data. Table 4.19 gives the results of the analysis of variance for the effects of presentation order and meaningfulness. Although the meaningfulness main effect did not achieve significance, the effect of presentation order was found to be significant at the .025 level. Consistent with predictions, the word-first order produced greater learning than the object-first order.

TABLE 4.18

SUMMARY STATISTICS AND DESIGNS FOR ANALYSES 1 AND 2*

		Analysis 1			Analysis 2	
		Meaningfulness Arrangement			Sets of Dyads	
Presentation Order		High Stimulus Low Response	Low Stimulus High Response	Total	High Word Low Object	High Object Low Word
Word-Object	M	11.60	10.33	10.96	11.60	10.33
	SD	2.44	2.87	2.70	2.44	2.87
	N=15					
Object-Word	M	9.20	10.00	9.60	10.00	9.20
	SD	1.82	3.38	2.70	3.38	1.82
	N=15					
Total	M	10.40	10.16	10.28	10,80	9.76
	SD	3.75	5.34	4.54	3.01	2.45
	N=15					

*Data for correct responses on all trials.

TABLE 4.19

ANALYSIS 1 INCLUDING PRESENTATION ORDER AND MEANINGFULNESS ARRANGEMENT

Source	df	MS	F	p
Between Subjects	29			
Meaningfulness (High-Low, Low-High)	1	.81	<1.00	
Subjects/Meaningfulness	28	297.87		
Within Subjects	30			
Presentation Order (Word-Object, Object-Word)	1	28.01	7.29	.025
Order x Meaningfulness	1	16.03	4.17	.06
Subjects/Order x Meaningfulness	28	107.46		
Total	59			

The interaction between meaningfulness arrangements and presentation orders also approached significance ($p < .06$). A Duncan Multiple Range Test was used to compare all four means of Analysis 1, but only one comparison was found to be significant; namely, that between the word-high object-low and object-high word-low means. Much of the variance among the four means was contributed by the one group of subjects (nested within the high-low meaningfulness condition) who learned the dyad set containing the high meaningful words with greater facility than the dyad set containing the high meaningful objects.

To control for the possibility that the significance achieved by the presentation order main effect was due to the unequal effectiveness of the dyad sets, a second analysis of variance was run in which variance due to the dyad sets was extracted as a main effect.

Presentation order was again included as a main effect in Analysis 2, and high and low meaningfulness conditions were counterbalanced within the statistical design. The results of Analysis 2, reported in Table 4.20, again indicated that the word-first order was more effective than the object-first order ($p < .05$).

TABLE 4.20

ANALYSIS 2 INCLUDING PRESENTATION ORDER AND DYAD SETS

Source	df	MS	F	p
Between Subjects	29			
Order x Dyad Sets	1	.83	< 1.00	
Subjects/Order	28	270.67		
Within Subjects	30			
Presentation Order	1	28.01	5.82	.05
Dyad Sets	1	16.01	3.33	
Subjects/Order x Dyads Sets	28	134.66		
Total	59			

Discussion

An interesting finding in the present study was that, although the word-first presentation order was more facilitative of learning than the object-first order, the extent of this difference was derived mainly from the condition in which stimulus items were high in meaningfulness and the response items were low. In this case, the word-first order was represented by the dyad set (word-high object-low) which may have been more facilitative of learning than the dyad set containing a high-meaningful object and a low-meaningful word. However, Analysis 2 showed that the greater effectiveness of the word-high object-low condition (in the comparison with object-high word-low) was not due entirely to the greater facilitative effects of this dyad set since the overall word-first order was again found to be more effective than the object-first order.

The greater effectiveness of the word-high object-low condition may have been due also to the occurrence in this condition of a high meaningful stimulus. Such a possibility gains credence when it is noted in Table 4.18 that the mean for the word-object order containing a high meaningful stimulus (M=11.60) was larger than the mean for the word-object order containing a high meaningful response (M=10.33). A similar effect in the data did not appear between the two object-word conditions, and thus the meaningfulness factor did not appear as a significant effect. In discussing this latter comparison one may speculate that the high meaningful object as stimulus in the object-high word-low condition, having a lower absolute level of meaningfulness than the high meaningful word as response in the object-low word-high condition, produced a lower mean learning score (the means were 9.20 and 10.00, respectively).

Although the results of this study are somewhat ambiguous, one set of implications is clear: that in learning to associate familiar names to relatively unfamiliar figures or objects, learning will be enhanced if the name is introduced first. The latter is correct so long as a sequential presentation is involved.

Another implication of the present study is provocative for a different reason. The possibility that a high meaningful stimulus in paired-associate learning might produce greater learning than a high meaningful response is contrary to the bulk of evidence available in this area of research (cf. Underwood & Schulz, 1960). There is, however, additional evidence which suggests that the occurrence of a high meaningful response item in the associative dyad does not always produce the greatest facilitation of learning (Epstein & Platt, 1964; Epstein & Streib, 1962; Kepros, Bourne, & Battig, 1962; Mueller, 1965).

Further clarification of the role in learning of meaningfulness on the stimulus and response sides of the associative dyad is clearly needed. In addition, further study of the relative effectiveness of the word-first and object-first presentation orders must be made. The problem of the relative equivalence between meaningfulness continua for words and objects is also a crucial one which has not been considered here but which needs to be considered in subsequent studies.

CONCLUSIONS AND IMPLICATIONS OF THE EXPERIMENTS REPORTED IN THE CHAPTER

The experiments reported here represent a series of studies designed to explore some of the conditions related to the learning of associations between words and objects. The tasks involved are essentially the same as those involved in the familiar human task of learning the names of objects, a task which frequently involves the use of audiovisual teaching techniques.

The first study of the series explored the advantages to be achieved in the retention of information about form or shape which accrues by giving a name to the form or shape. The results provide fairly clear evidence that giving a name does not, in itself, facilitate retention of the visual information. However, the evidence also clearly indicates that when the name serves the function of associating some feature or features of the visual presentation with previous knowledge that the procedure does facilitate the retention of information. One suspects that the process involved is essentially that of coding visual information in verbal terms and, by this means, linking it up with other previously-stored information. Thus when a student learns that a particular tumor looks like a cauliflower, he no longer has to learn and store information about the numerous gross features which are characteristic of the tumor. The simple word "cauliflower" already has incorporated in it information pertaining to all these features. Through the simple process of linking the word "cauliflower" with the particular tumor, the person is able to store all the information necessary for recognizing the gross features of the tumor.

In the second experiment, as in the first one, no superiority could be found for the audiovisual method of communicating information in contrast to the use of the visual channel alone. The data also agree with those of other studies in indicating that associations can be formed as readily across sense modalities as within a sense modality. One may reasonably presume that this generalization would not hold in cases in which there were difficulties in transliteration. This second study also revealed a phenomenon which was commonly encountered in subsequent research; namely, that the simultaneous presentation of the two elements involved in a paired-associate provides a more effective condition for learning than does the sequential presentation of the members of a pair. A similar phenomenon was also found in the third study which involved the association of words with semi-meaningful shapes which were in contrast with the highly meaningful shapes used in the first study. The third study also raised a number of problems concerning the relationship of this phenomenon to the relative meaningfulness of the item in the first position (the stimulus position) and the item in the second position (response position) of the pair of elements. The evidence indicated that the simultaneous presentation was more effective than the object-word sequential presentation but that it was not more effective than the word-object sequential presentation. Such evidence suggests that the control of the association process rests largely with the more meaningful member of the dyad which would account for the advantage achieved when the more meaningful member of a dyad was received first. On this basis the sequential presentation of the word-object would be equivalent to the simultaneous presentation of the word and object because, on the simultaneous presentation, the word rather than the object would be processed by the perceptual system first.

The final study in the series carried the work further into the problem of the relationship between learning in the simultaneous and sequential presentations and the relative meaningfulness of the two items in each object-word pair. This study ran into various unanticipated difficulties which made the results equivocal. At the core of these difficulties was the fact that the words tended to have a much higher level of meaningfulness than the objects, Indeed, the nonsense syllables may well have been more meaningful than the meaningful set of objects. This problem, involving the scaling of the meaningfulness level of both objects and words, limited the conclusions which could be drawn from the data. The only clear conclusion that could be drawn was that, where the task involves associating familiar names with relatively unfamiliar figures, learning will be enhanced if the name is presented first.

In summary, the studies reported in this chapter indicate the importance of hooking-up visual information with previously stored information through the use of verbal symbols. In addition, there appears to be a clear-cut advantage in transmitting the elements to be associated either with the more meaningful element first or with both elements simultaneously. The latter finding does not run counter to the single channel concept of information processing which has been embraced here since the evidence suggests that the presentation of two elements of a dyad simultaneously results in the receiver processing the more familiar or more meaningful element first.

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CHAPTER V

AN EXTENSION OF THE STUDIES OF SIMULTANEOUS VS. SEQUENTIAL INFORMATION TRANSMISSIONS TO THE LEARNING OF FOREIGN VOCABULARY*

*The study reported in this chapter was undertaken as a doctoral dissertation by Robert D. Card. The dissertation entitled "Conditions Related to Paired-Associate Learning and Their Implications for Foreign Language Learning," is in the library of the University of Utah.

In the studies reported in the previous chapter, evidence was found that the learning of word associations could be facilitated through the simultaneous presentation of the two elements to be associated. Superior results were achieved with this method of presentation in contrast with the traditional sequential method of presentation. At this point some curiosity was felt concerning the applicability of the finding to the learning of foreign vocabulary. With this in mind, the study reported in this chapter was planned. The study attempts to determine (1) whether the simultaneous presentation of the foreign word and the English equivalent produces more effective learning than when the two words are presented sequentially, (2) if a non-redundant audiovisual presentation is more effective for learning than an audial or visual presentation alone; (3) the extent of cross-channel transfer.

No previous studies could be located in the published literature in which a comparison had been made between the simultaneous and the sequential displaying of words to be associated in the learning of foreign vocabulary. C. R. Carpenter (personal communication) had explored the possiblility of presenting simultaneously sentences in German into one ear and the same sentence in English through the other. In the latter procedure, the order of the words in the English sentences was rearranged so that the corresponding English and German words could be ennunciated simultaneously. However, the results of Carpenter's exploration do not have any degree of applicability to the present research in view of the complexity of the learning situation involved.

Of particular importance in the planning of the present study was the series of researches carried out by Asher (1964) on the transfer of learning across sense modalities in the acquisition of foreign vocabulary. The research of Asher brings clearly into focus the fact that the degree of transfer depends upon phonetic fit, that is to say the extent to which a word can be pronounced correctly from an inspection of the written form of the word and the extent to which a word can be written correctly from the spoken form.

Method

Materials.--The twenty synthetic "foreign" words used in the experiment were derived from dissyllabic groups of letters split in the middle by two consonants; occasionally on the last syllable, the vowel was the last letter of the word.

An initial list was then presented orally to a number of independent judges who were asked to spell the words. The purpose of this procedure was to derive a list with a high degree of phonetic fit. Asher (1964) has shown that phonetic fit is closely related to transfer across modalities. Words which were inconsistently spelled were deleted. The concocted words thus selected were: laston, dastu, ferpad, sumdan, lasgat, gandas, systen, hadru, hebder, permap, hedlet, dampo, tadsen, remtus, debro, tasden, toclas, matpar, sanpat, pergos.

The English words used in the experiment were obtained from the Dale list of 769 Easy Words (Dale, 1931). Words chosen were dissyllabic nouns which usually split between two consonants. Nouns which could be used as titles for the "foreign" words were dropped from the list. For example, the noun "doctor" has very high association value when coupled with any of the "foreign" words. The English words were: people, summer, dinner, finger, garden, flower, corner, basket, market, yellow, window, lesson, letter, winter, matter, office, silver, season, number, butter.

English and "foreign" words were then paired using the following rules as a means of obtaining a low association value between members of a pair: (1) no pair of words could begin with the same letter, (2) no syllable in the word-pair could begin with the same letter, (3) the same two letters could not appear in the same syllabic position in word-pairs, and (4) no word-pairs could contain the same syllable. A number of individuals were then shown the complete list and instructed to indicate word-pairs having high associations for them. When consistent associations were found, the "foreign" words were presented as the stimulus member of the dyad and five different random orders were used on the test trials.

The visual conditions required one film strip for the simultaneous condition and another for the sequential. The words were projected on a screen with letters about 2.5 inches high. In the simultaneous condition, the two words in each pair were photographed together on one frame with the "foreign" member above the English. Between each pair of words was a blank frame. The sequential visual presentation was photographed with the "foreign" member of a pair on the first frame, followed by the English counterpart on the second frame, followed by a blank frame. The tests required five different film strips, one for each of the five random orders of "foreign" words. For an audial testing condition, the projector was left on, but no film strip was inserted in the projector.

The audial recordings were made on one track of a tape. Several recordings were made, and the most satisfactory recording of each was then used to obtain as many identical recordings of each list as was needed for the entire experiment. Each of the two-syllable words occupied just short of six and one-half inches of tape run at 7 1/2 inches per second. The simultaneous auditory condition involved the presentation of the "foreign" word by a male voice and the English word by a female voice, thus using pitch differences to facilitate discrimination of the two words. Both words were superimposed on the same tape track.

In order to control the time, duration and synchronization of presentation of audial and visual materials, signals recorded on the second track of the tape were utilized to trigger a relay which controlled the automatic advance on a Victor "soundview" filmstrip projector. This recording on the second track was made from a continuous one thousand cycle alternating signal produced by an Eico Signal Generator. One-inch sections of this continuous tape were then cut off as needed and spliced into the experimental tape to advance automatically the film strip.

Design.--Twelve experimental conditions were involved in the study. The dyads were presented under 3 conditions, (1) both visually, (2) both auditorially, or (3) with the foreign word presented visually and the English word auditorially. The reverse audiovisual condition was not used. For each one of these modality conditions of presentation, half the subjects were exposed to both members of the dyad simultaneously and half were exposed to them sequentially, one item following the other. Thus the combination of sensory modality and time relationship, simultaneous or sequential, produced six conditions. In addition, under each of these six conditions, half the subjects were tested with the stimuli presented visually and half were tested audially after each learning trial. Thus the two testing conditions increased the number of experimental conditions to twelve. These conditions are presented in Table 5.01 together with the numbers by which they are designated.

In a sequential condition, the foreign word was presented during a one-second interval followed by its English equivalent during the next one-second interval, and then followed by a space of one second before the next presentation. In a simultaneous presentation, both the foreign and English words were presented during a one-second interval followed by a two-second interval. Thus in each case three seconds was allowed for each dyad. The actual exposure time of a word on a screen was 0.87 sec. Ample evidence exists that exposure time to the word on the screen is unimportant within broad limits, but that the time available for processing the information is critical.

A test was given after each presentation of the 20 word-pairs. The foreign word of the pair was presented as the stimulus word for one second followed by four seconds of silence during which the subjects were to write out their answers.

Subjects.--Seventy women subjects or 58.3 per cent of the sample were obtained from educational psychology classes, while 50 women subjects, or

41.7 per cent were obtained by approaching students in the college of education and asking them to participate.

Women subjects only were used in the experiment since a series of studies by Kale, Grosslight, and McIntyre (1953) involving language learning with simultaneous auditory-visual presentations showed a consistent difference in learning ability in favor of their female subjects. Eliminating male subjects removed a known source of variance.

Physical Arrangement for Learning and Recording Responses. --Subjects seated themselves around a 3' x 6' table placed diagonally in a 7' x 12' counseling room. In one corner of the room projection and sound equipment was assembled on a table with the projector focused on a cardboard screen 30" wide x 20" high placed at the other end of the room. Distance from the projector to the screen was approximately 9 feet and the projected size of a word was approximately 1.5" high by 9.5" wide. The loudspeaker was located under the screen and at the left side of the room. The room was semi-darkened, but there was enough light for the subjects to enter their responses in the booklets provided.

Responses were recorded in a test booklet. The booklets contained ten pages, one page for each testing trial. As each learning test was completed, the page was folded back to prevent previous responses acting as cues for current questions.

Instructions to Subjects. --All subjects were recruited with the understanding that they were to participate in a foreign-language learning experiment. The general nature of the task was explained to them and they understood that, after each learning trial, they would be tested for their ability to produce the correct English word when the foreign word was either shown on the screen or enunciated through the speaker.

Results

Examination of the Learning Curves. --Ten subjects were utilized in each of twelve experimental conditions. The experimental main effects were modality (audiovisual, audial, and visual), time condition (simultaneous versus sequential), test modality (cross-channel versus same channel), and trials. Figures 5.01, 5.02, and 5.03 show learning curves obtained in each of the twelve experimental conditions. These curves show average learning for the ten subjects within each experimental group cumulatively plotted across trials.

Figure 5.01 represents curves for the audiovisual modality. It can be seen that learning in the simultaneous audiovisual with visual test

TABLE 5.01

SUMMARY OF EXPERIMENTAL CONDITIONS

Mode	Audiovisual				Auditory				Visual			
Time Conditions	Simultaneous		Sequential		Simultaneous		Sequential		Simultaneous		Sequential	
Testing	Test Aud.	Test Vis.	Test Aud.	Test Vis.	Test Aud.	Test Vis.	Test Aud.	Test Vis.	Test Aud.	Test Vis.	Test Aud.	Test Vis.
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII

condition started out as the most rapid condition for learning and that the differences between learning conditions increased over trials. The learning curves are typical of curves obtained with relatively familiar materials. By the tenth trial, almost all subjects had mastered the learning task. Out of a possible of two hundred responses, the ten subjects gave one hundred eighty-nine correct answers on the tenth learning trial. The simultaneous audiovisual condition with the added task of transfer to the audial modality in testing was consistently inferior to the visual or non-transfer condition. The transfer task involved recognition and association of the audial stimulus given during testing trials with the visual form of the stimulus presented during the learning trials. Only after this association had been made could the subject then proceed to associate the elements of the dyads presented during the learning trials. Sequential audiovisual learning with testing in the visual modality appears to be consistently superior to the same learning condition measured across sense channels. By the end of the tenth learning trial subjects in the sequential condition still had not reached an assymptote in learning. Figure 5.01 shows that the simultaneous audiovisual presentation appears to be more efficient for this type of learning than sequential presentations.

Figure 5.02 shows learning curves for the audial modality. The simultaneous learning curves appear to be typical for learning of completely new or novel material (Travers, 1963). Initial learning of novel material is very slow, but after the necessary skills have been learned, the typical S-shaped curve is approximated. In the simultaneous audial conditions, learning apparently never passed the initial slow-learning stage in the ten learning trials. Lack of previous experience was probably partially to blame for such slow learning, but signal separation in the simultaneous condition made it difficult to separate and recognize the stimulus and response. The audial receptor is a mechanical analyzer in nature and overlapping frequencies in two sources made source separation difficult. The added task of cross-channel transfer to the visual testing modality further reduced retention scores.

Sequential audial conditions (Fig. 5.02) were highly superior to the simultaneous audial conditions. In fact, sequential audial learning appears to be at least comparable to any but the simultaneous audiovisual with visual test condition. Sequential audial learning is a fairly familiar type of task, and there is no problem in signal separation. Cross-channel transfer to the visual testing condition, as might be expected, resulted in a small decrement in learning scores.

Learning curves for the visual modality are shown in Figure 5.03. Learning was very rapid and approximately equal for both simultaneous conditions. By the tenth learning trial subjects were approaching an

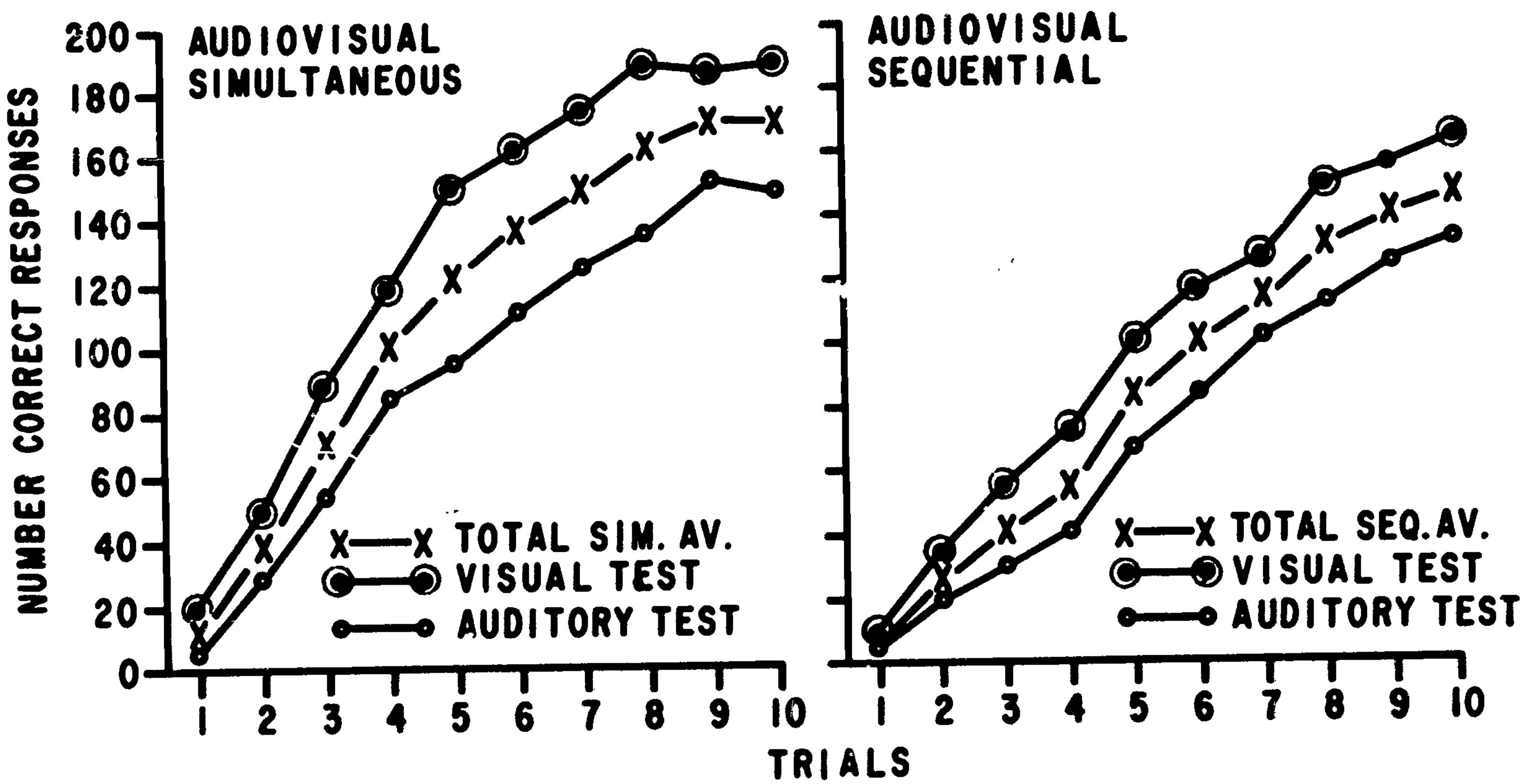

Figure 5. 01. Simultaneous and sequential learning curves for the audiovisual modality (N-10 for each curve).

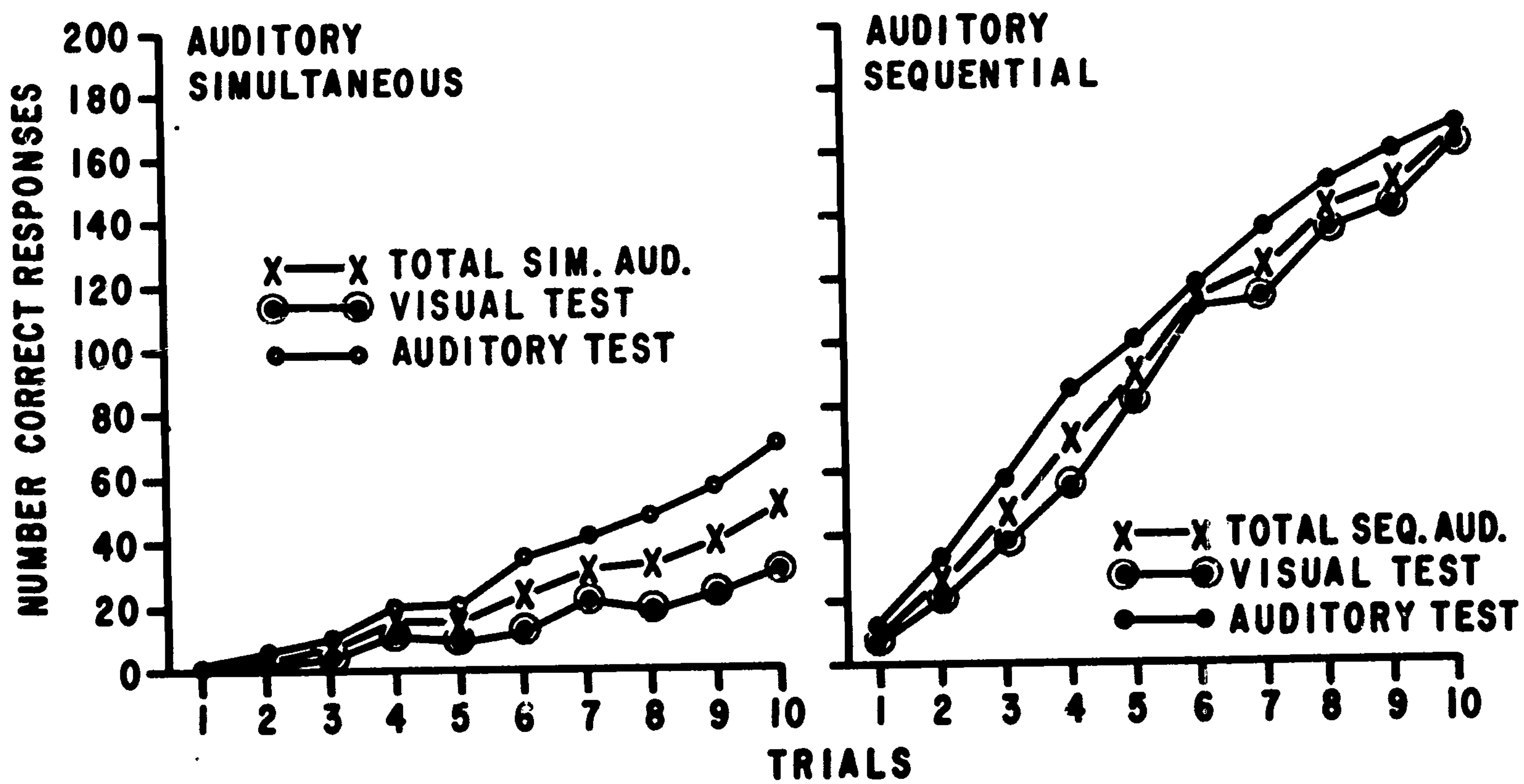

Figure 5.02. Simultaneous and sequential learning curves for the auditory modality (N=10 for each curve).

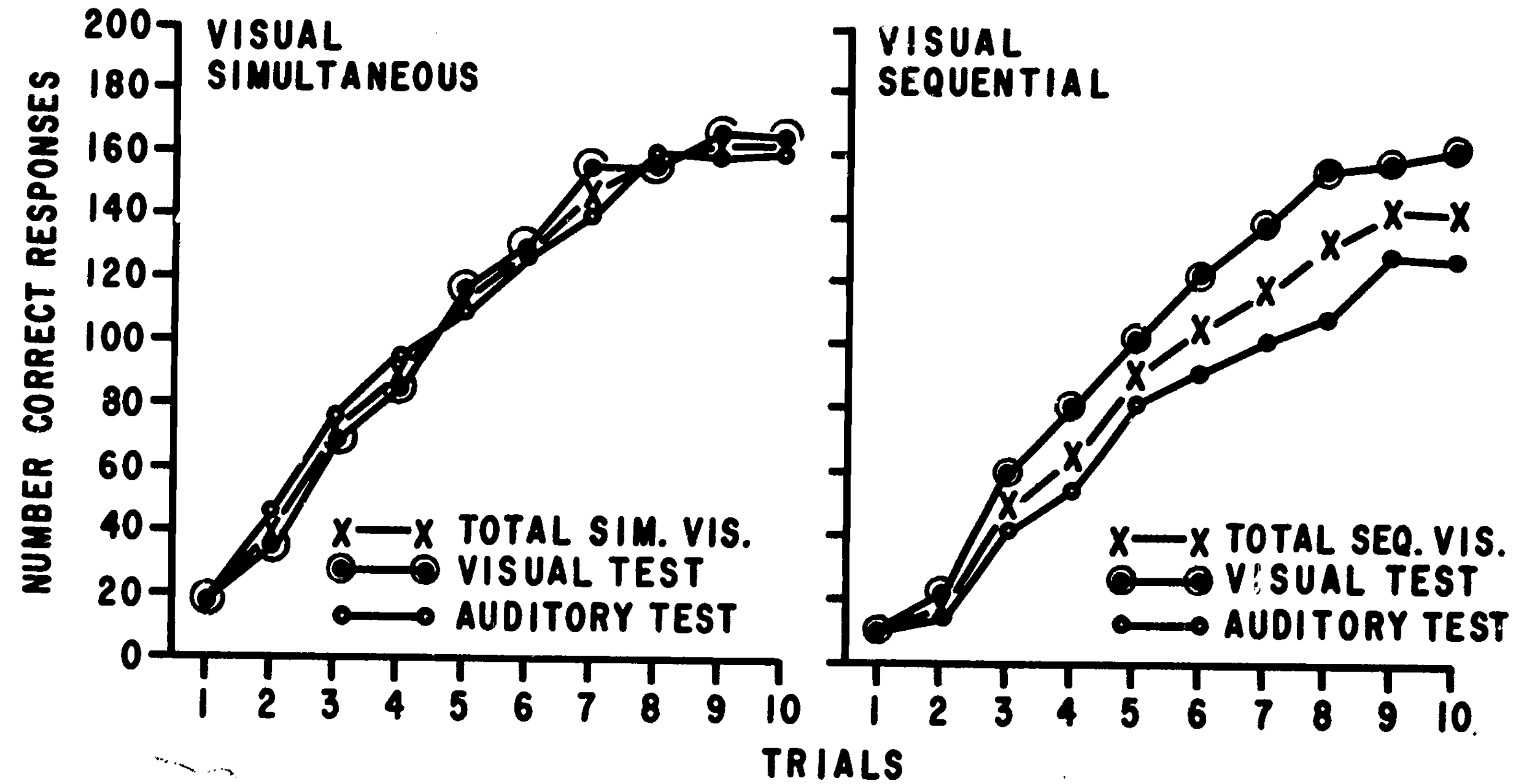

Figure 5.03. Simultaneous and sequential learning curves for the visual modality (N=10 for each curve).

assymptote in learning. For some reason, cross channel transfer appears to pose no problem in the simultaneous visual modality. In the sequential visual time condition, learning which did not involve cross-channel transfer was rapid and efficient, while the cross-channel transfer resulted in the expected decrement in scores. It is evident that simultaneous learning is more rapid and complete than sequential learning in the visual modality.

A comparison of the learning curves for all three modality conditions indicated a much more rapid and complete learning of the word-pairs in the simultaneous audiovisual with visual test condition than in any other experimental condition. Rate of learning and cumulative learning scores were approximately equal for both of the simultaneous visual presentations, the sequential visual-test-visual-presentation, and the sequential auditory-test-auditory-presentation. The simultaneous audial presentations were clearly inferior to all other methods of learning verbal materials of this type. A comparison of audiovisual and visual presentations shows that the simultaneous conditions appear in each of these two cases to be superior to the sequential conditions.

Statistical Analysis. --The number of correct responses on the test was used to measure the degree to which subjects learned to associate the response members of the twenty dyads to the stimulus members.

A summary of the statistics underlying the analysis of variance is given in Table 5.02. The means and standard deviations of the number of correct responses by learning trial and experimental condition are given together with grand means and standard deviations for each experimental condition.

It is interesting to note that the most efficient learning condition of all was the simultaneous audiovisual-with-visual test. This was shown to be significantly better ($p < .01$) by a Duncan Multiple Range test than all other conditions. The simultaneous visual-with-visual-test condition ranked second to the simultaneous audiovisual condition, but it was about equal in efficiency to the simultaneous visual-with-auditory test, sequential visual with visual,test, and sequential audial-with-audial-test conditions. It is not clear why a nonredundant simultaneous audiovisual presentation should be superior to a nonredundant simultaneous visual presentation. One can speculate that in simultaneous nonredundant usage of two channels there is somehow a time saving. Perhaps the required simultaneous usage of two channels is such a novel experience and so challenging that vigilance increases, resulting in faster and better learning. These explanations are purely speculative. Further experimentation should be undertaken to verify this finding and the conditions under which such efficient cross-channel transfer might take place.

TABLE 5.02

SUMMARY STATISTICS - MEANS AND STANDARD DEVIATIONS OF NUMBER OF CORRECT RESPONSES BY TRIAL AND EXPERIMENTAL CONDITION (N = 10 PER CONDITION)

Experimental Conditions		Trials 1	2	3	4	5	6	7	8	9	10	Grand Mean and S. D.
AV Sim.	M	.60	2.90	5.70	8.40	9.50	11.20	12.50	13.50	15.20	14.80	9.43
Test Aud.	SD	.52	1.59	2.71	5.04	4.69	5.79	5.74	5.54	4.64	4.83	6.37
AV Sim.	M	2.00	5.00	8.90	11.90	15.00	16.20	17.30	18.80	18.70	18.90	13.27
Test Vis.	SD	1.41	3.71	3.81	3.78	3.13	2.49	2.45	1.62	2.06	1.28	6.35
AV Seq.	M	.60	2.0	2.90	4.10	6.80	8.50	10.30	11.60	12.50	13.10	7.24
Test Aud.	SD	.96	1.73	1.85	3.03	3.42	3.75	4.29	4.78	5.60	5.86	5.72
Aud. Seq.	M	.80	3.40	5.60	7.30	10.20	11.70	12.60	14.90	15.60	16.30	9.84
Test Vis.	SD	.92	2.27	3.75	3.59	4.78	5.48	5.52	4.43	4.65	5.31	9.63
Aud. Sim.	M	.10	.50	.90	1.90	2.00	3.40	4.20	4.80	5.70	7.10	3.06
Test Aud.	SD	.32	.71	1.09	1.79	2.36	2.95	3.05	4.08	3.56	4.33	3.45
Aud. Sim.	M	.10	.10	.40	1.20	.90	1.30	2.20	1.90	2.30	3.0	1.34
Test Vis.	SD	.316	.316	.632	.787	.737	1.25	1.03	1.59	1.77	1.94	1.46
Aud. Seq.	M	1.20	3.20	5.70	8.40	9.90	11.70	13.40	15.00	15.90	16.60	10.10
Test Aud.	SD	1.03	2.15	2.11	2.83	3.95	4.24	4.30	4.03	3.87	3.22	6.09

TABLE 5.02 (CONT'D.)

Experimental Conditions		1	2	3	4	5	Trials 6	7	8	9	10	Grand Mean and S. D.
Aud. Seq.	M	.50	2.00	3.80	5.40	8.10	11.00	11.60	13.50	14.20	16.30	8.64
Test Vis.	SD	..707	1.56	2.39	3.27	3.03	3.56	3.71	3.86	1.51	2.86	5.95
Vis. Sim.	M	1.80	4.40	7.70	9.70	11.50	12.90	13.90	15.90	15.90	16.10	10.98
Test Aud.	SD	1.81	2.87	4.14	4.42	4.99	4.99	4.65	3.95	3.69	3.87	6.12
Vis. Sim.	M	1.80	3.50	7.10	8.60	11.70	13.00	15.40	15.60	16.70	16.40	10.98
Test Vis.	SD	1.88	2.51	4.07	3.77	3.89	3.61	4.09	4.45	1.83	4.03	6.24
Vis. Seq.	M	1.00	1.50	4.20	5.40	8.20	9.10	10.10	10.90	12.90	12.80	7.61
Test Aud.	SD	.49	1.18	2.93	3.75	4.29	4.58	4.86	5.38	4.93	6.28	5.80
Vis. Seq.	M	.90	2.30	5.90	8.10	10.20	12.30	12.80	15.60	15.80	16.10	10.10
Test Vis.	SD	.99	1.77	3.72	4.33	5.20	5.19	6.12	5.50	5.45	4.82	6.89

As expected, where the testing condition was in the same modality as the learning presentation, the mean learning per trial was higher than where learning was in one modality and testing in another. For example, in the simultaneous audiovisual presentations, visual testing resulted in a higher average number of correct responses than did audial testing. In this learning condition, the "foreign" member of the word-pair was presented visually in exactly the same manner as the stimulus words on the testing presentations. In the audial testing condition, however, subjects had to first associate the visual form of the "foreign" words, learned during the learning trials, with the sound of the "foreign" words, given as stimuli for the tests, before they could be associated with the English members of the pair. The same problem in reverse holds for audial learning tested in the visual modality.

Means and standard deviations for both simultaneous audial conditions were drastically lower than for any of the other conditions. The task of separating the two words both presented simultaneously and audially was difficult and resulted in very slow learning especially as measured by testing in a different modality from the learning modality.

The analysis of variance procedure involved a 3 x 2 x 2 x 10 design in which repeated measures were obtained on 10 learning trials for all twelve experimental conditions. The analysis of variance is reported in Table 5.03.

Differences between the audiovisual, audial, and visual modalities were found to be highly significant at the .001 level of confidence as shown in Table 5.03. A Duncan Multiple Range Test, summarized in Table 5.04, showed that overall learning in the audiovisual modality was not significantly different from the visual modality. Both of these modalities, however, were significantly better than the audial modality. A comparison of the learning curves of the three modalities shows that almost all of the variance which contributed to the significance of this main effect was produced by the simultaneous audial modality. Although it was possible, by listening carefully, to separate the words spoken simultaneously by the male and female voices, the time limit was too short to separate and also associate the elements of the dyads. Subjects usually left the testing room confused and a little bitter at such an unsettling experience. Typically such subjects required three learning trials before being able to remember a single-word pair. This very slow learning is reflected in the standard deviations for the simultaneous audial conditions in Table 5.02, which sometimes exceeded their means. The significance of the difference obtained between learning modalities is largely a reflection of the perceptual difficulties produced by the simultaneous audial conditions.

TABLE 5.02 (CONT'D.)

Experimental Conditions		Trials 1	2	3	4	5	6	7	8	9	10	Grand Mean and S. D.
Aud. Seq.	M	.50	2.00	3.80	5.40	8.10	11.00	11.60	13.50	14.20	16.30	8.64
Test Vis.	SD	..707	1.56	2.39	3.27	3.03	3.56	3.71	3.86	1.51	2.86	5.95
Vis. Sim.	M	1.80	4.40	7.70	9.70	11.50	12.90	13.90	15.90	15.90	16.10	10.98
Test Aud.	SD	1.81	2.87	4.14	4.42	4.99	4.99	4.65	3.95	3.69	3.87	6.12
Vis. Sim.	M	1.80	3.50	7.10	8.60	11.70	13.00	15.40	15.60	16.70	16.40	10.98
Test Vis.	SD	1.88	2.51	4.07	3.77	3.89	3.61	4.09	4.45	1.83	4.03	6.24
Vis. Seq.	M	1.00	1.50	4.20	5.40	8.20	9.10	10.10	10.90	12.90	12.80	7.61
Test Aud.	SD	1.49	1.18	2.93	3.75	4.29	4.58	4.86	5.38	4.93	6.28	5.80
Vis. Seq.	M	.90	2.30	5.90	8.10	10.20	12.30	12.80	15.60	15.80	16.10	10.10
Test Vis.	SD	.99	1.77	3.72	4.33	5.20	5.19	6.12	5.50	5.45	4.82	6.89

TABLE 5.03

SUMMARY SHEET FOR ANALYSIS OF VARIANCE

Source	df	SS	MS	F	Sig.
Between Subjects	119	22,765.00			
Learning Modality	2	4,584.52	2,292.26	24.37	$p < .001$
Time Condition (Simultaneous, Sequential)	1	166.51	166.51	1.77	n. s.
Test Modality	1	275.52	275.52	2.93	n. s.
Learning Modality x Time Condition	2	6,215.56	3,107.78	33.04	$p < .001$
Learning Modality x Test Modality	2	1,169.13	584.57	6.22	$p < .01$
Time Condition x Test Modality	1	19.00	19.00	.20	n. s.
Learning Modality x Time Condition x Test Modality	2	176.13	88.07	.94	n. s.
Subjects/Group (Error Term)	108	10,158.63	94.06		

TABLE 5.03 (CONT'D.)

Source	df	SS	MS	F	Sig.
Within Subjects	1,080	29,856.10			
Trials	9	22,989.93	2,554.4	588.57	$p < .001$
Trials x Learning Modality	18	873.61	48.53	11.18	$p < .001$
Trials x Time Condition	9	338.24	37.58	8.66	$p < .001$
Trials x Test Modality	9	61.67	6.85	1.58	n. s.
Trials x Learning Modality x Time Condition	18	1,033.68	57.43	13.23	$p < .001$
Trials x Learning Modality x Test Modality	18	72.77	4.04	.93	n. s.
Trials x Time Condition x Test Modality	9	47.39	5.27	1.21	n. s.
Trials x Learning Modality x Time Condition x Test Modality	18	185.14	10.29	2.37	$p < .01$
Trials x Subjects/Group (Error Term)	981	4,253.67	4.34		
Total	1,199	52,621.10			

The finding that audial presentations yielded poor learning with adults was one of the most consistent findings in the literature reviewed. The sequential audial learning conditions, however, did not differ significantly from the audiovisual or visual sequential conditions as shown in Table 5.05. This leads one to believe that the audial modality per se is not inferior to the audiovisual or visual modalities. The problem in the simultaneous audial condition lies in signal separation. If complete signal separation could be achieved, it is probable that simultaneous audial presentations would be in no way inferior to the simultaneous visual or audiovisual presentations, other conditions being similar to those in the present study. However, complete audial signal separation is difficult, perhaps impossible to obtain. It would be interesting to experiment with audial signal separation using band-pass filters, binaural presentations, physical separation of sources or some combination of these and other mechanical and electronic devices. The commercial communications industry has developed a variety of methods of signal separation including crystal filters, T-notch filters, band spread, etc.

No significant difference was found between the simultaneous and sequential time conditions. However, several interactions involving the time condition factor were significant and these suggested more detailed analyses of the data. An examination of the learning curves in Figures 5.01, 5.02, and 5.03 shows that rather large differences in favor of the simultaneous presentations in the audiovisual and visual modalities is balanced by large differences in the opposite direction in the audial modality. The simultaneous audial condition is extremely poor because of the problem of signal discrimination. For this reason, the effect of time conditions appears at a significant level, not as a main effect, but as an interaction effect.

Since the lowered performance under the audial learning condition was largely introduced by the problem of separating the signals in the simultaneous condition, the differences between simultaneous and sequential conditions were examined in just the audiovisual and visual modalities. The difference between the simultaneous and sequential conditions for these two sensory conditions was highly significant beyond the one per cent level of confidence. Excluding the audial modality, one can say with considerable assurance that with undergraduate university students, simultaneously-presented paired-associate learning is superior to sequential paired-associate learning.

No significant difference was found when comparing audial versus visual testing across the three learning modalities. The hypothesis to be tested was that testing in the same sense modality as was involved in learning would yield higher retention scores than cross modality testing.

TABLE 5.04

DUNCAN MULTIPLE RANGE TEST SUMMARY TABLE OF SIGNIFICANCE FOR DIFFERENCES IN TOTAL LEARNING SCORES BY MODALITY

	Modality		
	Audiovisual	Audio	Visual
Audiovisual	-------	.01	n. s.
Audio		--------	.01
Visual			-------

The analysis of variance, however, compared audial versus visual testing without regard to cross-channel or same-channel conditions.

Although the differences between the simultaneous and sequential time conditions were not significant when compared across all three learning modalities, a highly significant interaction ($p < .001$) was found between learning modality and time condition. A Duncan Multiple Range Test (Table 5.05) was computed comparing simultaneous versus sequential time conditions in all three learning modalities. Simultaneous audiovisual and visual presentations were significantly better than all other simultaneous or sequential presentations ($p < .01$), but they were not significantly different from each other. Sequential audiovisual, visual, and audial presentations were significantly better than simultaneous audial ($p < .01$) and significantly poorer than all other conditions ($p < .01$), simultaneous or sequential.

The reason simultaneous presentations under certain conditions are more efficient for learning was not apparent from the study. The most plausible explanation is that time saved in transmitting the information in simultaneous presentations can be used in forming associative bonds and for rehearsing the material. In a sequential presentation, associative bonds cannot be formed until the second member of the dyad is presented. If time for forming associative bonds <u>is</u> the critical factor in speed of paired-associate learning, then simultaneous and sequential conditions might be equated on this basis by changing presentation times.

TABLE 5.05

DUNCAN MULTIPLE RANGE TEST SUMMARY TABLE OF SIGNIFICANCE OF DIFFERENCES IN TIME CONDITIONS

	Audial Simultaneous	Audiovisual Sequential	Visual Sequential	Audial Sequential	Visual Simultaneous	Audiovisual Simultaneous
Audial Simultaneous	----	.01	.01	.01	.01	.01
Audiovisual Sequential		-----	n.s.	n.s.	.01	.01
Visual Sequential			------	n.s.	.01	.01
Audial Sequential				-----	.01	.01
Visual Simultaneous					-----	n.s.
Audiovisual Simultaneous						-----

A simultaneous presentation consisting of a one-second presentation of the paired associates followed by one second before presentation of the next dyad should be equivalent in terms of time for forming associations to a sequential presentation consisting of one second for presentation of the first member of a pair followed by one second for the presentation of the second member and one second before presentation of the first member of the next pair.

An interaction between learning modality and test modality, significant at the .01 level of confidence was produced by the fact that when the test was given in the same modality as the aquisition series then learning was superior to when it was given in a different modality. A similar result has been found in previous research.

The interaction of trials and learning modality, that is to say, differences among learning modalities viewed across learning trials was highly significant ($p < .001$). This means simply that rate of learning varied from one sense modality condition to another.

A high level of significance ($p < .001$) was achieved in the interaction of trials and time conditions in spite of the leveling effects of the audial conditions. Examination of the learning curves for the audiovisual and visual modalities clearly reveals consistent differences in favor of simultaneous learning conditions across trials. Simultaneous learning begins more quickly, is acquired at a more rapid rate, and reaches a higher level by the end of the tenth learning trial than in the sequential learning conditions.

The interaction of trials, learning modality, and time condition was highly significant ($p < .001$). This interaction can be restated by saying that subjects in certain testing modalities under certain time conditions learned significantly more with increasing number of trials. Subjects learned better and faster in the simultaneous conditions using the audiovisual and visual modalities than in the sequential time conditions and the audial conditions. However, in the audial conditions subjects learned considerably faster with sequential than with simultaneous presentations.

Although the fourth order interaction was found to be significant ($p < .01$), no meaningful interpretation could be given to it.

Discussion

Some of the findings of the study have implications for the theory of paired-associate-type learning.

Nonredundant simultaneous audiovisual and visual presentation of dyads having low meaningfulness in the stimulus element and high meaningfulness in the response element is superior to sequential presentation of dyads of the same type. This finding is in agreement with the findings of studies in the previous chapter using only the visual modality, and using a similar meaningfulness and time arrangement of dyads. It seems reasonable to conclude that a simultaneous nonredundant presentation functions as a very rapid sequential presentation. Apparently a shorter time for exposure of materials allows more time for rehearsal of the dyads and for the forming of associations, provided that shortened exposure time does not increase difficulty of materials by making perceptual discrimination of the material a problem, as happened in the simultaneous audial conditions in this study.

The usual method of presenting paired associates is sequentially through a single sensory modality. The present study demonstrated that simultaneous non-redundant usage of two sensory channels is a highly efficient means of presenting paired associates. In fact, the simultaneous audiovisual presentation was found to be superior to all other methods of presenting such materials.

The advantage of the simultaneous presentation probably resides in the fact that the hook-up of the two terms in a paired-associate learning task is unlikely to begin until both terms have been received. The reason for this would be that the particular meaning to be ascribed to the first term, for the purposes of hook-up, cannot be determined until the second term of the pair has arrived.

In most studies which have investigated paired-associate learning in the audial and visual sensory modalities, the audial modality has been found to be very inferior to the visual modality in learning efficiency. In this study also the audiovisual and visual conditions were found to be about equally efficient for learning (when testing condition was disregarded), while the audial modality was greatly inferior to both of these conditions. Sequential presentations in all three conditions, however, were not significantly different from each other. If the audial modality is not inferior in sequential presentations, it is doubtful that the audial modality *per se* is less efficient for learning. It seems reasonable to expect that, given suitable cues for signal separation, simultaneous audial presentations would be equal to the audiovisual or visual presentations.

The findings of the study can be generalized reasonably to other learning situations involving (a) paired-associate-type learning; (b) a high degree of pronunciability of the dyad elements; (c) a rather sophisticated adult population. The following practical suggestions, although discussed in a foreign-language learning context, have implications for learning of technical terminology, vocabulary, and to a lesser degree object-word relationships.

1. Word associations are more quickly and efficiently learned with a simultaneous audiovisual or visual presentation than with sequential presentation of the elements of word-pairs.

2. A simultaneous nonredundant audiovisual presentation appears to be superior to any other method investigated in the present study for learning of dyads.

3. If a high degree of transfer is sought, a simultaneous visual presentation appears to be the most efficient.

4. Rapidly-presented audial presentations should be avoided if the material being presented is hard to understand either because of difficulties in pronunciation or because of frequency overlap.

5. Transfer of verbally-learned material across sense modality almost always results in substantial losses in ability to make suitable responses. Hence, it would appear that whenever possible it is better to teach verbal materials using stimulus materials in the same sensory modality in which the words are later to be recognized.

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CHAPTER VI

THE PROBLEM OF SWITCHING TIME*

*The first study in the series is based on a doctoral dissertation completed in 1964 by I. E. Reid entitled "Sense Modality Switching in Relation to Learning" which is on file in the library of the University of Utah. The second and third studies of the series were developed largely through the work of Adrian Chan. The second study in the series has been published in a paper by Adrian Chan and Robert M. W. Travers entitled "Effect of Sense Modality Switching on Serial Learning," published in Perceptual and Motor Skills, 1965, 20, 1185-1191. The third study is based on an unpublished manuscript which may have reached a publisher by the time this chapter goes to press.

Introduction

The issue involved in this chapter is whether switching reception from one message to another message, or from a message arriving through one sense modality to a message arriving through another sense modality, occupies time which cannot be used for learning. For example, if a task requires the learner to receive information alternately through the eye and the ear, is time lost in switching from one sense to the other and back again which reduces the time available for learning? The determination of the amount of time lost in switching, if time is lost at all, could be an important matter in designing audiovisual materials. While the problem which has been typically studied in the past in relation to this problem is that of the time lost in switching from a message transmitted to one ear to a message transmitted to another, the problem here involves switching from auditory to visual inputs or the reverse.

History of the Problem of Switching Time. -- There has already been considerable data amassed concerning the problem of switching time. Broadbent, for instance, noted in his study reported in 1954 that there was an advantage to spatial separation of sources of sound if call signals were being presented at a slow rate, but that this advantage diminished or vanished when the rate of presentation was fast. In this context, a slow rate is one pair of call signs every two seconds, and a fast rate is one pair every second. His interpretation of this finding is that the spatial separation of the two sources provided the S system, the selective filter, with some means for discriminating the two information channels, and once the channels were discriminated, the subject could switch from one channel to the other. But when the rate of presentation was speeded up to one pair every second, then there was not sufficient time to listen to a call sign on one channel, switch to the other channel, listen to the call sign presented on the other channel, and then switch back in time for the next presentation on the first channel. Since this feat was evidently possible in the 2-second condition, but not in the 1- second condition, he concluded (1958) that a complete cycle including two perceptions and two switches of channel requires between one and two seconds.

Following this finding Broadbent then produced the immediate memory experiment (1954) in which he presented pairs of digits simultaneously, one to each ear. It was his finding in the case when the rate of presentation was one pair each second, that the subjects were not very successful in performing the task of reporting the digits in their order of arrival. However, the subjects were much better in the performance of this task as the rate of presentation was slowed to one pair every one and one-half seconds, and best when the rate of presentation was one pair of digits every two seconds. Broadbent (1956) in a new experiment transmitted different

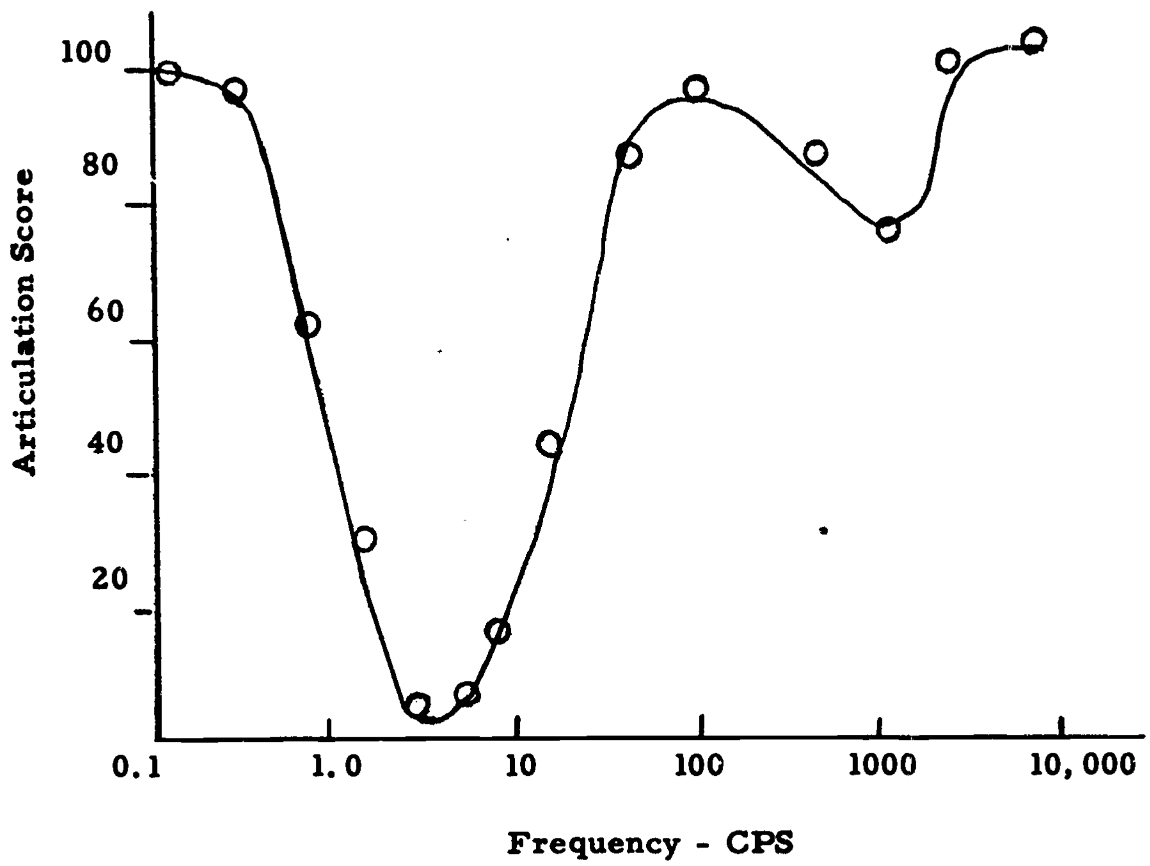

Figure 6.01 Articulation score for one subject when continuous speech is switched periodically from one ear to the other. (From Cherry and Taylor, 1954).

digits to the eyes and the ears. Again, the subjects were successful in repeating the digits in the order of reception when the presentation rate was one pair every two seconds.

Further data bearing on the topic comes from Cherry and Taylor (1954) who used a technique that was considerably different from that of Broadbent. They presented continuous prose to the subject in such a manner that the prose could be presented to either of two earphones with which the subject was fitted. This enabled the experimenter to switch the message from one ear to the other at a predetermined rate. In this situation, then, the subject was presumably made to alternate 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 presentation in order to repeat (shadow) the passage being presented. 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 prose by the subject. The rate of switching that had this affect, as shown in Figure 6.01, was typically between three and five cycles per second. Cherry and Taylor surmised that on the left side of the curve, the subject is effectively switching attention from one ear to the other, but as the rate of switching approaches the speed at which the duration of the presentation before the switch is equal to 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 alloted for perception and this is presumed to be the same as the time required for switching at the minima, 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 in 1/6 seconds, or approximately 160-170 msec. with the range observed in his experiment varying from about 100 msec. to 170 msec. Broadbent concluded that this compared favorably with his estimate, for he reasoned that if the perception of a digit required .5 seconds, and the change of attention required 1/6 of a second, then this would result in successful performance when pairs of digits were spaced at intervals of one and 1/3 seconds. This is something lower than his own finding of 1-1/2 to 2 seconds, but he points out that he used naval recruits rather than subjects with a university background as did Cherry and Taylor.

Moray (1960) observed that Broadbent's technique of presenting two digits simultaneously afforded the subject direct access to the one digit of each pair but to only a trace of the other digit and surmised that this might 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, and furthermore, he also 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 in the order of presentation, the former yielding much better results, but he was not able to confirm a difference between successive and alternate recall when the digits were presented in the staggered manner mentioned above. He proposed as an explanation for this that the subjects might not have been alternating their attention in any of the conditions mentioned to this point, but might have simply been "listening to both ears." This is the same sort of explanation tendered by Cherry and Taylor to account for the ability of their subjects to follow the prose passage when the rate of alternation 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 Broadbent's entire position was predicated upon the finding that the organism has a limited capacity for handling information, and it is this limitation in capacity that places a restriction on the input of information to the P system. It seems also that Broadbent has seriously overestimated the perception time of a digit at .5 seconds, for as Moray found, 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 msec. Moray (1960) suggests that it may be lower even than this, for he found that only the first 30-40 msec. of a digit, the normal length of which was in excess of 200 msec., was necessary to obtain almost unerring accuracy in recognition. But it would be a mistake to confuse the required stimulus time with the time required for perception. Gilbert (1959) has shown that these two times are quite distinct. His technique was to use a tachistoscopic presentation of a stimulus and then allow varying durations before the presentation of interfering stimuli. If the interfering stimulus came too soon, the subject was unable to report the first stimulus. But if the subject had time to develop a full percept (to process the information), the interfering stimulus did not interrupt the percept. He found that there were wide individual differences in amounts of time necessary for freedom from interference, but that it was normally of the order of 200-250 msec. It should be noted that the information value of the stimuli used by Gilbert, words and short phrases, are of a higher information value than digits, so this seems to confirm the previously calculated upper limit for the perception of digits. It also calls into question the estimate of switching time arrived at by Broadbent. If the time required to perceive a digit is not .5 seconds as he assumed in his calculation, but is rather closer to .25 seconds, then his estimate of switching time would be increased to perhaps as high as .5 seconds. If this estimate is at all accurate, then the phenomena reported by Cherry and Taylor

(1954) would have to be attributed to something other than switching time. However, there was some incongruity in their interpretation, for in one condition which showed the same minima, there was no need for the subject to alternate attention. Rather, it would seem that when alternation is occurring at such a rapid rate that only 100 to 150 msec. of sound are presented to either ear, then there are at least two factors interfering with perception in addition to any sort of 'dead time' that can be attributed to switching. The first factor is that there seems to be some minimum time required for the sampling of information from a sensory channel. In line with this, 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, to be between 60 and 70 msec. 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 fairly pure sensory input, as used in the experiment, establishes the base sampling time necessary for a judgment concerning a stimulus, and that increasingly more stimulus samples are necessary with increasingly complex stimuli.

The problem of switching time is probably not quite as complex as suggested by Moray, for experimental data rules out the possibility of the subject attending to both channels of sensory input, at least under the same conditions. Mowbray's (1953, 1954) data pointed in this direction in a task in which perception of the information in both channels would have resulted in successful completion of the task, and the same conclusion could be drawn from Moray's later work (1959) in which he found that when a subject was shadowing a passage being transmitted to one ear, the subject had no recall of the content of a passage transmitted to the alternate ear. Cherry (1953) had previously noted that the subject in this sort of situation would be aware of only minor properties of the speech in the second ear, such as the sex of the speaker, but was often unaware of the language of the discourse.

Second, Broadbent and Gregory (1961) provided a situation in which the presentation of digits to the eye and ear were staggered and found that there was still a decrement in the amount of recall between the successive and alternating conditions of recall indicating that time was occupied by the switching process which resulted in a decrement in retention. However, in this study the difficulty of estimating perception time prevented the research workers from obtaining any alternate estimate of switching time.

Finally, there is a possibility that the effect of switching, if there is indeed such an effect, is of negligible consequence in an educational situation. The fact that Gilbert (1959) is able to distinguish stimulus time and perception time suggests that switching could occur during the perception time. In any event for the concept of switching time to have significance for designing audiovisual devices it must be demonstrated that the effect of switching must be great enough to have an accumulative effect in learning.

An appropriate test, it would seem, would require a verbal learning situation in which the stimuli selected would have sufficient information that the perception time would be maximized. Care should be taken, however, that the time allotted for perception should not grossly exceed the time required for a full percept, for if this were the case then the effect of switching would not be evident.

The first study reported here represents an attempt to determine whether sense modality switching time is a sufficiently time-consuming phenomenon that it can interfere with learning. For the purpose of this study a learning task involving nonsense syllables was selected since such syllables are fairly uniform in information content if they are well selected. A presentation rate of one syllable per second was chosen for the list of 10 syllables since sense modality switching should then produce a decrement if time lost in switching is of the order of 100 to 300 msec. The decrement in learning should be of the order of 10 to 30 percent.

The second study in the series attempts to delve into what happens at the time of switching and provides information on the matter of where the decrement occurs. The third study was also concerned with a similar problem but abandoned the use of nonsense syllables in favor of a series of light flashes or "blips" of sound. The third study also takes up the problem of the effect on switching time of the subject's expectancy that information is to be received through a particular sense modality.

EXPERIMENT 1

The central purpose of this experiment was to test the hypothesis that serial learning tasks involving sense modality switching produce a slower rate of learning than tasks involving a single sense modality.

Method

Experimental Conditions. -- The various experimental conditions were obtained by varying the presentation of the syllables between the visual and the auditory sense modalities. The 8 different experimental conditions are shown in Table 6.01. The first two conditions listed provide no alternation and, together, provide a basis for evaluating the effect of alternation of sense modality as it occurs in other conditions. Condition 5 provides the fewest alternations with a single switch of sense modality after the fifth syllable, while condition 4 provides the greatest number of within trial alternations.

TABLE 6. 01

SENSE MODALITY USED IN PRESENTING SYLLABLES IN EACH POSITION IN EACH LEARNING CONDITION

Condition	Syllable Position 1 ZAS	2 WUB	3 YAG	4 POF	5 JIV	6 ZAB	7 ZEN	8 BUV	9 KUG	10 YUT	Number of Intra-list Alternations
1	A	A	A	A	A	A	A	A	A	A	0
2	V	V	V	V	V	V	V	V	V	V	0
3	Random alternation of the auditory and visual presentations										49
4 Odd No. Trials	A	V	A	V	A	V	A	V	A	V	90
Even No. Trials	V	A	V	A	V	A	V	A	V	A	
5 Syll. given first	A		A		A		A		A		10
Syll. given second		V		V		V		V		V	
6	A	V	A	V	A	V	A	V	A	V	90
7	A	V	V	A	A	V	V	A	A	V	50
8 Odd No. Trials	A	V	V	A	A	V	V	A	A	V	50
Even No. Trials	V	A	A	V	V	A	A	V	V	A	

Subjects. -- Subjects for the investigation were obtained mainly from the educational psychology courses required of all teaching majors at the University of Utah. An auxillary supply was obtained from the introductory general psychology course in the College of Letters and Science and education courses in the College of Education. Student participation in at least one research is a course requirement in both the introductory psychology course and the educational psychology courses, so it seems a fair conclusion that the subjects from both of these sources fairly represent the students within the classes. Those from the education courses were, as far as possible, conscripted on a class basis so as to avoid the selective factor associated with volunteers.

Subjects were allowed to sign up for an experimental session at their convenience, and it seems likely that subjects often participated with one or more friends. The groups, typically of three to five subjects, were arbitrarily assigned to a particular learning condition. Normally, six or seven groups were required to complete the 25 cases exposed to a particular experimental condition.

Materials. -- The materials used in the present experiment were devised as simply as possible while remaining consistent with the objectives of the investigation. The dependent variable was the number of syllables retained immediately following the presentation of a series of ten nonsense syllables. Since the syllables were presented both visually and auditorily it was necessary to prepare the materials that would permit either type of presentation.

Nonsense Syllables. -- The syllables used in the present task were selected from a group of syllables that had been used previously in the Bureau of Educational Research. These syllables had been selected from among those studied by Krueger (see Appendix A in Underwood and Shulz, 1960) and had association values ranging from 50 to 60 on Krueger's scale. The syllables had been further selected on the basis of pronounceability and lack of ambiguity (Van Mondfrans, 1964). With these criteria, 36 syllables had been previously selected. For the present experiment, ten syllables were arbitrarily selected from the earlier list of 36. The syllables used in the present experiment were as follows: ZAS, WUB, YAG, POF, JIV, ZAB, ZEN, BUV, KUG and YUT. They are presented together with some of their characteristics in Table 6.02.

Visual Materials. -- The syllables were prepared on manila folders with the use of Letraset transfer letters. The syllables were then photographed with a microfilm camera and the negatives were mounted in 35-mm half-frame cardboard mountings. Ten copies of each syllable were prepared in this manner. The image on the film was approximately 3.27 mm tall and resulted in a projected image approximately 200 mm tall.

TABLE 6.02

CHARACTERISTICS OF NONSENSE SYLLABLES USED FOR THE LEARNING TASK

No.	Syllable	Phonetic Rendition	Approximate Duration Msec. Before Edit.	After Edit.	Modality in Condition 5, 6, 7
1	ZAS	zæs	468	300	auditory
2	WUB	wʌb	379	237	visual
3	YAG	jæg	460	265	auditory
4	POF	paf	350	225	visual
5	JIV	dziv	400	240	auditory
6	ZAB	zæb	600	280	visual
7	ZEN	zen	535	370	auditory
8	BUV	bʌv	390	210	visual
9	KUG	kʌg	370	240	auditory
10	YUT	jʌt	460	260	visual

Auditory Materials. -- The services of a male speech major were solicited for the purpose of composing a master tape of the syllables to be used in the experiment. In preparation for the tape session, the speech major was instructed to practice uniformity in the amount of stress given each syllable. A phonetic rendition of each syllable was agreed on, the vowel sounds of each vowel remaining constant throughout the series of syllables. The phonetic rendition of each syllable is also given in Table 6.02.

After suitable practice each syllable was recorded several times. Following the recording session, the syllables were auditioned for clarity and in those cases where there were evident differences in quality, the best rendition of each syllable was selected for further use. In the remaining cases, the selection of the syllable was arbitrarily made from among those of comparable quality. The initial recording was done with an Ampex which had been modified to permit full-track recording at 15 inches per second (15 ips). The length of the syllable on the tape was taken as a measure of the temporal duration of the syllable, and particularly long syllables were shortened somewhat by cutting out segments of the tape. The segments taken out were approximately one quarter of an inch long, hence of approximately 16 msec duration. Each syllable was then made into a continuous loop tape so that the syllable, at normal running speed, occurred about once a second when played on a tape deck that had been slightly modified to handle this kind of tape. The output from this was put into a second tape recorder and the syllables were recorded onto a second tape. In this manner, all of the syllables were recorded at the same intensity, and every audial rendition of a particular syllable was identical, having been derived from a record from the same master syllable. The tape speed, in the transition from the first to the second recording, was reduced from 15 ips to 7-1/2 ips and from a full-track to a half-track recording.

Presentation of Stimuli. -- For each of the preceding experimental conditions, a magnetic tape was first developed with the auditory nonsense syllables spliced into the appropriate serial position. These were carefully measured 7.5-inch segments of tape which, in case of intervening visual stimuli, were separated by equally carefully measured segments of blank magnetic tape. Following the construction of the appropriate auditory portion of a tape for each experimental condition,the tape was transcribed to another tape ten times to provide for a total of ten trials. Thus in Conditions I, II, V, VI, and VII, the conditions in which the sequence and modality remained the same for all ten trials, the master tape was transscribed a total of ten times with sufficient tape to allow one minute between trials. For Conditions IV and VIII in which the sensory modality varied on successive trials, there were two conditions and a total of five transcriptions.

In these conditions also, blank tape was also inserted to permit one minute between trials. A short 1000 cps. tone was added to the auditory track three seconds before the first syllable and right after the last syllable on each trial. Both the auditory and visual stimuli were presented by means of an integrated tape deck, amplifier, and slide projector unit, the La Belle Maestro model. This particular unit is equipped to read and record on two channels of a magnetic tape and has an internal signal generator which controls a circuit to operate the slide projector. With this system, it is possible to record signals on the second channel of the tape to synchronize the auditory and visual presentations; each time the signal is read by the pick-up head the slide projector is actuated and the visual display is changed.

The LaBelle was modified to permit external control of the signal generator by a pair of reciprocating Hunter decade interval timers. One timer was set to control the duration of the auditory signal (the duration was about 340 msec.) recorded on the tape and the second timer would reset the first timer after 660 msec. The result of this procedure was that by means of the magnetic tape, the visual display was changed every second, and the change in display was synchronized with the auditory presentation. The duration of the visual display was about 650 msec.

The visual display was obtained by projecting the 2" x 2" slides mentioned above. Sufficient slides were included in a sequence for two trials, a sequence consisting of the appropriate nonsense syllables in their proper sequence with blank slides occupying the places in the sequence in which the syllables were presented auditorially. Blank, nearly opaque slides were also included before and following the normal sequence to avoid bright illumination of the projection screen.

Following the above procedures, a magnetic tape and corresponding sequence of slides was developed for each experimental condition. The sequence for the use of the materials associated with the various conditions was determined rather arbitrarily, but generally the materials for the condition with the fewest subjects at any given time was selected for use. This procedure was modified in those cases in which many subjects were being drawn from the same class during the class period. In these cases a different condition was used for each group that was used.

All of the recording and projection equipment was housed in a sound-dampened booth that had a small double pane window for the projection of the visual image to a screen about 12 feet from the booth. Below the screen was a speaker connected to the tape recorder. About eight feet directly in front of the screen, between the screen and the booth, there was a table that provided for the seating of five subjects. Adjacent to this was an additional table that permitted the accommodation of three more subjects. With this arrangement, then, it was possible to present the stimuli to up to eight subjects under fairly uniform conditions that provided for a minimum of distracting stimuli due to the operation of the tape recorder and slide projector.

Dependent Variable. -- The dependent variable was the number of correct responses. It was necessary that a judgment be made in the case of every stimulus presentation whether or not the subject had correctly reproduced the stimulus. This judgment was very straightforward in the case of visual stimuli but was more difficult in the case of auditory stimuli because of the inherent ambiguity of our phonetic system. If two of the three letters of a syllable were correctly produced in the proper places then credit for the syllable would be given. In none of the conditions was it a strict requirement that the syllable be produced in the correct position on the response sheet.

Although the criteria for scoring auditory responses were flexible and perhaps somewhat liberal, the adequacy of the criteria is reflected in the fact that when the protocols were scored a second time, the total learning score correlated .96 with the total score obtained on the first scoring. While it is true that this correlation is somewhat inflated by the fact that the variance was particularly high ($\bar{X} = 39.62$, $s^2 = 16.38$, Range 5-61) - some subjects simply failed to show any evidence of learning - it still reflects a reliable scoring system.

Results

The major hypothesis of the present experiment is 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, will result in an impairment of learning. This impairment will presumably accrue from the fact, according to the model proposed by Broadbent, that the organism can attend to only one sensory channel when the information level is approaching or exceeding the information processing capacity of the organism. It is anticipated that a bisensory presentation of information will 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.

Analysis of Total Learning

The design of the experiment provides for several tests of this hypothesis which involves an analysis of the total learning scores and several analyses of the variance of the subjects' performance with the learning task. The first analysis for the test of the hypothesis is on the total learning in the eight experimental conditions.

The summary statistics underlying this analysis are shown in Table 6.03. An examination of the treatment means reveals that Condition 1, the auditory condition, resulted in the fewest number of correct responses with the exception of Condition VIII, and that Condition II, the visual condition, resulted in the highest level of learning. The remaining conditions resulted in performance somewhere between these two extremes.

It is also interesting to notice that the mean for the combination of Conditions I and II, the two conditions that involve no switching of sensory modality, exceeds the mean for every other condition, all of which were bisensory, involving the presentation of the stimuli both visually and auditorily but not the two simultaneously. The learning curves comparing the average of Conditions I and II with the average of the remaining conditions is presented in Figure 6.02. The means describe a fairly typical learning curve.

The analysis of variance associated with the means in Table 6.03 is presented in Table 6.04. It shows that the progression of the means across the ten trials is highly significant, yielding an $\underline{F}$ of 298.1 ($p = .001$). There is also significant variance among the means of the eight experimental conditions, but this is not in and of itself confirmatory of the hypothesis. Indeed, it was expected that there would be a significant difference between the performance of subjects in the visual and auditory conditions, for the visual condition has been shown in previous research to be the easier condition for the learning of nonsense syllables in this type of task. The contrast of Condition I with Condition II, as a separate component of the sums of squares, would account for most of the variance within that portion of the analysis. The analysis that is of greater relevance for the present hypothesis, is obtained by partitioning the sums of squares attributable to differences between the conditions into a contrast of Conditions I and II with the remaining conditions; this provides a comparison of learning with and without the switching of sensory modality. It will be noted that this analysis yielded a result that is at least suggestive, an $\underline{F}$-ratio of 2.71 which is significant at the .10 level of confidence. That this is in favor of accepting the hypothesis is indicated by the fact that the mean learning scores for the combination of Conditions I and II is 46.96 in contrast to a mean of 42.63 for the remaining six conditions.

Reference to Table 6.04 will also reveal that the variance of the total learning scores is exceptionally high, suggesting that the above total learning scores is exceptionally high, suggesting that the above comparisons suffer from an inflated error term. As a matter of fact, it became apparent very early in the analysis that individual differences in the task were extreme. While 100 correct responses were possible if the subjects were to reproduce each syllable correctly on every trial, the subjects actually ranged in performance from 5 to 82. A score of 10 would indicate an average of one syllable reproduced accurately on each trial.

TABLE 6.03

MEAN RETENTION SCORES ON EACH TRIAL FOR EIGHT EXPERIMENTAL CONDITIONS N=25 IN EACH CELL (REPEATED MEASURES ACROSS TRIALS)

Trial	1	2	3	4	5	6	7	8	T
1	1.68	2.16	1.92	1.56	1.64	1.72	1.64	1.32	1.70
2	2.76	3.16	2.44	2.40	3.12	2.76	2.76	1.96	2.67
3	2.80	4.44	3.40	3.48	3.80	3.48	3.76	2.72	3.48
4	3.16	5.36	3.84	3.48	4.24	4.20	4.32	3.32	3.99
5	4.36	6.04	4.48	3.92	4.60	4.76	4.92	3.52	4.57
6	4.24	6.20	4.84	4.40	5.44	4.64	5.00	3.60	4.79
7	4.44	6.64	5.08	4.52	5.24	5.04	5.28	4.12	5.04
8	4.68	7.04	5.20	5.40	5.72	5.24	5.48	5.48	5.53
9	4.88	6.88	6.12	5.48	5.68	5.32	6.08	5.36	5.72
10	5.36	7.64	6.08	6.04	6.28	5.56	6.48	6.12	6.19
Total	38.36	55.56	43.40	40.68	45.76	42.72	45.72	37.52	43.71
S	16.53	19.30	18.72	14.07	15.50	15.48	11.51	16.23	
$\bar{X}$	46.96		42.63						

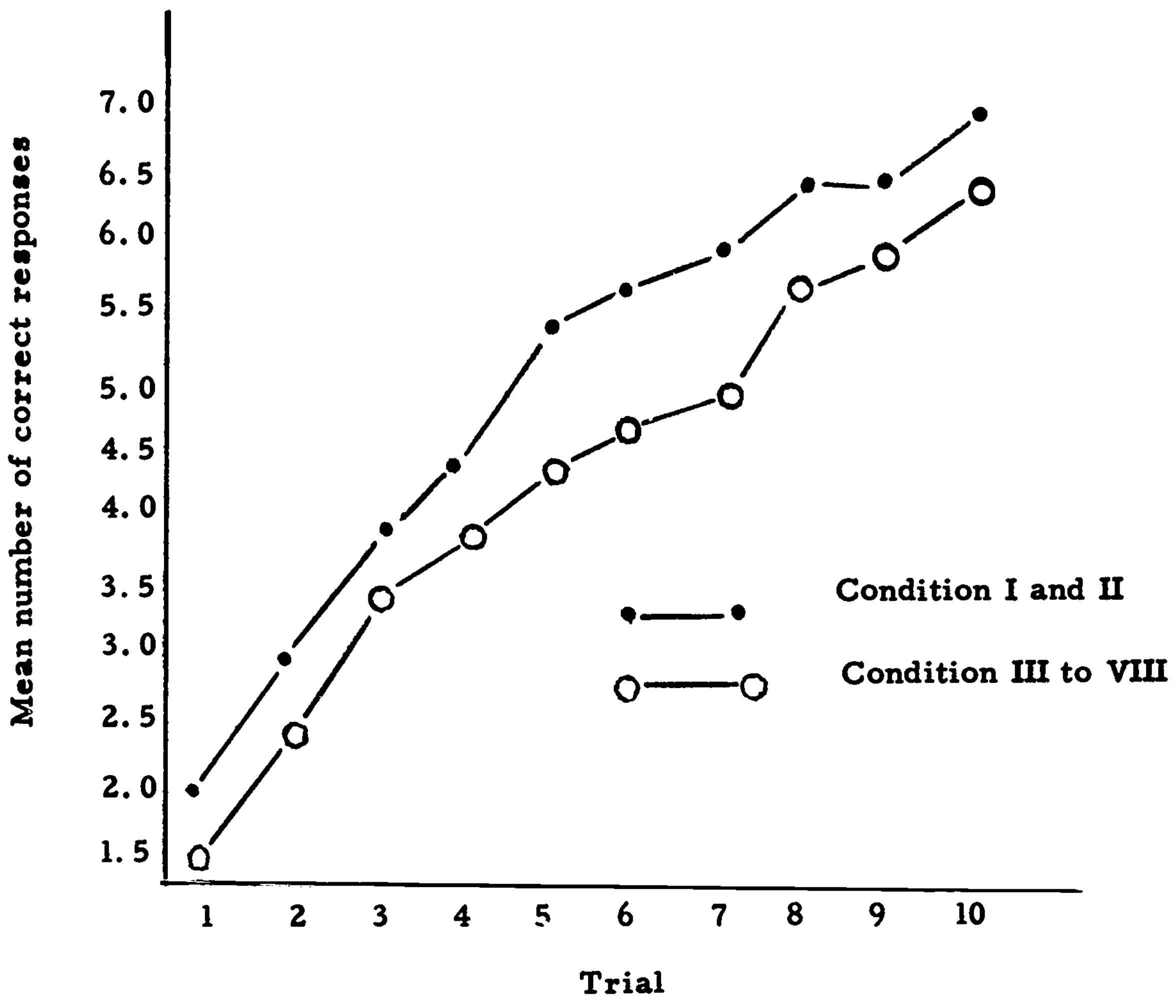

Figure 6.02 Learning curves for the combination of Conditions I and II and Conditions III to VIII

TABLE 6.04

ANALYSIS OF VARIANCE OF TOTAL LEARNING BY TRIALS FOR SUBJECTS IN EIGHT EXPERIMENTAL CONDITIONS*

Source	Ss	df	Ms	F	p
Between Subjects	5532.7	199			
Between Conditions	564.6	7	80.66	3.12	.01
I & II vs. Rest	70.2	1	70.20	2.71	.10
Residual	494.4	6	82.40	3.18	.01
Ss/Conditions	4968.1	192	25.88		
Within Subjects	6670.0	1800			
Trials	3622.0	9	402.44	298.1	.01
Conditions x Trials	721.0	63	11.44	8.5	.01
Residual Within	2327.3	1728	1.35		
Total	12203.0	1999			

* See text for description of Conditions

TABLE 6.05

SUMMARY STATISTICS OF TOTAL LEARNING SCORES FOR SUBJECTS PASSING CRITERION OF LEARNING

	Condition							
	I	II	III	IV	V	VI	VII	VIII
N	20	24	21	22	22	24	23	22
$\overline{X}$	44.8	57.1	47.7	43.3	47.4	43.2	47.2	39.1
S^2	114.48	328.08	269.37	153.66	224.43	242.63	101.00	270.85
S	10.70	18.11	16.41	12.40	14.98	15.76	10.05	16.46

TABLE 6.06

ANALYSIS OF VARIANCE OF TOTAL LEARNING SCORES WITH SUBJECTS FAILING TO MEET CRITERION OF LEARNING DELETED

Source	Ss	df	Ms	F	P
Between Conditions*	4862	7	694.6	3.23	.01
I, II vs. All Others	1565	1	1565.0	7.28	.01
Residual	3297	6			
I, II, V vs. all Others	1511	1	1511.0	7.03	.01
Residual	3341	6			
Ss/ Within Conditions	36539	170	214.9		
Total	41401	177			

*Between conditions was not partitioned into orthogonal components.

TABLE 6.07

ANALYSIS OF VARIANCE CONTRASTING SUBJECTS FROM DIFFERENT SOURCES IN CONDITION 8

Source	Ss	df	Ms	F	p
Between Groups	904.82	1	904.82	4.39	.05
Within Groups	5151.85	25	206.07		
Total	6056.67	26			

TABLE 6.08

ANALYSIS OF VARIANCE FOR TOTAL LEARNING SCORES IN CONDITIONS I, II, III IV, VI, AND VII WITH SUBJECTS THAT HAD FAILED TO LEARN DELETED

Source	Ss	df	Ms	F	p
Between Conditions	3157.33	5	631.53	3.05	.05
I and II vs. Others	1131.92	1	1131.92	5.46	.05
Residual Between	2406.74	4	601.68	2.90	.05
Alternations (0, 50, 90)	1519.09	2	759.55	3.66	.05
Linearity	1519.09	1	1519.09	7.32	.01
Residual Between	1638.24	3	546.08	2.63	.05
(I vs. II	1648.22	1	1648.22)*		
I vs. II	1636.24	1	1636.24	7.89	.01
Residual	2.00	2			
Within Conditions	26528.88	128	207.26		
Total	29686.21	133			

* This component was slightly inflated when estimated from the variance of the means; consequently the residual was obtained by direct computation and the component obtained by subtraction.

Because of the extreme variability of performance, it was decided to apply a criterion of learning that had to be met in order for the score of the subject to be included in the analysis. This involved a total performance in excess of nine correct responses and a greater number of correct responses on the last five trials than on the first five trials. One subject was rejected solely on the basis of the first part of the criterion and 21, or just over 10 per cent of the subjects, on the basis of the second part of the criterion. Summary statistics for the subjects retained are shown in Table 6.05.

After this adjustment of the data, the first portion of the analysis of total learning scores was recomputed with the results shown in Table 6.06.

It is apparent from this analysis that the adjustment of the means for the various conditions had only a slight effect in increasing total variance of the means, but that the ploy of establishing a criterion for learning had the very desirable effect of reducing the error term. In this analysis, the contrast of Conditions I and II with the remaining conditions resulted in an *F* of 7.28 which is significant at the .01 level of confidence.

It would be at best hazardous to press the interpretation of the data at this point, for the mean of Condition VIII does not fit the remaining data. This condition resulted in a mean performance of 39.1 when the scores for the subjects that failed to show learning had been discarded, which is appreciably lower than the mean of 44.8 which was obtained in the auditory condition. The decrement cannot be attributed to either the syllables or method of presentation, for these conditions were quite similar in other conditions. The condition differs from Condition IV only to the extent that Condition IV is a single alternation condition whereas Condition VIII is a double alternation condition. If anything, one would expect IV to be more difficult. Instead, it is found that Condition VIII resulted in scores that were considerably, although not statistically, lower.

For these reasons, the record of subject participation was examined in close detail and it was found that an inordinately high number of subjects had been obtained from an auxillary source, specifically, an evening course in the college of education that served as a general introduction to the field of education. An analysis of variance was performed contrasting the subjects from this class with the remaining subjects and it was found, as is shown in Table 6.07, that the subjects from this source scored significantly lower ($p = .05$) than the remainder of the subjects in the condition. With these subjects excluded, the mean for Condition VIII was increased to 44.14, just slightly lower than the mean for Condition IV. Because of this apparent contamination, this condition was excluded from further analysis involving total learning scores.

A final analysis of variance was computed on total learning scores with Conditions VIII and V omitted, Condition VIII for the reason given above, Condition V because of its high similarity to Conditions I and II. The results of this analysis are shown in Table 6.08 and supporting data for the interpretation in Table 6.04. It was determined first to test whether or not, with extraneous sources of error variance eliminated, there was a demonstrable effect attributable to the experimental conditions in which the sensory modality of presentation was switched during the presentation of the stimuli. For the purpose of this comparison, the between conditions sums of squares was partitioned into a component attributable to the difference between the combination of Conditions I and II and the remaining conditions. This comparison, with 1 and 128 degrees of freedom, yielded an *F* ratio that is significant at the .05 level of confidence. Since the effect of switching had been confirmed, it was decided to further the analysis by testing the variance attributable to the three amounts of alternation within the experimental conditions included in the analysis. Conditions I and II provided a total for a condition of no alternations, Conditions III and VII the condition of 50 alternations, and Conditions IV and VI the condition of 90 alternations. The means associated with this component of variance are shown in Table 6.09. This component of variance, which is not orthogonal to the preceding component, accounted for nearly half of the sums of squares attributable to variance between conditions and resulted in an *F* ratio of 3.66 which was significant at the .05 level of confidence.

Switching Time. -- Previous estimates of the time involved to make this switch in channels of information have been derived from studies involving immediate memory (Broadbent, 1953, 1954, 1956: Broadbent and Gregory, 1961) and from studies involving shadowing while the message has been alternated from one ear to the other (Cherry, 1953; Cherry and Taylor, 1954). The estimates of switching-time required to change attention from one source to another that have been derived from these studies fall in the range of about 170 msec. as estimated by Cherry and Taylor (1954) to 250 or 300 msec. as estimated by Broadbent (1958). There is a striking similarity in these values which is all the more remarkable because of the dissimilarity of the methods used for estimating the time. In the first instance, the estimate is based upon determining the rate of switching a message from one ear to the other at which the subject presumably can no longer switch attention quickly enough to pick up the message on the alternate ear. In the second instance the estimate is based upon the rate of transmission of different digits to two ears or to the eye and ear that permits the subject to recall the digits in the order of presentation.

Because of the similarity of the estimates it appears that there may be a genuine and general phenomenon involved in the switching of sensory modalities. Further, in light of the time estimated to be required for

TABLE 6.09

MEANS FOR EXPERIMENTAL CONDITIONS AND COMPARISONS OCCURRING IN THE ANALYSIS SHOWN IN TABLE 6.08

Means	Condition					
	I	II	III	VII	IV	VI
For each Condition	44.8	57.1	47.7	47.2	43.3	43.2
For I + II and Others	51.5			45.3		
For Each Level of Alternation	51.5 (0 Alt.)		47.4 (50 Alt.)		43.3 (90 Alt.)	

switching, the factor is not trivial in matters of education. The present experiment, therefore, has been conducted largely to determine whether the effect is of importance in a situation in which the stimuli maintain a high level of information, but with redundancy of material from one trial to another. This approximates better the typical learning situation than do shadowing and immediate recall.

In the present experiment it is assumed that Cherry and Taylor (1954) are correct and 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, therefore, is attributed to the switching time. Since there were 10 syllables presented at the rate of 1 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 available. 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 8 percent it is concluded that 50 alternations required 8 percent of the perception time or a total of 8 seconds. Eight seconds apportioned over 50 switches results in an estimate of 160 msec. as the time required to switch channels.

These estimates are highly similar to those provided independently by Cherry and by Broadbent, in spite of the fact that a highly dissimilar method has been utilized to estimate the time. Whether the decrement in learning is or is not directly attributed to switching time, it does indicate that conditions that provide for multi-channel input, (the requirement is an amount of information in excess of the capacity of the organism that can be partitioned into separate sources) will result in a less efficient transmission of information, and in the case of the present experiment, less efficient learning.

Conclusions

The performance of the subjects in the present experiment serves to support several conclusions. These conclusions are reported below, but the order has been changed from the order of certitude to an order of importance especially in terms of their implications.

The first of these conclusions concerns the very foundation of educational psychology. Individuals differ very markedly in terms of the speed with which they can process visual or auditory material. This finding is similar to that of Gilbert (1959) who found that poor readers required about twice the perceptual time to perform equally well as better readers in a perceptual task.

The introduction of the necessity for switching sensory channels during the course of a presentation results in a decrement in learning, a decrement that can accrue either from time lost in switching or a loss of stimulus presentation due to the operation of the filter. Phrased somewhat differently, the use of bisensory presentations with high levels of information (compared to the individual's capacity) results in switching which detracts from the perceptual time. This increases the load on the perceptual channel and further increases the likelihood of an even greater cut of the sensory input by the filter or S system. Switching time was estimated to be 160 msec., an estimate which corresponds closely to the estimates derived by other research workers involving entirely different procedures.

Finally, a few words must be said about limitations of the present study. These limitations require that the conclusions be evaluated cautiously. First, there is the fact that not all subjects may have followed directions and alternated attention from one channel to the other. At least some are known to have followed the procedure of first learning the syllables arriving through one channel and then the syllables through the other. The tendency to do this appears to have been more marked in the early stages of learning than the late stages. Insofar as this occurred, error would have been introduced into the estimate of switching time. An additional caution in the interpretation of the results is that the phenomenon of switching would appear to occur only when information is arriving at such a rate that the perceptual system is working to the limit of its capacity. When information is arriving at a slower rate, the perceptual system may have direct access simultaneously to information arriving from different sense modalities.

EXPERIMENT 2a AND 2b

One explanation of the phenomenon explored in the previous study is that there is time lost in switching sensory channels from the visual to the auditory and vice versa, and since the time required for switching sensory channels detracts from perception time, the time required would be reflected in decrement in the total amount of learning. The various estimates of switching time range from 160 to 300 msec.

In the previous study the measurement of decrement in learning was determined from total amount learned on each trial, as well as across the 10 trials. In the present study, a direct attempt was made to determine the decrement in learning immediately after switching sensory channels, that is, instead of analyzing the amount learned on each trial, an analysis was made at each serial position where the switching occurred.

In the present study there is only one alternation from visual to auditory to visual or vice versa. Thus, measures of the degree to which a syllable was learned on the trial involving a switch of modality and the amount learned on the syllable involving the switch-back are provided.

From what is known about the phenomenon, certain expectations follow. Assume that switching time is of the order of 200 msec. and is dead time, that is, time out from learning. Let us assume also that the perceptual processing time required for a syllable is about 500 msec. as Broadbent (1956) suggests, and that syllables are presented at the rate of one every 500 msec. through one sense modality but with one syllable switched to a different modality. If the assumptions are correct, then the presentation of the syllables through one sense modality at the rate of one syllable every 500 msec. should permit Ss to learn the series without any difficulty since the minimum time needed for processing each syllable is provided. However, if the sense modality of one syllable is switched, then an additional 200 msec. would be required for the switch to the different modality and another 200 msec. would also be needed for the switch back. If the rate of presentation were kept at 500 msec. then the switch should produce a decrement in learning either in the syllable involved in the switch or on the syllable following the switch. One possibility is that S may spend more than the allotted time on the syllable on which the switch occurs and a correspondingly smaller amount of time on the next syllable. This would depress learning on the syllable after the switch. The von Restorff effect -- the tendency for the oddity in the list to be more readily learned -- enhances the likelihood of the latter possibility.

Two studies are reported here. The first involves a presentation rate of 500 msec. per syllable and the other a presentation rate of 370 msec. per syllable. The latter represented the upper limit of speed of the equipment available.

Method

Design. -- The experimental design consisted of presenting 7 nonsense syllables in sequence, with one of these syllables being given in a different sense modality in one position on each experimental trial. If A represents an aurally presented nonsense syllable, and V a visually presented nonsense syllable, then the 4 experimental conditions could be symbolized as follows: (1) A V A A A A A, (2) V A V V V V V, (3) A A A A V A A, and (4) V V V V A V V.

An example of what occurred under Condition 1 may be given. If the syllable (WUB) in the first position was presented aurally, then the syllable (ZAS) in the second position was presented visually -- this is the sensory switch; the third, fourth, fifth, sixth, and seventh syllables (YAG, ZAB, BUV, KUG, and YUT) were presented aurally (this is the sensory switch-back).

When the performances on the first 2 experimental conditions are added together (keeping each position separate), the combined data for the two treatments represents an auditory and a visual presentation in each position thus:

(1) A V A A A A A
\+ + + + + + +
(2) V A V V V V V

The effect of switching can then be observed by comparing data thus derived with those derived by combining 2 control groups exposed to Conditions 5 and 6:

(5) A A A A A A A
\+ + + + + + +
(6) V V V V V V V

A similar comparison can be made for combined data in Conditions 3 and 4 and those of the same control groups.

Since resulting phenomena could be a product of the particular syllable used in the switched position, 2 different syllables were used in the switch position. Conditions 1 through 6 involved ZAS in the second position and BUV in the fifth, while experimental Conditions 7 through 12 repeated the same experimental conditions and control conditions but with BUV in the second position and ZAS in the fifth.

Materials. -- The visual stimuli were 7 nonsense syllables chosen from Krueger's list of monosyllables (Underwood & Schulz, 1960), all of which had association values ranging from 50 to 60 (percentage of subjects who had association). The syllables were: WUB, ZAS, YAC, ZAB, BUV, KUG, YUT. In four of the eight experimental conditions the positions of ZAS and BUV were reversed.

These seven nonsense syllables were photographed on filmstrips, with the syllables appearing in the orders called for by the experimental conditions. Tape recordings were made for every condition involving one or more auditory syllables.

Subjects. -- Undergraduates from educational psychology and education classes were used as subjects; 120 subjects were randomly assigned to 12 conditions of 10 subjects each.

Apparatus. -- The experimental facilities consisted of a room with a table and ten chairs, and a movie screen. A Victor Soundview projector was used for projecting the syllables onto a screen placed 8 ft. from subjects. The letters were about 6 in. high on the screen. The auditory stimuli, recorded on tapes, were reproduced through a speaker system. In Experiment 1a reported here the time per syllable was 0.5 sec. and in Experiment 1b 0.37 sec.

Procedure. -- When subjects entered the experimental room, each was given eight sheets for recording responses. They were instructed to sit at a table facing the movie screen. The instructions given to subjects were that they would be presented with some syllables on the screen and some syllables through the loudspeaker. Subjects' task was to learn as many syllables as possible and write them down on a sheet after each trial. Subjects were presented with eight trials. A syllable was scored as correct either if two of the three letters were correct or if the written version was phonetically correct (e.g., COG instead of KUG).

Results

Experiment 2a. -- The main points to be noted require an examination of the data for the second and fifth positions separately.

The syllables in the second and fifth position switch. -- The graphical representation of the data involving a switch in the second position and the control group is shown in Figure 6.02. The graph shows the mean number of correct responses in each serial position for eight trials. All conditions involving a switch of modality in the second position (1, 2, 7, 8) are combined. The reader should note that the control conditions show a typical U-shaped serial learning curve.

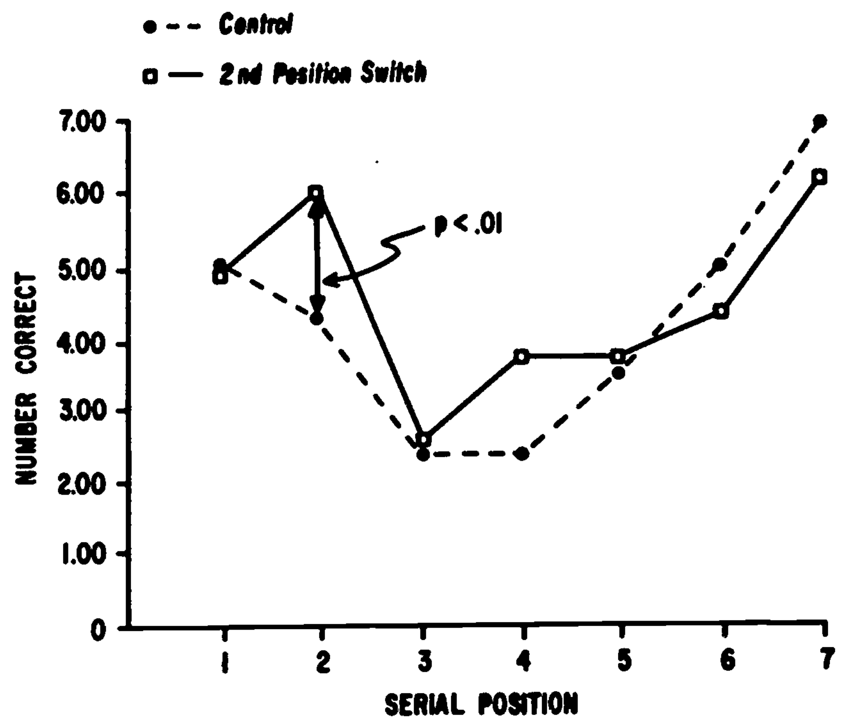

Figure 6.02. Data showing the effect of switching in the second position on the number correct in Experiment IIa

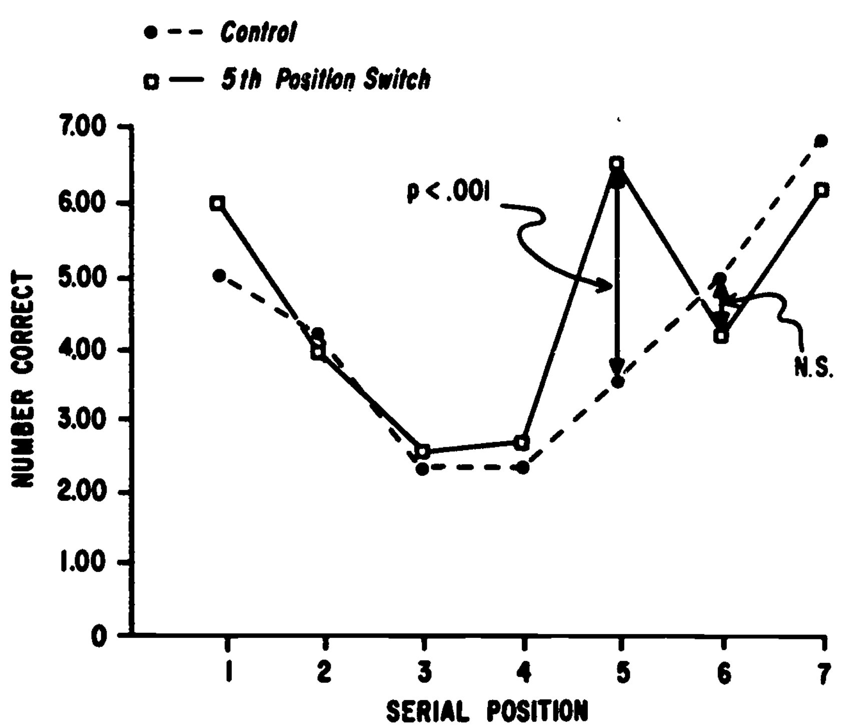

Figure 6.03. Data showing the effect on switching in the fifth position on the number correct in Experiment IIa.

The reader should also note that in the second position of the experimental groups where modality switching occurred, there was a sharp increment in the learning of the syllables in that position. Thus the graph shows a combination of the following four treatments:

(1) and (7) A V A A A A A

(2) and (8) V A V V V V V

with the following four controls combined:

(5) and (11) A A A A A A A

(6) and (12) V V V V V V V

The mean number of correct responses learned in the second position under the experimental conditions was 6.03, while the mean number of correct responses learned in the second position under the control conditions was 4.20. A _t_ test indicated that significantly greater learning occurred under the experimental conditions where the sensory switching occurred in the second position than under the control conditions where no sensory switching occurred ($t = 2.82$, $df = 78$, $p < .01$).

Figure 6.03 indicates the mean number of correct responses in each serial position for eight trials for data involving a switch in the fifth position. The graph compares the following experimental conditions combined:

(3) and (9) A A A A V A A

(4) and (10) V V V V A V V

with the combined four conditions:

(5) and (11) A A A A A A A

(6) and (12) V V V V V V V

It should be noted that in the fifth position there was a sharp increment in mean correct responses and in the sixth position for experimental groups there was also a sharp decrement. A _t_ test showed that the experimental conditions were significantly superior ($t = 5.67$, $df = 78$, $p < .001$).

The syllables in the third and sixth position switch-back. -- In Figure 6.02 it is apparent that there is little difference in the mean number of correct responses of the switch-back position (third position) for the experimental conditions and the third position for the control groups. Figure 6.03 suggests that there might be a significant difference between the experimental groups with control groups on the sixth position (the switch-back syllables). However, a t test showed that this difference was not significant (t = 1.41, df = 78). Thus, the notion that learning syllables after the switch would be depressed was not supported by these data.

Experiment IIb. -- The syllables in the second and fifth position switch. -- Figure 6.04 represents the mean number of correct responses in each serial position for the eight trials. The mean for the control group was 3.53 and for the experimental groups 4.58 for the syllable where the sensory switch occurred. A t test indicated that the difference was not significant (t = 1.37, df = 78).

Figure 6.05 also presents the mean number of correct responses in the fifth position where the modality switch occurred. The mean for the control groups was 3.93 correct responses and that for the experimental groups was 5.23. The t test showed the difference to be significant (t = 2.03, df = 78, $p < .05$). Thus, in the fifth position when a sensory switch occurred for the experimental groups, there was significantly more learning than when no sensory switch occurred, as in the control groups.

The syllables in the third and sixth position switch-back. -- One of the hypotheses stated that learning the syllables immediately after the switch will show a significant decrement. Thus, in Figure 6.04 and Figure 6.05 one should expect to find a decrement in the average number of correct responses for the experimental groups in the third position and for the sixth position, respectively. In Figure 6.04 there was very little difference between the means of the two groups in the third position. By contrast, in Figure 6.05 there was an appreciable difference between means. At the sixth position (t = 2.38, df = 78, $p < .05$).

Discussion

Several features of the data call for comment. First, there is clearly no deterioration in learning of the syllable during the switch in transmission modality. Indeed, performance on this item is superior. This could arise because this condition is an example of the oddity effect. Another possibility is that any time lost in switching may be more than balanced by the perceptual effectiveness which derives from a change of modality, a phenomenon discussed at length by Broadbent (1958). The latter explanation seems to be supported by the fact that the effect appears to be more dramatic in the fifth position than in the second.

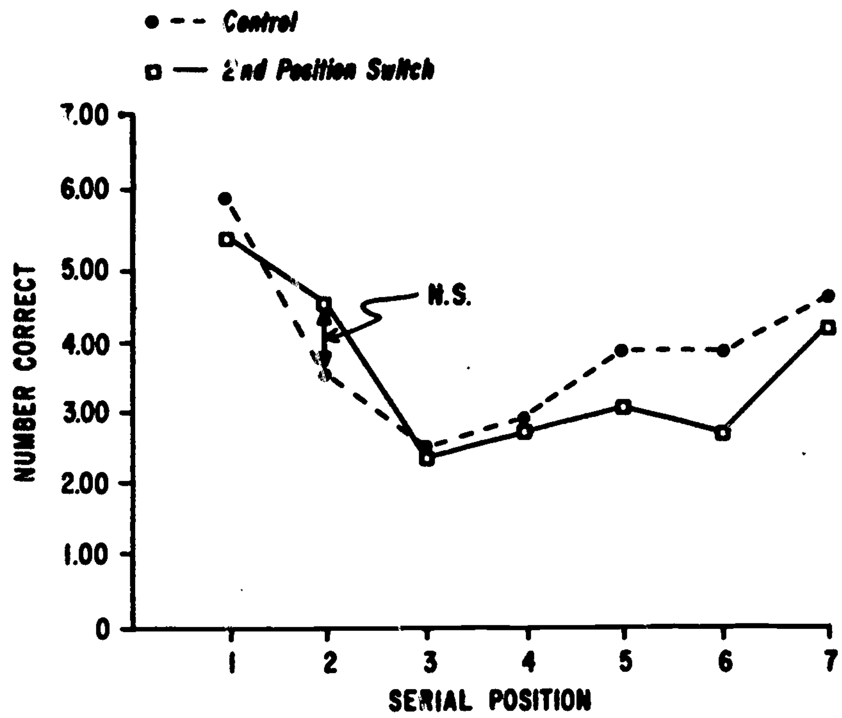

Figure 6. 04. Data showing the effect of switching in the second position on the number correct in Experiment IIb.

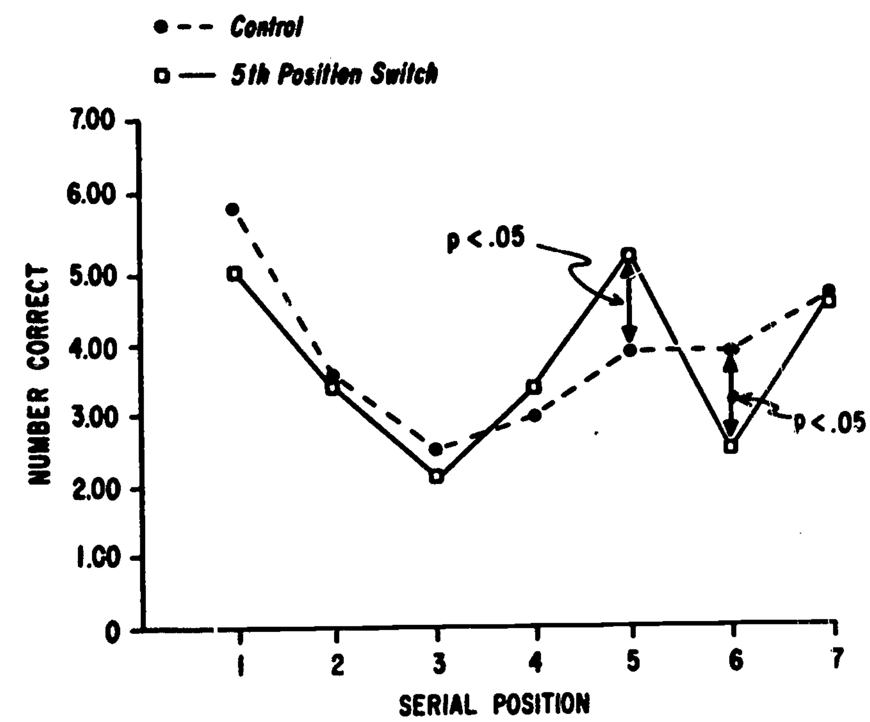

Figure 6. 05. Data showing the effect of switching in the fifth position on the number correct in Experiment IIb.

One should note that learning of the syllable on which the sense modality is switched back tends to be depressed, but only the decrement at the faster speed reached significance ($p < .05$). One would expect the effect of switching to be more marked at the faster of the two speeds of presentation, as is the case.

A further point of interest is that the effect of switching is much more marked in the fifth position than in the second. Why this is so can only be a matter for speculation. One possibility is that the first four syllables may build up an expectation that the information is to be received through the same modality and hence the transmission of information through a different modality is both unexpected and increases the time taken to process the information. This would leave less time for processing the information after the switch.

A further point to note is that, when the syllable in the switched position was presented visually, it was learned more readily than when it was aurally presented. This may well be an artifact of the experimental situation for aurally presented nonsense syllables generally have an ambiguity which visual syllables do not. This ambiguity may become an important factor producing a decrement in learning when the time available for learning is reduced to a very small amount as in the present research, and particularly when a switch is involved.

The data from the position following the switch support the hypothesis that the time involved in switching is dead time, but since the effect is significant only at the more rapid rate of presentation, the original estimate of the time taken for perceptual processing is probably too high. It is more likely that the estimate of perceptual processing time is incorrect than the estimate of switching time. Switching time has been estimated in many different ways but with approximately the same results, so some validity can be ascribed to the obtained values.

EXPERIMENT III

The fact that in the previous study the effect of switching was much more marked in the 5th position than the 2nd suggests that, as information is received through a particular sense modality, switching to another modality requires an increasing amount of lost time. The present study investigates further this tendency for switching effects to become more marked as a particular sense modality continues to be used for information transmission.

The lack of equivalence of nonsense syllables suggested that it would be advisable to substitute for them signals which would be more nearly equivalent to each other. For this reason the present study used as signals either brief series of flashes of light or brief series of sound "blips". Each signal consisted of either 3, 4, 5, or 6, flashes or blips. Four signals were given consecutively through either the auditory or the visual modality and the task of the subject was to report the number of flashes or blips in each of the four consecutive signals.

While no recent related study using flashes and blips could be identified Judd (1927) had used a similar task in which adult subjects were to estimate the number of flashes presented at various rates from 3 to 5 per second and sounds which varied from 3 to 8 per second. His data showed that increasing rates of presentation resulted in increasing errors, that errors increased as the number of flashes or sounds increased in number, and that auditory signals were more readily estimated numerically than were flashes. The latter finding was attributed by Judd to the fact that adults have had more experience in counting sounds than in counting flashes.

Method

Materials. -- The task of the subject was to estimate the number of blips or flashes in each of four consecutive signals. Each blip or flash within each signal involved .09 sec. of either light or sound followed by an interval of .03 sec. Thus three blips and the interval following them occupied 0.36 sec., four blips occupied .48 sec., and so forth. A single signal consisting of either 3, 4, 5, or 6 blips or flashes was transmitted and then was followed by a 1-sec. interval before the next signal was transmitted. The blips were produced by recording a 900 cps sine wave tone on tape. The flashes were produced by a 3-watt neon lamp placed 5 feet from the subject in a dimly lit room. The 1-sec. interval between signals was established empirically by running subjects with intervals between signals which varied from 0.2 sec. upwards.

Intervals lower than 1 sec. did not permit the subject to provide any accuracy in estimating the number of flashes or blips.

Conditions of Presentation. -- The different conditions of presentation of the signals varied the position on which the switch of modality occurred. The positions of the auditory and visual signals in each of the 10 experimental conditions is shown in Table 6.10. The last two experimental conditions represent the control conditions in that no switch of modality is involved. Each subject was exposed three times to each one of the 10 conditions.

The experimental design required that there be thirty sets of four signals each. These were prepared by assigning the numbers 3, 4, 5, and 6 at random to the cells of a 30 x 4 matrix, with the restriction that no number should appear more than once in a single row of four cells. Each signal within a set of four signals could be transmitted either through the auditory or the visual modality depending upon the particular condition involved. In addition, since a particular condition might provide an easier task when it occurred in one position than in another in the series of 30 trials, four different orders for the learning conditions within the 30 trials were prepared.

Subjects. -- Subjects were derived from undergraduate courses in educational psychology. Forty subjects were divided into four groups each of which was assigned to one of the four randomized presentation orders of 10 subjects each.

Apparatus. -- The experimental facilities consisted of a room with a table and five chairs, a loudspeaker, and a tape recorder synchronized with a relay device connected to a 3-watt neon lamp. The auditory stimuli were produced through the loudspeaker which was placed behind the subjects, while the visual stimuli were reproduced through the neon bulb mounted on a black piece of cardboard located directly in front of the subjects.

TABLE 6.10

POSITION OF THE AUDITORY (A) AND VISUAL (V) SIGNALS IN EACH CONDITION

Condition	Position of Signal			
	1	2	3	4
1. Experimental	V	A	A	A
2. Experimental	A	V	V	V
3. Experimental	A	V	A	A
4. Experimental	V	A	V	V
5. Experimental	A	A	V	A
6. Experimental	V	V	A	V
7. Experimental	A	A	A	V
8. Experimental	V	V	V	A
9. Control	A	A	A	A
10. Control	V	V	V	V

RESULTS

Table 6.11 presents the mean number of errors per-trial and standard deviations on each serial position of the experimental conditions and the control conditions. It should be noted that these experimental conditions are paired according to the serial position on which the switch and switch-back occurred. For example, if the switch and switch-back presentations occurred in the 2nd and 3rd positions, then the experimental conditions involving AVAA and VAVV would be combined together. Likewise, the same procedure was used for the other serial positions for the experimental groups. For the control groups, the AAAA condition and the VVVV condition were combined together.

The nature of the experimental design made possible the use of *t* tests between correlated means, mainly comparing learning in the switch and switch-back positions with learning in the corresponding control positions. Correlated *t* tests were also used in determining the significance of the differences in learning when sensory switching occurs in progressively later positions as in the 2nd, 3rd and 4th positions.

The switch positions. -- Table 6.11 shows the mean number of errors for the second-position switch involving experimental conditions one and two and three and four. These are not too different from the mean of the corresponding 2nd position in the control group. A comparison of the data from these switch positions with the control position indicated no significance of the difference. However, the 3rd position switch, involving conditions five and six, seem to have considerably more errors than the corresponding position of the control group. A significant difference was found between the two groups means using a *t* test ($t = 3.59$, df = 78, $p < .01$). A significant difference was also found when comparing the experimental groups 7 and 8 on the 4th position switch with its corresponding control position ($t = 8.00$, df = 78, $p < .001$). Thus in the 2nd position, there was no marked decrement in learning, whereas, in the later positions, i.e., the 3rd and 4th positions, considerable decrement in learning occurred.

The switch-back positions. -- There are only two pairs of experimental conditions which yield information about the switch-back position, these are conditions three and four and conditions five and six. In condition three and four the switch-back occurred in the 3rd position and in conditions five and six the switch-back occurred in the 4th position. In comparing the mean of 1.05 for the 3rd position switch-back of conditions three and four, with the mean of 0.80 for the 3rd position of the control group, a significant difference was found between these two means ($\underline{t}$ = 5.84, df = 78, p <.01). A significant difference was also found when the means of the 4th position switch-back of conditions five and six (1.01) were compared with the corresponding mean (0.74) of the control group ($\underline{t}$ = 2.38, df = 78, p <.05).

Comparison of auditory condition with the visual condition. -- The difficulty of the task in the all auditory or predominantly auditory conditions could be compared with the difficulty of the task in the all visual or predominantly visual conditions. From Table 6.13 it is evident that the visual treatment yielded more errors in learning. A significant $\underline{t}$ indicated the high degree of confidence that could be placed in the difference between the two groups ($\underline{t}$ = 3.90, df = 7.99, p <.01).

DISCUSSION

Of primary importance is the gradual increment in difficulty which occurs as the position where switching occurs is moved from the 2nd to the 3rd, and to the 4th serial positions. This similar phenomenon occurred in the previous study (1965) where the later position switching resulted in a greater facilitation of learning and then a greater disruption of learning. The explanation given in that study was that the earlier syllables in the presentation build up an expectation that the information is to be received through the same modality and as a result, the transmission of information through a different modality becomes progressively more unexpected and, hence, increases the difficulty of making the switch and probably the time taken to make the switch. This, in turn, leaves progressively less time for processing the information after the switch. This explanation seems to fit very well the results discussed here. The evidence presented seems to suggest that the decrement due to switching is dependent on the serial position of the switch, that is, the amount of disruption increases as the switch occurs later in the list.

Several features of this study seem to be inconsistent with some of the results obtained in the previous study reported here and in the study by Judd (1927). In the present study, analysis of the data both in the switch and switch-back positions clearly indicate a decrement in performance; whereas, in the previous study, analysis of the results shown an increment in learning in the switch positions and a decrement in the switch-back positions (for the 5th and 6th positions).

The differences in findings could well be due to differences in the tasks in the two studies. The task in the present study places emphasis on perceptual recognition and short-term storage of the information--that is to say storage for a matter of a few seconds. In contrast, the task in the previous study places little emphasis on perceptual processes, for each of the syllables is easily read in the time allotted, but it required retention for a much longer period of time. The difficulty of the task in the present study comes from the difficulty of discriminating the signals. The difficulty of the task in the earlier study would appear to derive from the requirement that a considerable amount of readily recognizable information has to be retained for a period which may be as long as several minutes.

Finally the data from the present study are consistent with those of Judd who reported that subjects found it easier to recognize the number of auditory blips than the number of flashes of light. Judd's explanation that adults have more experience in counting intermittent sounds than they have in counting flashes still seems plausible.

TABLE 6.11

MEAN NUMBER OF ERRORS AND STANDARD DEVIATIONS FOR EACH SERIAL POSITION OF RELATED PAIRS OF EXPERIMENTAL CONDITIONS AND CONTROL CONDITIONS.

Experimental Conditions		1 M	1 SD	2 M	2 SD	3 M	3 SD	4 M	4 SD
1 & 2	VAAA AVVV	0.49	0.79	1.14*	1.53	1.10	1.43	0.84	0.84
3 & 4	AVAA VAVV	0.94	1.31	1.09*	1.42	1.05**	1.31	0.86	1.18
5 & 6	AAVA VVAV	0.67	1.00	0.94	0.97	1.11*	1.05	1.01**	1.20
7 & 8	AAAV VVVA	0.69	1.08	0.74	1.07	0.93	0.63	1.41*	1.72
Control Conditions									
9 & 10	AAAA VVVV	0.86	1.36	1.11	1.43	0.80	1.06	0.74	0.99

* Switch position
** Switch-back position

TABLE 6.12

MEAN NUMBER OF ERRORS AND STANDARD DEVIATIONS ALL AUDIO OR PREDOMINANTLY AUDIO CONDITIONS AND ALL VISUAL OR PREDOMINANTLY VISUAL CONDITIONS.

Conditions	M	SD
AAAA, VAAA AVAA, AAVA, AAAV	0.84	0.88
VVVV, AVVV, VAVV, VVAV, VVVA	1.01	0.85

CONCLUSIONS AND IMPLICATIONS OF THE EXPERIMENTS REPORTED IN THE CHAPTER

This chapter has explored some of the phenomena related to the switching of sense modality during the acquisition and storage of information. In the first of the experiments reported, evidence was found that the phenomenon could have relevance for the design of audiovisual materials. The data indicated that switching from the auditory to the visual channels and back again could result in a substantial depression of learning. The data fitted well the conception that channel switching resulted in time lost to the process of acquisition and that the depression in learning was a function of the total amount of time lost. Such a depression was assumed to occur only when the individual was receiving information to the limit of his capacity and placing it in temporary storage. Depressions in learning of the amount found are sufficient to be of genuine significance in learning situations in schools.

The first study also permitted the estimation of the amount of time lost from learning when a single switch is made from one sense modality to another. The estimate derived from the data agrees surprisingly well with those previously derived from other procedures by other workers. Particularly remarkable is the close agreement of the estimate reported here with that of Cherry and Taylor (1954) who were concerned with switching from ear to ear rather than from ear to eye to ear. These data raise the interesting question whether the same amount of time is lost in switching from message to message, when both messages come through the same eye or ear, as is lost when two different sense modalities are involved.

The second and third studies in the series were designed to investigate some distinct aspects of the switching phenomenon. The second experiment attempted to investigate the switching effect at the level of a particular switch. In this study, the von Restorff effect played a prominent role in the shaping of the data. The empirically determined effect of the switch appeared in the switch-back position rather than at the first switch. The novelty effect (von Restorff effect) is marked in those series that involve a single switch and, in the case of the slower of the two rates of presentation, was sufficient to balance the depression produced by the switch.

The final study of the series also involved the investigation of what happens at the position of the sense-modality switch and at the switch-back position. However, in place of nonsense syllables, flashes of light and "blips" of a pure tone were used. It was hoped that these would control some of the problems of meaningfulness encountered in typical nonsense syllable studies. The design of the study also involved a switch in sense modality at each one of the four possible positions in the series. This design made it possible to determine whether the transmission of information through one sense modality makes it progressively more difficult or more time-consuming to switch to a source of information transmitted through another modality. The evidence generally supported the contention that as information is received through a particular modality there is a build-up of the disruption involved in switching sense modality. A similar experiment should be repeated with signals received through one modality over much longer periods in order to determine the extent to which this build-up may progress.

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CHAPTER VII

STUDIES OF LEARNING FROM COMPRESSED VISUAL INFORMATION*

*The experiments reported in this chapter are reported in full in a doctoral dissertation by Robert L. Overing which is now in progress at the University of Utah. The dissertation will be on file in the library of the University of Utah when it is complete.

Information reaching the receptors is compressed during the process of transmission to those centers that result in the information being utilized, being temporarily stored, being permanently stored, or having some or all of these operations undertaken with it. The evidence is overwhelming that some form of information compression takes place and that the capacities of the higher centers for handling information are small compared with the capacity of the system at the sense organ level. Compression appears to be partly a process built into the nervous system which takes place simply because the mechanical arrangement of the nerves results in the reduction of information during the transmission process, but some of the more complex compression processes are the result of learning. Through experience organisms learn that whole groups of events can be treated as the same and that, hence, information which differentiates these events can be discarded.

Much more is known about the compression of visual information than the compression of auditory information. The knowledge which appears to be most relevant has been reviewed by Travers, et al, (1964) in a previous monograph. Visual information, at the level of the retina and optic nerve, is compressed by a process which tends to retain information pertaining to boundaries and to discard information between boundaries. At higher levels, of course, other information compression processes come into play.

The model of information, reception, and processing considered here leads to the suggestion that visual information might well be compressed prior to reaching the eye for the purpose of improving the effectiveness of the transmission. Educational practice has already done this to some extent. Simplified diagrams and line drawings, and other examples of compressed information, are commonly displayed on the walls of classrooms and on the pages of textbooks. This practice appears to assume that there are advantages in transmitting information in a compressed form, perhaps because such information is uncomtaminated by a mass of irrelevant detail.

While the problem is obviously one of central importance for the planning of pupil experiences, it is one which has not been studied. Books on audiovisual techniques tend to advocate realistic presentations which retain all the irrelevant sources of information. However, classes designed to teach teachers the techniques of audiovisual instruction have typically devoted long hours to the study of techniques for producing line drawings and other simplified materi als. There is much inconsistency in this situation, but this is hardly surprising in view of the extraordinary absence of knowledge.

This chapter presents studies designed to explore the value of compressing visual informationprior to presenting it to a learner. The process of compression as it is considered here involves the elimination of both irrelevant details and also, to some extent, redundant information. This compression process takes place when a realistic situation is reduced to a greatly simplified line drawing in which only the essential features of the visual information are retained.

The first study considered here explores the extent to which a principle learned in a situation involving compressed visual information can be transferred effectively to the solving of a problem in a new situation. The second study attempts to determine the role played by irrelevant cues when learning is accomplished in realistic situation and when the knowledge thus acquired is applied in situations which include either the same irrelevant cues or different irrelevant cues. The second study also investigates the effect of omitting irrelevant cues both in the learning and the transfer situation.

EXPERIMENT I

THE EFFECT UPON TRANSFER OF COMPRESSING VISUAL INFORMATION

Previous experiments (Judd, 1908; Hendrickson and Schroeder, 1941) indicate that verbal knowledge of a principle has a facilitating effect on the amount of transfer evident in a situation requiring application of that principle. Hendrickson and Schroeder, further, showed that the amount of transfer was related to the amount of information taught - the less information, the less transfer, and vice versa.

Neither of these previous experiments, however, investigated the effect of teaching the principle by different means. In fact, in the experiment reported by Judd, we are not informed at all of the manner in which the information was taught, or for that matter, what information was taught. We are simply told that the experimental group was given a full theoretical explanation of refraction (Subjects were Gr. V and VI boys) while the control group received no training. As a test for the effect of this knowledge on transfer, all subjects were then tested in a series of tasks requiring them to throw darts to hit an underwater target.

Hendrickson and Schroeder in their 1941 experiment, which was a modified reproduction of Judd's, describe both the method by which they taught the information and the information itself. Essentially, each subject was presented with a brief (though somewhat inaccurate) statement and diagram representing the refraction of light in water and the resulting apparent displacement when an underwater object is viewed at an angle from above. Each subject was permitted to study this information until he stated that he understood it. As in Judd's experiment, the control group received no instruction or information relating to refraction or displacement. Like Judd's, also, the transfer task again was an attempt to hit an underwater target, only in this case an air rifle and pellets were substituted for the darts.

The experiment which is described in this report was an attempt to extend the findings of Judd, and of Hendrickson and Schroeder, to see what the effect upon transfer might be of introducing variations in training conditions, where information and time were held constant. The dimension varied was essentially that of relevancy, e. g., in the "realistic" treatment, all sorts of irrelevant cues were present, whereas, in the "visually" compressed treatment an effort was made to eliminate many irrelevant bits of information by reducing the visual aspect of the presentation to a series of line drawings.

It was hypothesized that the transmission of information should take place most effectively under conditions where the information to be transmitted has been pre-compressed, either by the elimination of redundancy and/or by the elimination of irrelevant information.

However, the possibility also exists that conditions of compression, whilst facilitating transmission of information may not be optimum where transfer is called for. In other words, the optimum conditions for learning a concept may not be the optimum conditions for transfer related to that concept. The research is an attempt to cast some light on these problems. The experimenters set out to determine:

1. Whether knowledge of the principle of refraction from physics acquired under visually compressed or under realistic training conditions would best facilitate transfer.

2. Whether verbalization of the knowledge taught would facilitate performance on the transfer task.

3. Whether contact with a relevant problem immediately preceding instruction with visually compressed materials would establish a set, thus facilitating performance on the transfer task.

Method

Experimental Design

The experimental design was a 2 x 2 x 4 x 2 x 12 factorial design comprising a verbalization-nonverbalization condition, two sexes, four training conditions, two tests, and twelve repeated measures within each test.

Training Conditions

Four training conditions were introduced into the experiment. The attempt was made to teach all groups the same information but to vary the way in which the information was taught. The time devoted to teaching was the same for all groups. The verbal information provided was reproduced in each case by means of a tape recorder. The four teaching conditions were as follows:

I. Verbal Information Only.--In this condition subjects listened to a tape which provided all the information they received. The script described: (1) the principle of the refraction of a light ray entering and leaving water, and (2) the phenomenon of the visual displacement of an underwater object when viewed at an angle from above. The time taken to run this tape became the base time used in all teaching procedures. The script of the tape also became the basis for verbal materials used in all other teaching conditions.

II. Visually Compressed Information plus Verbal Information.--In this teaching condition line drawings were introduced to transmit some of the information and some of the redundant items of the original verbal script were deleted. The drawings provided very simple representations of the phenomena discussed, but colors were used to facilitate the identification of parts of the drawings from the verbal descriptions. Every effort was made to ensure that the information content of this and all other teaching procedures was identical.

III. Realistic Demonstration plus Verbal Information.--This teaching condition involved a visual presentation of a light beam passing into the water in a 10-gallon fish tank. The beam was reflected by a mirror on the bottom of the tank and also could be observed as it left the water. The beam of light was produced by a 500-watt film-strip projector arranged to produce an approximately parallel beam of light which was 0.25 inch in diameter at the place where it could first be observed. In order to improve the visibility of the beam of light, chalk dust was knocked out of a blackboard eraser over the tank. In this condition the pupils were free to observe the beam of light from different angles.

In addition, pupils were given a demonstration of the phenomenon of the visual displacement of an underwater object which involved two identical tanks and were shown that when water was added to one of the tanks, the apparent position of a coin on the bottom appears to move upwards and also away from the pupils. They were shown how the position of a coin in an empty tank had to be changed to make it appear to be in the same relative position as a coin in a similar tank partly filled with water.

IV. Visually Compressed Information plus Verbal Information Preceded by an Orienting Problem--This teaching condition was the same as Condition II but pupils were first given a problem to point out some of the practical implications of the principle of refraction. In this problem the pupils were told the story of an explorer who had to cross a river but who first had to shoot and kill a crocodile three feet below the surface and 20 feet from the explorer. The pupils were then asked to indicate on a diagram the point on the surface of the water where the explorer should aim. Pupils were not told whether their solutions were right or wrong, but the purpose was only to focus attention on a practical problem involving the phenomenon of refraction.

Half of the subjects of each training condition were required to undertake a written test in which their task was to verbalize aspects of the information given. The other half of the subjects proceeded directly to the testing situations.

In the case of some of the groups of subjects run early in the experiment, every fifth subject was assigned to a control group that was given no training, but proceeded immediately to the testing situation. The function of this group was to determine whether training did produce learning.

Test Conditions

The tasks used to measure differences in the amount of transfer resulting from each of the four training conditions involved the activity of shooting at a target under water. The task was similar to that used in the previous studies of Judd (1908) and Hendrickson and Schroeder (1941), but certain important modifications were made. First, the testing situation involved a mock pistol mounted on a stand in such a way that only the angle of elevation could be varied. The target object was immersed in a large tub of water and the surface of the water in the tub was covered with a rigid plastic sheet on which was marked a numbered grid. The pupil in the test situation did not actually have to shoot but was required only to indicate the numbered line on the grid at which he was aiming. This procedure was designed to eliminate differences in the ability to aim and shoot a gun which would have contributed substantially to the error term in the subsequent analysis.

Each subject performed two similar tests which differed in that the water was deeper in the second test (9 inches in comparison with 5 inches), and the second test involved a more oblique viewing of the object under water. In the first test the lower edge of the tank was 31 inches horizontally from the gun stand and the gun itself was 39.5 inches above the floor, but in the second test the horizontal distance was increased to 47.5 inches and the vertical height to 48.75 inches. The second test also involved a different shaped target and tub from the first and was administered in a different room. The second test appeared to involve a more difficult task than the first test.

Subjects were instructed before the tests that each time they reported their point of aim they would be told either "hit," "miss," or "bullseye." They were also told that a "bullseye" meant that they had hit the very center of the target while a "hit" meant that they had struck some part of the target but not the center area. They were also told the depth of the water for each test. Each subject was allowed up to 12 shots to find the bullseye. Those who hit the bullseye before the twelfth shot had the task terminated.

Subjects were tested individually and while each was asked not to give away the answer to other pupils some effort was made to arrange the procedure so that the pupils returned to their classes after the testing where little opportunity to discuss the experience was provided. In one of the early tryouts of the materials, leakage of information concerning the correct place to aim the gun was identified as a serious problem.

A small group of subjects run as a control group without any training had to be given special instructions as follows: "Underwater objects, when viewed at an angle from above, do not really lie in the exact position that they appear to lie. Knowing this fact, your task, now, is to aim the pistol so that a bullet from it would strike the underwater target."

Subjects

Subjects (N=215) were fifth, sixth, seventh, and eighth graders drawn from three public schools in Salt Lake City, Utah, as follows:

1. Stewart School (campus demonstration school, K-IX) Grade VIII, 40 pupils; Grade VII, 40 pupils, Grade V - VI (combined grade), 32 pupils.

2. Wasatch School (middle class, K-VI) Grade VI, 39 pupils.

3. Whittier School (lower middle class, K-VII) Grade VII, 32 pupils; Grade VI, 32 pupils.

The grade VII and VIII pupils from the Stewart Demonstration School (N=80) served as pilot subjects and eight of them provided the control group given no training. Their test results suggested several modifications in the experimental conditions viz., the importance of controlling for information leakage among subjects, and the desirability of increasing the difficulty

TABLE 7.01

NUMBER, SEX, AGE AND I.Q. OF SUBJECTS, BY SCHOOLS

School	Grade	N	Sex		Age Range	$\bar{X}$	I.Q.	$\bar{X}$
			M	F		Age	Range	I.Q.
Wasatch	VI	32	16	16	11-3 to 12-2	11-7	103-133*	117.62
Stewart	V-VI	32	16	16	11-0 to 12-3	11-7	101-131**	113.11
Whittier	VII	32	16	16	11-11 to 13-4	12-8	103-127*	113.72
	---	96	48	48	--------	----	-----	----

*Pintner Intermediate

**WISC

of the second test of transfer. In addition, the pilot group served to show that differential amounts of learning were occurring among training conditions, and that, therefore, the project was worth pursuing.

Of the remaining 135 subjects, one complete block of 32 was dropped (Whittier School, Grade VI,) since their scores indicated that no learning had taken place. Although no definite reason for their chance-level scores can be given, the authors hypothesize that the lack of learning was due to the unsophisticated level of the subjects, and the high anxiety level which appeared to be generated among them by having to take part in a mysterious activity which involved, among other things, being called down to the Principal's office (the rendezvous point), being lined up outside the nurse's office (one of the testing stations), and the anxiety generated by having measures taken of their learning (although in all cases subjects were assured that their scores would be known to no one in the school and would never form any basis for a report card mark.)

Of the remaining 103 subjects, seven from Wasatch served to provide some of the control data. The data in Table 7.01, therefore, are based on 96 subjects - 16 boys and 16 girls at each of the three schools.

The 96 subjects undertook the experiment at their respective schools. At each school subjects were pre-selected in the sense that pupils with I.Q.'s either below 100 or much above 130 were not considered and equal numbers of boys and girls were assigned to each training condition. Subjects within each school were then randomly assigned to one of the four training conditions.

Results

The two main measures obtained from each subject were the scores for Transfer Tests I and II. These scores were converted to error scores by subtracting the value of the criterion aiming point from the value of the point of aim for each shot.

Figures 7.01 and 7.02 show the learning curves which resulted for Tests I and II. These curves give the impression that no differences between treatments occurred on Test I but that differences did occur on Test II, a finding which corresponds closely with that reported by Judd (1908). On test II the Realistic Condition and the condition involving compressed visual material preceded by a realistic problem were superior to the other two. An arbitrary decision was made to run analyses on the scores of the first seven shots only, since scores obtained on shots beyond this point inevitably show a declining effect of group differences. One presumes that

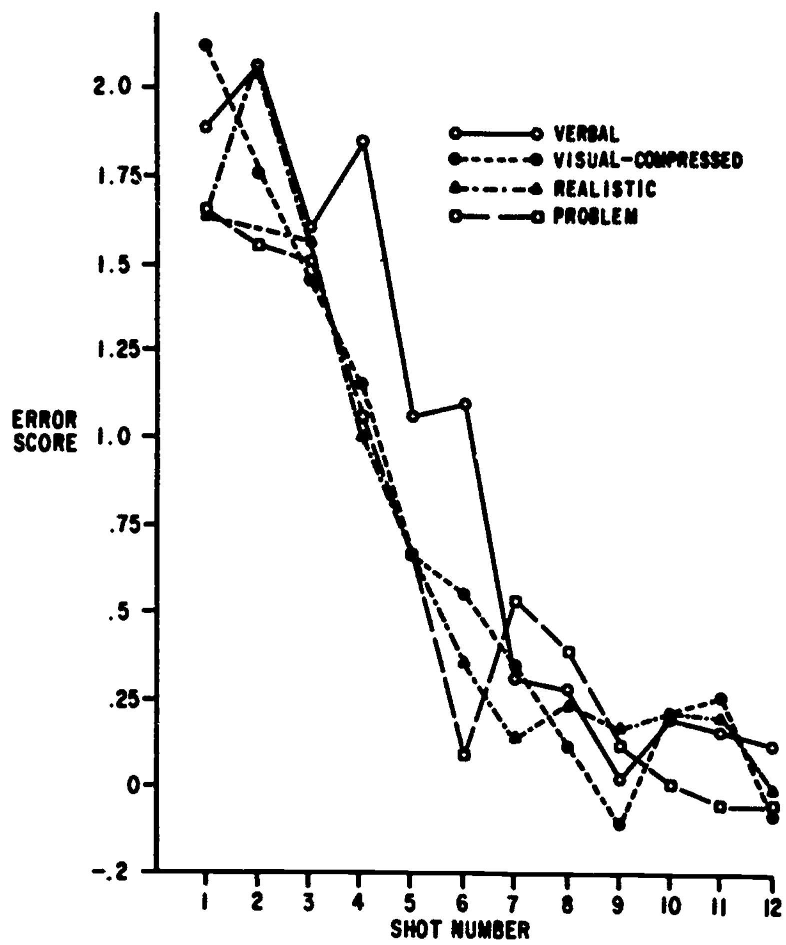

Figure 7.01. Test 1 learning curves showing each condition separately.

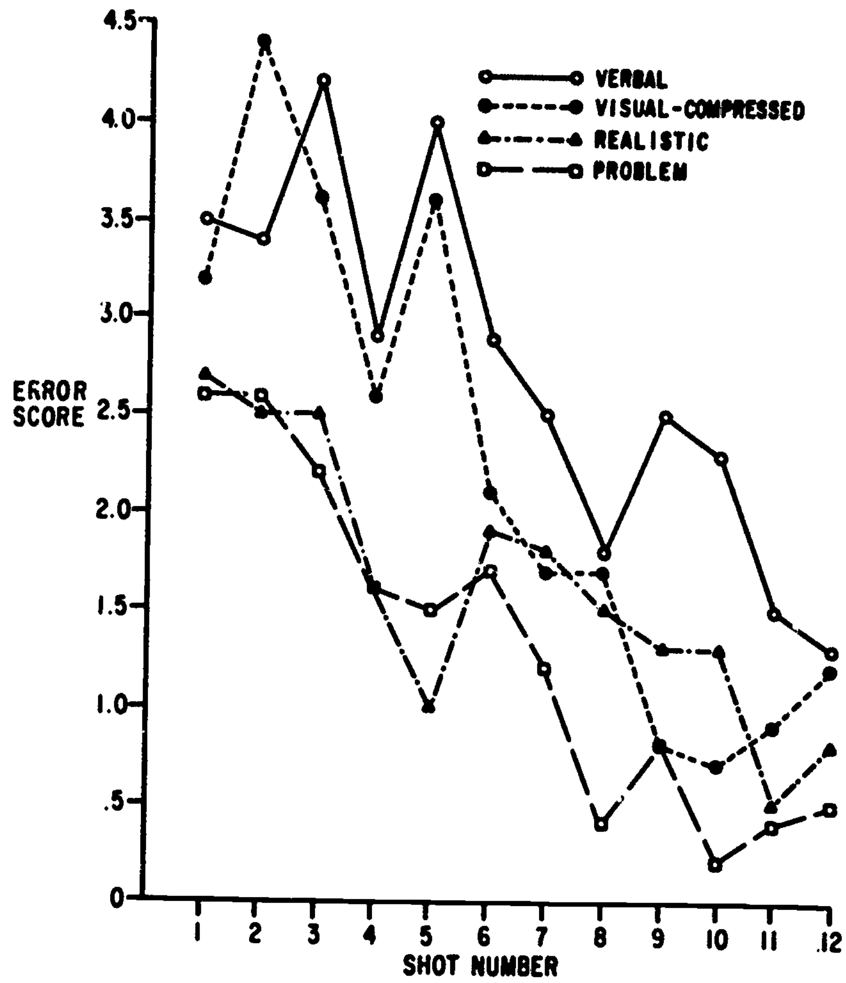

Figure 7.02. Test II learning curves showing each condition separately.

if the testing trials were to be continued long enough that all subjects would achieve perfect scores. In addition, by shot number 7 most members of most treatments had achieved criterion and, thus, shots beyond this point tend to be weighted heavily by the scores of one or two subjects who showed little or no learning. Obviously, too, with a sufficient number of shots, curves of all four treatments would eventually coincide and differences between treatments would disappear.

Control data, used for establishing a baseline from which the amount of learning resulting from instruction could be estimated, was obtained from a block of eight control subjects in the pilot group and a second block of seven subjects drawn from one of the experimental schools. These subjects were merely given Tests I and II, and apart from a small amount of information contained in the initial sentence of their instructions for Test I, they received no instruction or information relating to refraction or displacement. Comparisons were made between the control and the experimental groups using error scores of shots 1=7. Significant differences were obtained between the error scores of the control groups and the error scores of the experimentally trained groups, on a t-test, as shown in Table 7.02.

Table 7.03 gives means and standard deviations for error scores on Test I and Test II respectively for each of the training groups. Error scores appear to be preferable in many ways to scores provided by trials to criterion. Error scores provide a more symmetrical distribution and can be derived from that part of the learning curve where differences between groups are a maximum. An analysis of variance was made of Test I error scores, numbers 1-7, and also of Test II error scores, numbers 1-7. The results are summarized in Table 7.04. It is apparent from Table 7.04 that Test I showed no significant differences between treatments, or between those who verbalized and those who did not, or between male and female subjects. These results, coupled with those of Table 7.02 comparing the control and experimental groups. might appear to indicate that, although teaching pupils information facilitates performance in a task requiring application of that information for its solution, the manner in which the information is taught is of little consequence. However, the analysis of variance of the scores of the more difficult Test II shows a different picture. Here the difference due to treatments is significant at the .06 level of confidence. Application of a Duncan's New Multiple Range Test shown in Table 7.05 does not provide a particularly clear picture since the difference between the realistic and the visually compressed learning conditions is of marginal significance. A t-test comparing the two conditions was significant at the .06 level.

In addition, in the Test II analysis of variance a Verbal-Non-Verbal main effect reached the .08 level of significance in favor of the verbal condition.

TABLE 7.02

COMPARISON OF CONTROL MEAN WITH THE MEAN OF CONDITIONS I-IV OBTAINED IN TEST I

	School	Control Mean (N = 15)	Combined Experimental Mean (N = 64)	df	t	p (two-tailed)
1. Error Scores shots 1-7	Wasatch Gr. VI Stewart Gr. VII	2.41	1.18	77	2.90	<.01
2. Trials to Criterion	Wasatch Gr. VI Stewart Gr. VIII	8.45	5.45	77	3.28	<.01

TABLE 7.03

MEANS AND STANDARD DEVIATIONS OF MEAN ERROR SCORES FOR PERFORMANCE ON TEST I AND TEST II (N = 12 FOR EACH CELL)

Learning Condition	Test I				Test II			
	Group Required to Verbalize		Group Not Required to Verbalize		Group Required to Verbalize		Group Not Required to Verbalize	
	M	SD	M	SD	M	SD	M	SD
I. Verbal Information Only	1.60	1.49	1.24	1.70	2.32	2.43	4.34	2.62
II. Visually Compressed Information plus Verbal Information	1.36	.80	.99	.64	2.99	1.26	3.19	2.34
III. Realistic Demonstration plus Verbal Information	.62	.76	1.54	1.16	1.45	1.19	2.58	2.79
IV. Problem plus Learning Condition II	.52	.95	1.54	1.55	1.94	2.39	1.87	2.36

TABLE 7.04

ANALYSIS OF VARIANCE OF TEST I ERROR SCORES FOR CONDITIONS I - IV AND SHOTS I - 7

Source	df		Test I MS	Test I F	Test I p	Test II MS	Test II F	Test II p
Between Subjects	95							
Learning Condition - C		3	4.92			89.53	2.64	.06
Verbal - Nonverbal		1	15.48	1.60	n.s.	113.40	3.34	.08
Male - Female		1	14.88	1.54	n.s.	70.70	2.08	n.s.
C x V-NonV		3	25.04	2.59	n.s.	38.10		
C x M-F		3	14.80	1.53	n.s.	71.40	2.10	n.s.
V-NonV x M-F		1	9.29			46.10		
C x V-NonV x M-F		3	10.52			20.33		
Subjects within cells		80	9.68			33.95		
Within Subjects	576							
Shots		6	34.41	18.70	.01	32.33	7.14	.01
Shots x C		18	1.17			5.54		
Shots x V-NonV		6	0.42			8.53	1.88	n.s.
Shots x M-F		6	0.08			4.22		
Shots x C x V-NonV		18	1.11			4.54		
Shots x C x M-F		18	1.06			7.12		
Shots x V-NonV x M-F		6	1.06			3.63		
Shots x C x V-NonV x M-F		18	3.47	1.89	.05	8.62	1.91	.05
Shots x Subjects within cells		480	1.84			4.52		
Total	671							

TABLE 7.05

SUMMARY OF THE DUNCAN'S NEW MULTIPLE RANGE TEST
COMPARING THE MEANS OF THE TEST II ERROR SCORES
FOR CONDITIONS I - IV AND SHOTS 1 - 7

Treatment	IV	III	II	I
Mean	1.90	2.01	3.09	3.33
Conditions				
Problem (IV)	---	n. s.	<.10	<.05
Realistic (III)		---	<.10	.05
Visual-Compressed (II)			---	n. s.
Verbal (I)				---

Discussion

The results obtained would appear to confirm the findings of Judd, and Hendrikson and Schroeder, that knowledge of a pertinent principle facilitates performance in a task requiring application of that principle. Furthermore, the results obtained from the analysis of variance Test II scores would appear to indicate that when a transfer task is sufficiently difficult, the amount of transfer evident is related to the manner in which the relevant principle is taught.

The results indicate that one of the significant variations in manner of teaching is the presence or absence of irrelevant information, i.e., in terms of performance on Test II, the realistic condition (III), with all its irrelevant cues, is significantly better than the visually compressed condition (II), which has had most of the irrelevant visual cues removed.

However, we must note that teaching conditions II (visually compressed) and IV (problem) are identical, except for the introduction of a problem to establish set as the initial phase of Condition IV, and yet Condition IV results are significantly better than Condition II results. It would appear obvious then that it is not the presence of irrelevant information alone which can account for the facilitation of the application of the principle to a new situation. The establishment of a set, prior to dealing with the visually compressed material, appears also to have had the same facilitating effect upon performance as the presence of irrelevant information in the realistic condition (III).

How can the failure of the visually compressed treatment (II) be explained? Probably, on occasion, line drawings compress information in a psychologically inappropriate fashion, or actually eliminate relevant information.

However, even if this were true of the line drawings used here, we are still left with the task of explaining why the mere act of preceeding Treatment II with a rather simple problem, for which, and from which subjects received no feedback, should have had such a facilitating effect. If we assume that some set was established and that somehow some process of selective attention was aroused we must still ask such questions as:

1. Does the establishment of a set somehow permit subjects to reshape inappropriately compressed information into an appropriately compressed form?

2. Does the establishment of a set inevitably provide additional relevant information?

Perhaps a clue to the solution of the problem lies in the second of these questions. Berlyne (1960) notes that one of the factors affecting processes of selective attention is a class of stimulus events which he labels indicating stimuli, a class which includes verbal directions. It is logically conceivable that the establishment of set serves to arouse processes of selective attention similar to those aroused by Berlyne's indicating stimuli. If this were so, possession of an appropriate set might serve to permit subjects to select out from the stimulus complex those stimulus elements which contained the most information. These highly loaded pieces of information to which he has now directed his attention may, in turn, serve to permit subject to process the remaining information in a manner different from another subject who, lacking set, perceives the stimulus complex in a relatively unselective fashion. In other words, we are really suggesting that provision of a set may be comparable to the provision of additional information. Reese (1964) has discussed the phenomenon of performance set which would also appear to be closely related to the point of view expressed here.

An explanation of the facilitating effect of set, such as the above, however, seems to do little to explain the apparent facilitating effect of irrelevant information, which was evident in the realistic treatment (III). One clue did emerge from the written answers provided by the verbalization task. Several of the written answers of pupils exposed to the conditions which used line drawings stated that the coin appeared to move "to the right side, and slightly closer to the surface of the water." Subjects who provided this type of answer appear to have failed to differentiate between those drawings which showed an end elevation and those which showed a side elevation. This confusion was not evident with subjects in the realistic treatment. In addition, inasmuch as the criterion tests, involved a form of depth perception and inasmuch as depth perception is dependent on three dimensions, or the illusion of three dimensions, it is possible to hypothesize that the visually compressed treatment, lacking a third dimension, or even the illusion of a third dimension, actually was deficient in relevant information as compared with the realistic treatment.

The third variation in training conditions investigated in this experiment was provided by the Verbalization-Nonverbalization conditions, wherein one-half of the subjects of each treatment were required to give written answers to two questions relating to the information to which they had just been exposed. No significant differences between the Verbalization-Nonverbalization groups appeared in Test I. In Test II, a difference favoring the group who verbalized did appear, but was significant only at the .08 level. This, however, would suggest the possibility that verbalization prior to a transfer task of sufficient difficulty may facilitate performance.

Finally, we must ask why transfer was very much the same for all the experimental training conditions in the initial transfer test. Judd, himself, noted a related phenomenon in his original experiment and attributed it to the fact that his subjects were still learning to throw the darts. As very little learning of an "aiming" nature was required in this present experiment, his explanation would seem not to apply. Henrikson and Schroeder concluded from their experiment that possession of knowledge did facilitate transfer in the initial task. However, an examination of the results on which they base this conclusion shows that, by present day standards, their differences between the control group and the two experimental groups, or between the two experimental groups themselves, were not statistically significant.

Throughout the discussion, to this point, we have observed that certain variations in training conditions appear to have a notable facilitating effect on performance of a more difficult second task. If we are correct, and if we find no facilitating effect of these same variations, in training conditions upon a similar but less difficult task, we would appear to be justified in concluding the following: Subjects in all experimental treatments learned enough to solve the relatively easy Transfer Task I, i.e., for its solution it required relatively little learning and this minimal amount of learning was provided for by all four treatments. In contrast, Test II, being considerably more difficult, required a level of learning for its solution which had been acquired only by those subjects exposed to Conditions III (realistic) and IV (problem).

However, at least two other possibilities may be considered. The first of these is that the scores on Test I were at the chance level for all treatments. That is, having fired at the visual target and being told that it was a "miss", as many subjects would then proceed to lower their point of aim as would proceed to raise it. As aiming below the apparent target as little as one point of the scale on the grid, would result in a "hit", those who lowered their aim would soon be on their way to a "bulls-eye". Although the comparison of control scores with treatment scores shown in Table 7.02 would seem to discount this possibility of chance level performance, we much recognize that control data for this experiment is somewhat deficient both in number of subjects and in comparability.

The second possibility is related both to the difficulty of Test II and and to its position. While performances in Test I were essentially the same for all experimental groups, only subjects of Conditions III (realistic) and IV (problem) were able to benefit substantially from the learning experience which resulted from participation in Test I. That is, we might hypothesize that, because of their exposure to a particular type of instruction subjects were able to process the feedback which they received while participating in Test I differently from those subjects who had received a different type of instruction. Thus, while all subjects, in effect, went into Test I with equal ability, those who had earlier received instruction in Condition III and IV emerged from Test I with superior ability.

In the light of the results reported and discussed above, we may conclude tentatively that the most efficient conditions for transfer exist where irrelevant cues present in the testing conditions are also present in the training conditions. To generalize further, we might hypothesize that, the most effective learning, as regards transfer, occurs in the presence of irrelevant cues. To test this hypothesis we must verify whether the negative effect of the visually compressed treatment was due to the particular line drawings used, or whether it was due to the absence of irrelevant cues, per se. Secondly, we must ask ourselves what is the relationship between the presence or absence of irrelevant cues in the training situation and the presence or absence of irrelevant cues in the test situation. To answer these questions a second experiment was designed.

EXPERIMENT II

VARIATION IN THE AMOUNT OF IRRELEVANT CUES IN TRAINING AND TEST CONDITIONS AND THE EFFECT UPON TRANSFER

In the previous experiment, the realistic treatment consisted of an actual demonstration of (1) the refraction of light rays entering and leaving water, and (2) the apparent displacement of an underwater object, when viewed at an angle from above. For this demonstration three-dimensional physical apparatus was used, and the verbal components of the instruction were transmitted by prerecorded tape. For the visually compressed treatment the same tape was used, thus ensuring that the verbal information was constant for each treatment, but the visual components of the demonstration of refraction and displacement were taught using life-sized, four-color line-drawings, designed to exclude all information or cues judged to be irrelevant.

One interpretation of the results of the previous experiment is that training with compressed information fails to give the learner experience in dealing with situations involving many irrelevant cues. This interpretation suggests that the person who learns to understand a principle in the absence of irrelevant cues has more difficulty in applying the principle to a situation involving many irrelevant cues than he would have had if the original learning had been undertaken in the presence of irrelevant cues. The suggestion is that the advantage of learning under realistic conditions is that such conditions generally involve many irrelevant cues. Simplified situations, such as are presented by diagrams, do not involve irrelevant cues and, hence, may provide inefficient teaching situations. The study which follows represents an attempt to investigate further the extent to which learning either with or without irrelevant cues facilitates transfer to new situations which also may be either with or without irrelevant cues.

Method

Design and Materials. -- The experiment involved two 1 x 2 x 2 x 2 x 12 factorial designs, each comprising one training condition, two sexes, two test conditions, two tests within each test condition and twelve repeated measures within each of the two tests.

Training Conditions. -- Of the two training conditions, one was identical to the realistic condition of the earlier experiment (i.e., the demonstration of refraction and displacement was conducted with actual physical apparatus and no effort was made to control for the presence of irrelevant cues) and for purposes of this experiment is designated here as Training Condition Positive (TC+). The second training condition, designated Training Condition Negative (TC-), used identical apparatus to TC+ except that every effort was made to remove or minimize irrelevant cues. To this end large black screens were built to screen off much of the apparatus and to provide a neutral background. Sections of the apparatus were coated with flat black paint to eliminate reflections and to minimize edges and surfaces of the apparatus. All ancillary apparatus such as light source, water pail, dust making apparatus (used to make light beam show up in air) were all partially or completely screened from the subjects. The subject viewing the demonstration in this training condition could see little except the light beam passing through the air and water.

In both the negative and positive training conditions, the identical sound track transmitted the verbal component of the instruction, this sound track being the same one which had been used for the realistic treatment of the previous experiment.

Testing Conditions. -- After training, subjects were exposed first to one of two test conditions. This first test, regardless of condition, is referred to as Test 1. They were then exposed to one of two conditions in a second test, referred to as Test II. Both Tests I and II involved the problem of aiming a pistol correctly at an underwater target which, because of the refraction of light, did not really lie where it appeared to lie.

Of the two test conditions, the one designed Test Condition Positive (Test +) was very similar to the test conditions of the original experiment. It was, however, somewhat embellished in that realistic pistols were substituted for the former plain wooden guns, new target objects suggestive of real organisms (a fish and a tadpole) shown in Figure 7.03 replaced the former simple cross and circle, and the numbers on the plastic grid (used to permit subjects to call off their point of aim) were represented both in red and blue, as opposed to being merely blue in the original experiment. Thus a number of new irrelevant conditions were introduced into this training condition.

In the other test condition, designated as Test Condition Negative (Test -), subjects were exposed to several modifications designed to eliminate or minimize all possible irrelevant cues. First, the tests of the negative condition were conducted in darkened rooms, so that as little as possible of the general surroundings were visible; second, the size and shape of the test tanks were obscured by covering the tanks with black cloth, in which was cut an aperture just large enough to permit the numbered portion of the grid to show. The target pistols were the simple wooden pistols of the first experiment, but were now covered with flat black paint. The target objects, as before, were the simple cross and circle shown in Figure 7.03. The only source of light was from a lamp placed under the black cloth so as to shine directly into the tank. Some light, naturally, escaped through the grid aperture and dimly illuminated the surroundings.

As in the previous experiment, each test condition comprised two tests, designated Test I and Test II. However, the difficulty of the two tests in this second experiment was increased by changing the water depth in the tanks and altering the angle of incidence of the gun to the water to increase the visual displacement between the actual target and the apparent target. The main purpose of this increased displacement was primarily to see if increasing the difficulty of Test 1 would modify the Test I results. In the previous experiment no differences among training conditions on Test I were found and it was hypothesized that this might have been due to the first test having been too easy, thus resulting in scores which approximated a chance distribution.

Procedure. -- Subjects (N = 96) were sixth grade pupils, attending two elementary schools in a middle-class section of Salt Lake City. The group comprised 52 boys and 44 girls. As in the first experiment, subjects were pre-selected in the sense that those with IQ's below 100 or over 130 on the Pintner Intermediate were excluded. Pupils were randomly assigned to each experimental condition. The mean and standard deviations of the pupils in each treatment are shown in Table 7.06.

The procedure followed was very similar to that of the first experiment. Each of the four groups, each group comprising thirteen males and eleven females, reported to the teaching station where they were exposed either to the negative training condition or to the positive training condition. Upon completion of the teaching program the group was then divided and one-half of the subjects reported to the Negative Test Station and and the other half reported to the Positive Test Station. Subjects entered the Test I area of their respective stations individually, and were given a printed sheet of directions which read as follows:

> "You have just learned that underwater objects, when viewed at an angle from above, do not really lie in the exact position that they appear to lie.
>
> "Remembering this fact, your problem, now, is to aim the pistol so that a bullet from it would strike the underwater target. The depth of the water over this particular target is 5-3/4 inches.
>
> "The plastic grid over the target has numbered lines marked on it. These lines will enable you to report your point of aim to the attendant.

"When you have reported your point of aim, the examiner will say one of the following: 'HIT,' 'MISS,' or 'BULLSEYE.'

"'HIT' means that you have hit some part of the target, either above or below the center of it.

"'MISS' means that you have not struck any part of the target.

"'BULLSEYE' means that you have struck the very center of the target. Your object is to score a bullseye in as few shots as possible. You are to go on shooting and reporting your shots as quickly as possible until the attendant tells you to stop.

"Any questions?"

The instruction sheets, to subjects at the negative and positive stations, were identical except that in each case the appropriate target was drawn on them. Subjects were invited to question the attendant about the instructions if they were in doubt on any point. Subjects then aimed the gun so as to attempt to hit the underwater target, indicating their point of aim by reference to the numbered plastic grid, and the attendant provided feedback by saying, "Hit," "Miss," or "Bullseye," whichever was appropriate, after each shot. Subjects, as before, were permitted 12 trials in which to achieve criterion. If they did so before the twelfth trial, they proceeded to the Test II cubicle where they were presented with the following instructions:

"Your task here is similar to the one in the other room. You are to aim the pistol so that a bullet from it would strike the underwater target. The depth of the water over this target is 8-1/2 inches, that is, it is deeper than in the previous task. As before, you will be told 'HIT,' "MISS,' or 'BULLSEYE.' Any questions?"

As with Test I, the instructions for negative and positive conditions were identical except for the appropriate target representations.

Results

As in the earlier experiment, each subject's scores on Test I and II were converted to error scores by subtracting the value of the criterion aiming point from the value of the point of aim for each shot.

Figure 7.04 shows the learning curves which resulted from Test I, Training Condition Positive, and Figure 7.05 shows the Test I learning curves resulting from Training Condition Negative. Figures 7.06 and 7.07 show the Test II learning curves for Training Conditions Positive and Negative, respectively.

Examinations of the curves themselves and of the tables from which the curves were constructed indicated that a majority of subjects had achieved criterion by shot number 7, and that the learning curves from shot number 7 on, tended to be weighted heavily by the scores of one or two subjects who had shown little or no learning, and who in some cases, by this stage, were resorting to wild guessing. On this basis the same arbitrary decision was made, as was made in the earlier experiment, to run the analyses of variance on the scores of the first seven shots only.

The means and standard deviations on which subsequent analyses are based are shown in Table 7.07. Analyses of variance of the Test I error scores presented in Table 7.08 showed no differences between test conditions positive or negative for either of the training conditions. A significant difference between boys and girls did, however, occur for both Training Condition Positive ($p < .001$) and Training Condition Negative ($p < .01$).

The analyses of variance of the Test II error scores presented in Table 7.09 also showed no differences between positive and negative testing conditions when learning had occurred under Training Condition Positive. A sex difference was also evident ($p < .01$) with this positive training condition. The results of the analysis of the Test II scores from the negative, or visually compressed, training condition are in sharp contrast. Here, a difference, significant at the .06 level, did occur between positive and negative testing conditions, and no male-female differences were evident.

In order to provide a basis for comparing present results with the results of the previous experiment a *t*-test was run between Training Condition Positive, Test Positive and Training Condition Negative, Test Positive, which, in effect could be considered to be the training-testing combinations replicating the realistic - visual compressed conditions of the previous experiment. Although the difference between the means was in the anticipated direction, (i.e., TC + Test + better than TC -, Test +) the results were not significant, achieving a *p* of slightly less than .10, for a one-tailed test.

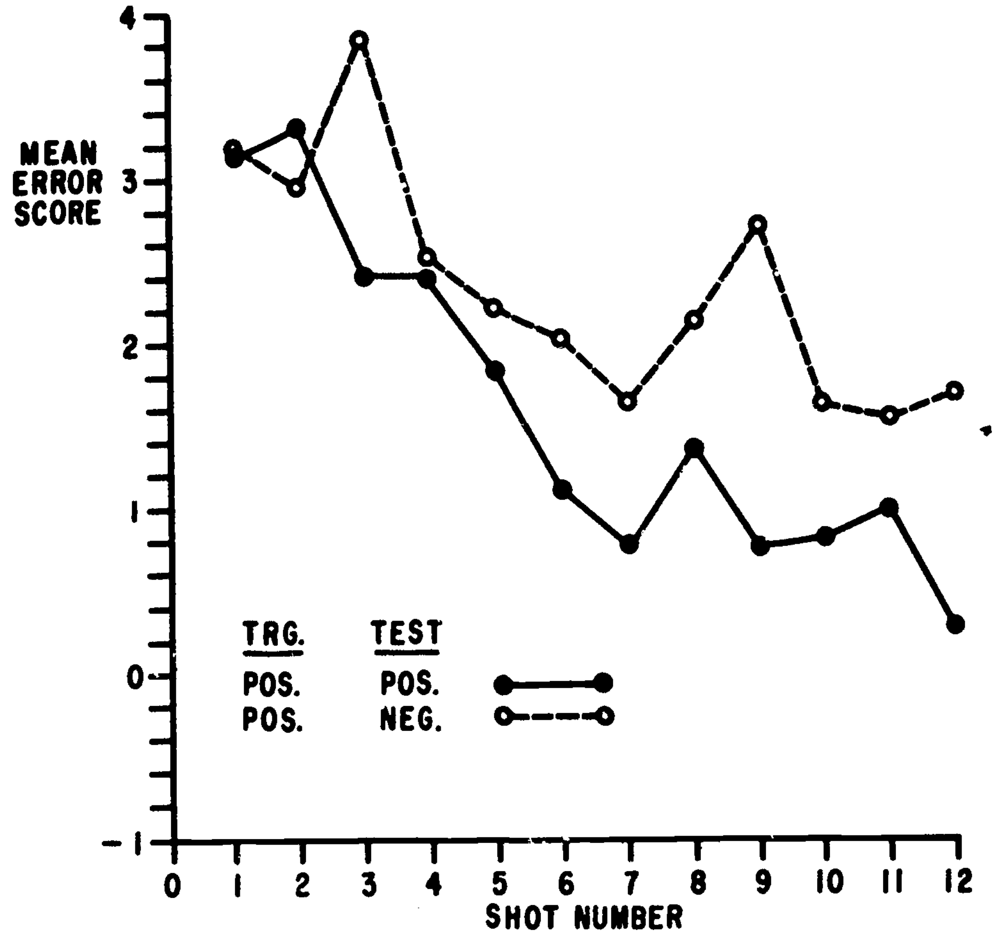

Figure 7.04. Learning curves for Test 1 for training condition positive.

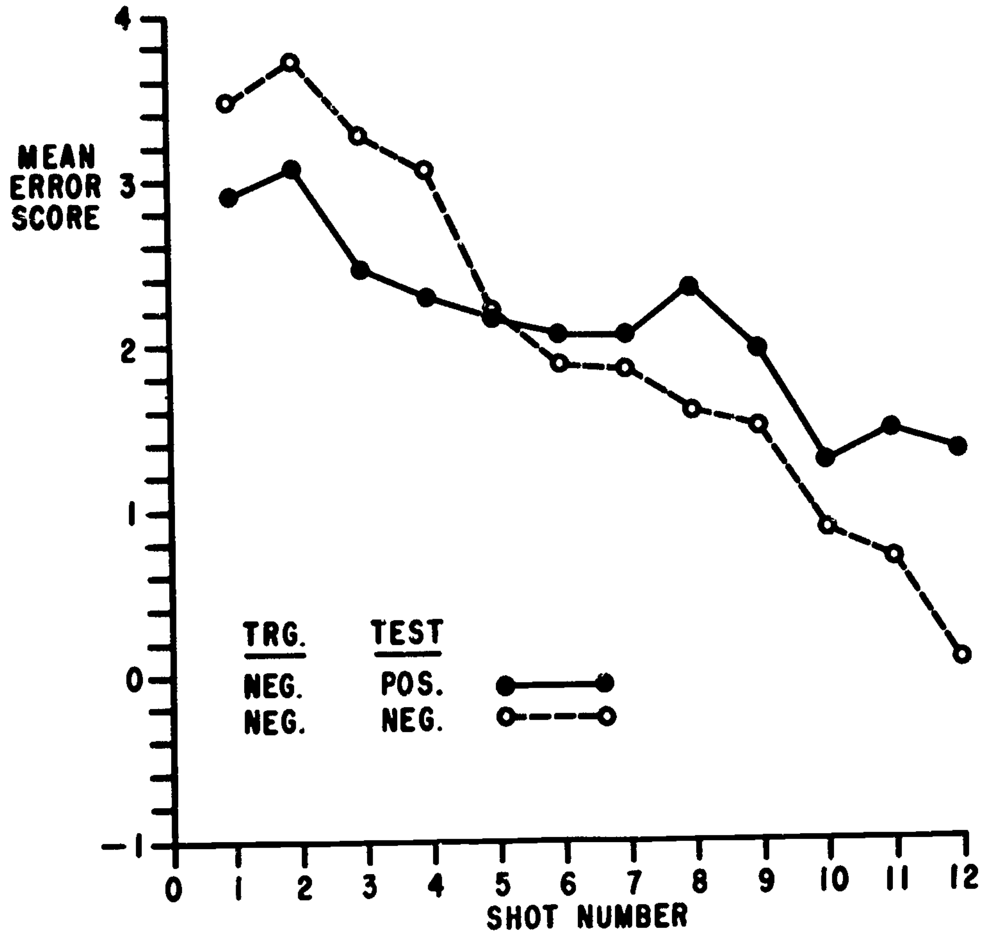

Figure 7.05. Learning curves for Test 1 for training condition negative.

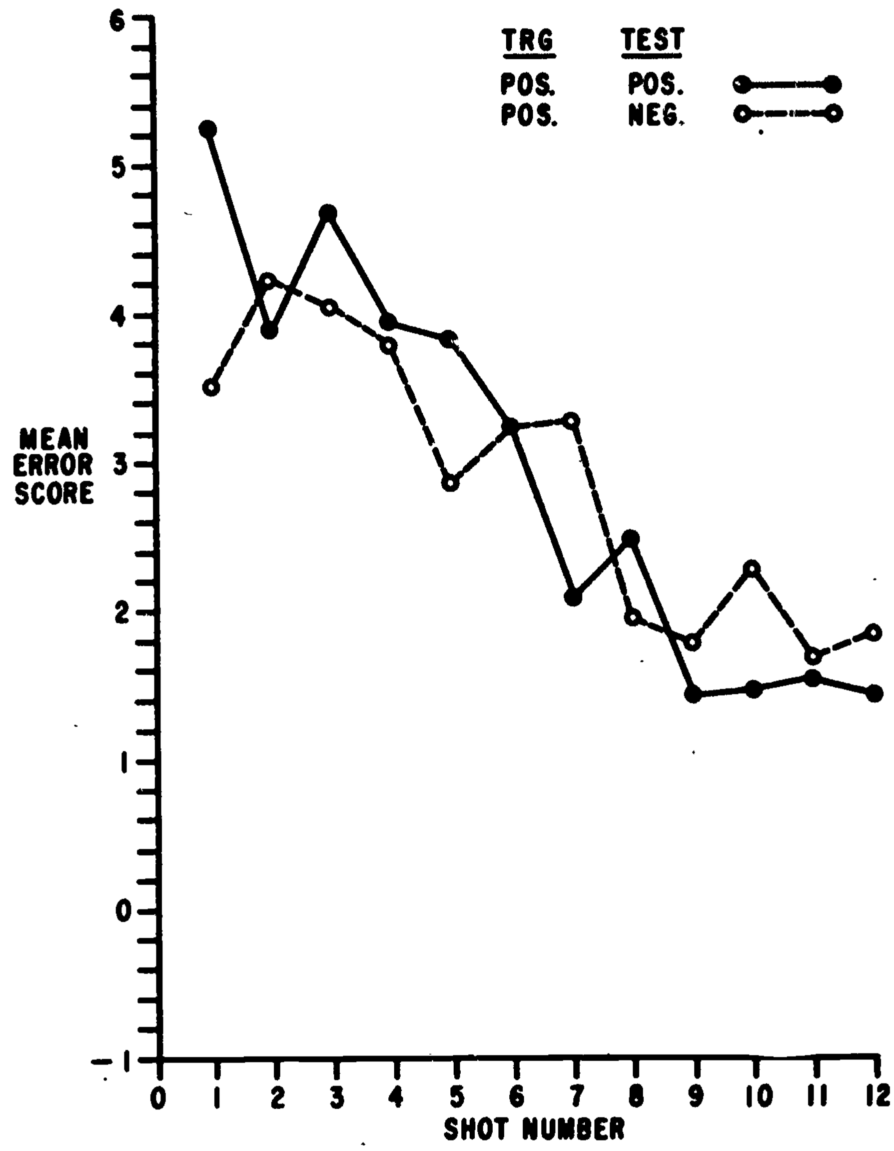

Figure 7.06. Learning curves for Test II for training condition positive.

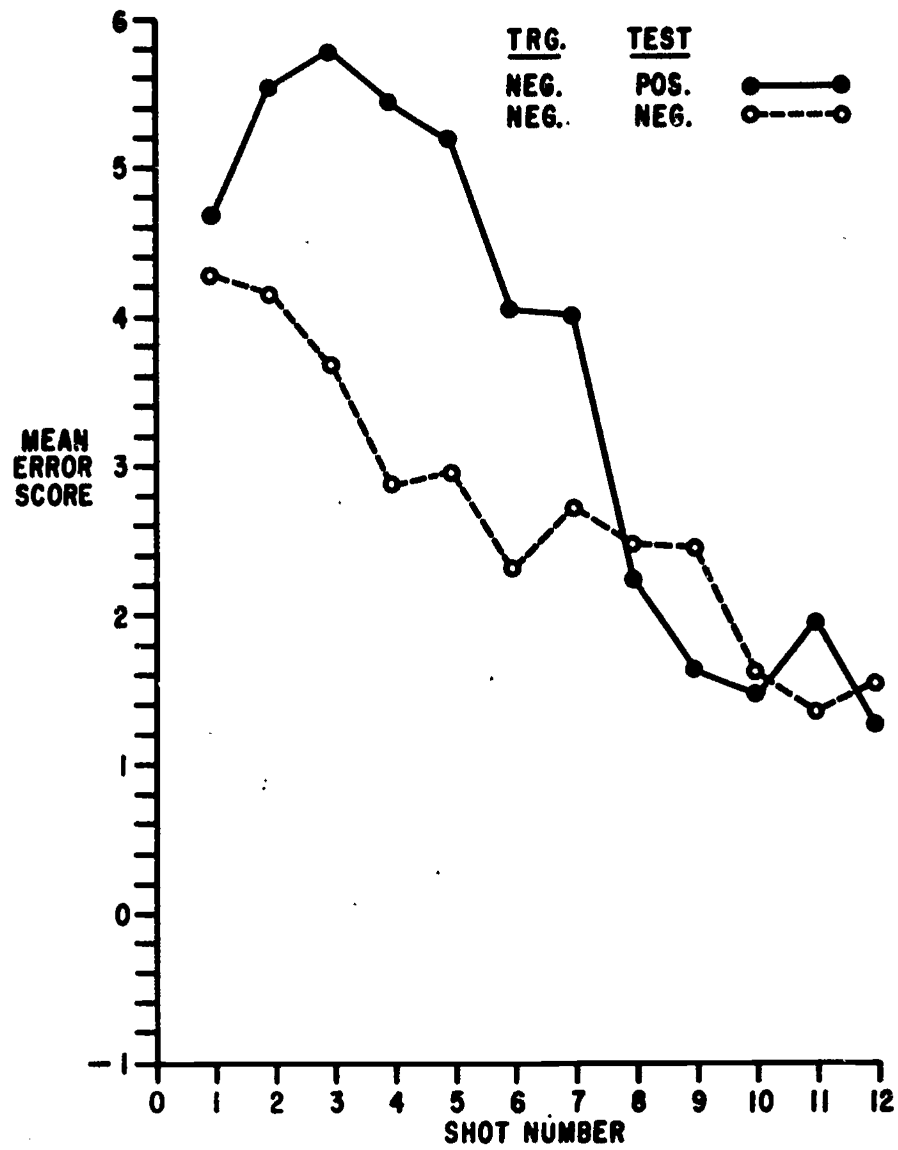

Figure 7.07. Learning curves for Test II for training condition negative.

TABLE 7.06

MEAN I. Q. OF ALL SUBJECTS BY TREATMENT

Treatment	$\overline{X}$ I.Q.	SD	N M	N F
Pos. Trg. - Pos. Test	112.58	7.89	13	11
Pos. Trg. - Neg. Test	115.12	8.32	13	11
Neg. Trg. - Pos. Test	115.92	10.23	13	11
Neg. Trg. - Neg. Test	114.21	9.49	13	11
			52	44

TABLE 7.07

MEANS AND STANDARD DEVIATIONS BY LEARNING CONDITION, TESTING CONDITION, SEX, AND TEST I AND TEST II

		Irrelevant Cues Added (Test +)				Irrelevant Cues Reduced (Test -)			
	Training Condition	Male M	Male SD	Female M	Female SD	Male M	Male SD	Female M	Female SD
Test I	Pos. Trg.	1.54	1.32	2.87	1.87	1.57	1.16	3.89	1.88
	Neg. Trg.	2.03	1.46	2.93	1.57	2.17	1.23	3.51	1.45
Test II	Pos. Trg.	3.55	2.48	4.19	2.42	1.71	2.35	5.73	3.69
	Neg. Trg.	4.59	3.08	5.40	3.53	2.84	2.71	3.80	2.43

TABLE 7.08

ANALYSIS OF VARIANCE FOR SCORES ON TEST I

	df	Training Condition Positive			Training Condition Negative		
		SS	MS	p	SS	MS	p
Between Subjects	(47)	1068.85			743.48		
Tests (Pos. and Neg.)	1	19.52	19.52		9.84	9.84	
Sex	1	276.96	276.96	<.001	104.48	104.48	<.01
Tests x Sex	1	20.52	20.52		3.73	3.73	
Subjects within cells	44	751.85	17.09		625.43		
Within Subjects	(288)	1089.54			1175.11		
Shots	6	183.99	30.66	<.01	97.42	16.24	<.01
Shots x Tests	6	28.27	4.71		14.58	2.43	
Shots x Sex	6	16.14	2.69		22.02	3.67	
Shots x Tests x Sex	6	21.78	3.63		44.61	7.43	
Shots x Subjects within cells	264	839.36	3.18		996.48		

TABLE 7.09

ANALYSIS OF VARIANCE FOR SCORES ON TEST II

	df	Training Condition Positive			Training Condition Negative		
		SS	MS	p	SS	MS	p
Between Subjects	(47)	3046.65			3009.52		
Tests (Pos. and Neg.)	1	7.29	7.29		236.68	236.68	.06
Sex	1	451.47	451.47	$<.01$	65.06	65.06	
Tests x Sex	1	237.28	237.28	$<.05$	.46	.46	
Subjects within cells	44	2350.61	53.4[illegible]		2707 32	61.53	
Within Subjects	(288)	2087.54			2779.72		
Shots	6	117.67	19.61	$<.02$	122.28	20.38	$<.05$
Shots x Tests	6	62.89	10.48		37.36	6.23	
Shots x Sex	6	36.56	6.09		59.80	9.97	
Shots x Tests x Sex	6	30.03	5.00		37.50	6.25	
Shots x Subjects within cells	264	1840.39	6.97		2522.78	9.55	

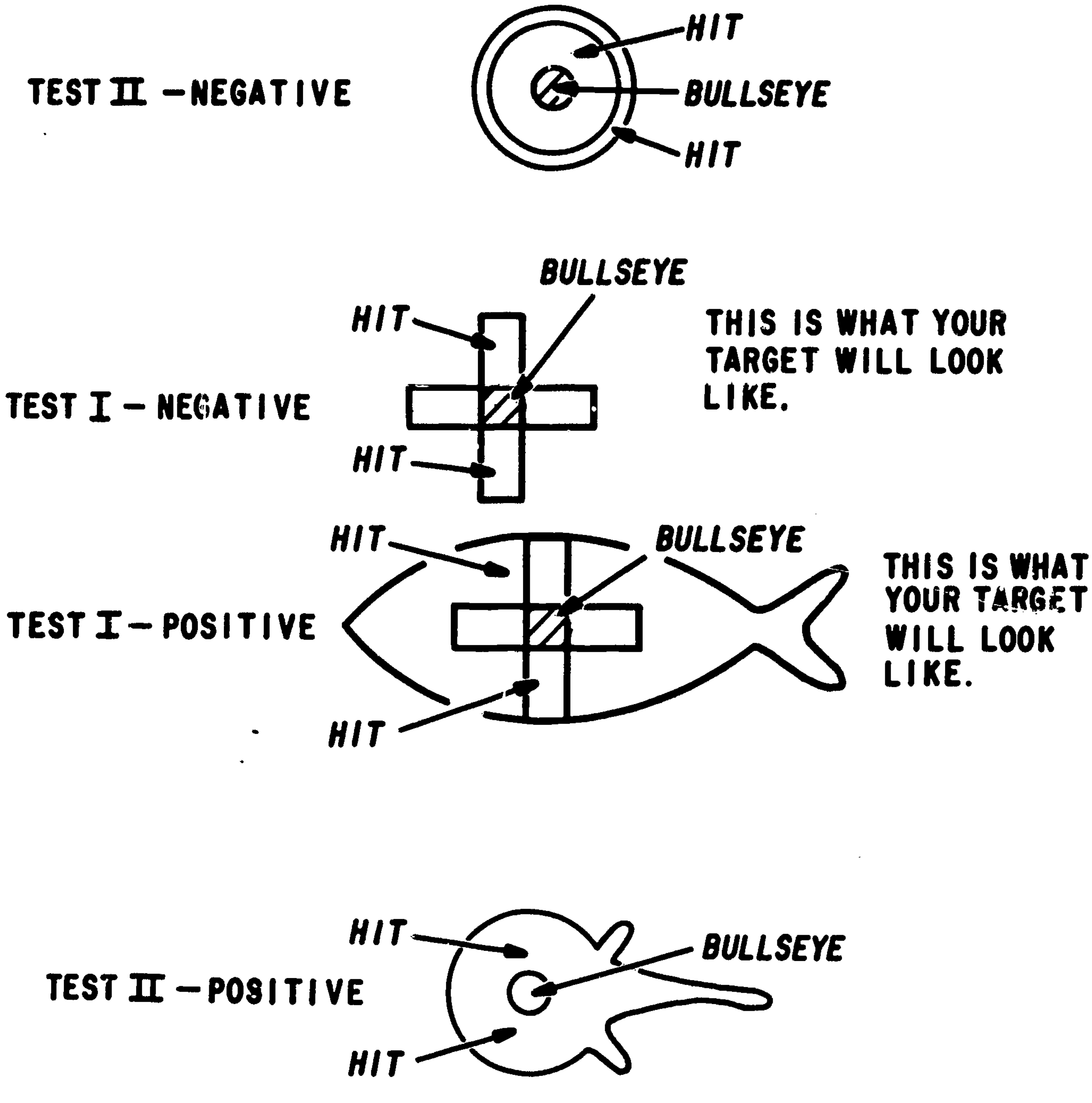

Figure 7.03. Targets used in Tests I and II as they appeared on the mimeographed sheets and as they appeared on the bottom of the tank.

Discussion

Examination of the learning curves for Test I shows that there were no differences in performance between those subjects trained under the condition with irrelevant information (TC+) and those subjects trained under the condition with reduced irrelevant information (TC-). This held true regardless of whether subjects were tested under the test condition with irrelevant information (Test +) or the test condition with reduced irrelevant information (Test -). This finding confirms the results of the previous experiment where no differences between conditions were observed on Test I. Also confirmed were differences between certain of the training-testing combinations of Test II. These Test II results would seem to suggest the following conclusions: Subjects trained under conditions possessing irrelevant information seem able to transfer their learning to test situations possessing irrelevant information, or alternatively, to test situations with reduced irrelevant information, equally well. However, subjects trained under conditions of visual compression, i.e., with reduced irrelevant information, are less able to transfer their learning to test situations possessing irrelevant information than they are to transfer learning to test situations with reduced irrelevant information.

Although the results of this experiment do not appear to confirm the earlier findings viz., that a TC+, Test+ combination is significantly better than a TC- Test+ combination, the reader should note that both the Training Condition Negative and the Test Condition Positive of this experiment were different from experiment 1. However, the significant difference between the TC-, Test- combination and the TC-, Test + combination do appear to add support to the original supposition that when irrelevant cues are encountered in the testing situation which were not present during training, the level of performance will be lower.

The male-female differences evident in the Test I results of both positive and negative training conditions, as well as in the Test II results of the positive training condition, but absent in the negative training condition, Test II, require some comment. The subject matter taught in this present experiment is of a scientific nature and in addition the particular transfer task used appears to be by its nature a "masculine" task comprising activities and apparatus more familiar to boys than to girls. Girls, accordingly, could be presumed to be at a disadvantage which was reflected in generally poorer performance. Why this difference between male and female performance should disappear in Test II of Training Condition Negative is a phenomenon for which we have no explanation. Speculation might suggest that confronted with a learning task that was relatively unfamiliar and of low interest, females were able to learn more from the less distractive training condition in which irrelevant information had been reduced, and thus were able to perform comparably to males. What is of interest and suggestive of further research is the fact that having seen this phenomenon in this experiment the authors returned to the data of the previous experiment and found a somewhat similar finding. That is, in Test II of this experiment, females trained under the condition in which irrelevant information had been reduced performed comparably to males.

Discussion of Experiments on Visual Compression

As far as the authors were able to determine, the experiments presented in this chapter represent the first that have been taken to evaluate the merits of compressed visual materials for instructional purposes. Although such materials are used extensively both for illustrating textbooks and for wall charts, the conditions under which they can be used effectively have not yet been established.

The argument on which these studies are based is that the mechanism of transmitting visual information in the nervous system involves the compression of the information arriving at the retina. This process involves both discarding of redundant information and the retaining of information pertaining to boundaries - information that is presumed to be of particular value to organisms negotiating their way around a complex environment. The assumption underlying the present series of studies was that the compression of information prior to reception by the eye would facilitate reception, since this procedure might spare the organism the task of discriminating relevant from irrelevant detail and would, hence, facilitate learning.

The argument seemed to be both simple and straightforward, but what it did not take into account was the possibility that the effective learning of a principle also involves discriminating between the relevant and the irrelevant aspects of the situation in which the principle is applied. When a principle is learned within a framework of compressed visual information, the subject has no opportunity to learn to discriminate relevant from irrelevant features of the situation for there are few irrelevant features present. The use of compressed visual information generally proved to be an ineffective method of teaching with the particular age group involved. While the teaching situation involving compressed information provided all the knowledge necessary for understanding the principle of refraction, the pupils were not able to apply the knowledge they had acquired to the solution of a new problem as effectively as those pupils who had been exposed to a teaching situation involving a real beam of light bending as it reached the surface of the water.

A particularly interesting finding is that the group that had contact with a realistic problem before being exposed to the compressed visual information was able to apply the knowledge acquired as effectively as the groups exposed to realistic training conditions. The data suggest that compressed visual information may be used effectively when the learner is familiar with the differences between the compressed information and the information that might be derived from a problem presented in a realistic setting. Under the latter conditions, the subject may learn to discriminate between relevant and irrelevant features of situations in which the principle is to be applied.

The findings of the first experiment concerning the value of compressing visual information for instructional purposes led to an exploration of the reasons why such material is effective. While the literature of audiovisual education has long praised the virtues of realistic presentations, few reasons are ever cited to explain why such should be the case. Our hypothesis was that one of the merits of learning in a realistic situation is that it provides the learner with practice in discriminating relevant information from irrelevant information. Such a discrimination has to be made when a principle that has been learned is applied in some realistic situation in which, inevitably, much irrelevant information has to be discriminated from relevant information. The second experiment provided data consistent with this hypothesis.

The two studies reviewed can, obviously, only begin to explore the conditions under which visual information can be effectively transmitted in a compressed form. Several conditions which might have been varied, but which were not, need to be explored. For example, one would expect that the age of the subjects would be crucial in determining whether compressed information could or could not be effectively used. Those who have studied the development of perception have generally voiced the opinion that, the younger the child, the more he has to learn in concrete situations. The ability to handle information abstracted from concrete situations is an ability which grows with age. The children used in the present study might be expected to have limited ability to deal with abstractions from naturally occurring situations, an expectation consistent with the findings presented here. One would also expect that children in the upper grades of high school who are above average in I. Q. sould have much less difficulty than our subjects in learning from compressed information. Additional experiments need to be undertaken involving the age variable.

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CHAPTER VIII

EXPERIMENTS WITH COMPRESSED VERBAL MATERIAL*

*The first two experiments reported in this chapter also appear in a doctoral dissertation by Robert Jester entitled "The comprehension of connected meaningful discourse as a function of individual differences and rate and modality of presentation," which is on file in the library of the University of Utah. The first experiment is also in publication in the Journal of Educational Research. The third study in the series was conducted by John Allen.

The compression of visual information, investigated in the previous chapter, presents clear-cut problems about which the specialist in the audiovisual field should be concerned with obtaining further information. In the case of verbal information, in contrast, the problems of compressing and storing information within the human organism are not understood. While substantial information exists concerning the manner in which the nervous system compresses and stores visual information, analogous knowledge is not available concerning the neural mechanisms involved in the internal processing of verbal information. There is agreement that most transmissions of verbal information provide a high degree of redundancy and the inference is commonly made that, prior to storage in the brain, some of this redundancy is eliminated. The function of redundancy appears to be that of compensating for the inadequacy of the auditory mechanism for analyzing sounds. Without redundancy auditorially transmitted messages would have a high degree of ambiguity. But once the message is received at the higher centers, the redundancy, having served a purpose, is no longer useful. At that point one would expect the surplus material to be discarded before storage takes place. Suppose that somebody confronts us with the statement "Jones is opening a jewelry shop downtown." This statement consists of seven words and suppose also that I want to store the essential information in it. I already know that Jones is a jeweler so all I have to store is the fact that he has a shop and it is probably unnecessary to store the information that it is downtown, for all the stores are downtown. If I were to record the information coded in the form "Jones has shop," I would have st. the essence of the seven-word transmission. Discarding the remainder of the information simply discards what is redundant and what I already know. Presumably, some kind of discarding of this kind goes on prior to storage and retention. In the absence of information from either physiology or neuroanatomy, the study of auditory compression processes can take place to a limited extent through the study of the effects of compressing verbal information before it is ever transmitted. The argument is that those external methods of compressing verbal information which are similar to the internal methods will best provide transmissions of information. In the pursuit of this line of enquiry we have to try and ensure that the redundancy removed is unnecessary for the transmission of information. This we can never be entirely sure that we are doing. The argument for this approach cannot be made so forcefully in the case of verbal information as it can in the case of nonsymbolic visual information.

The studies that follow attempt to build on some of the facts that have already been established with respect to the transmission of compressed verbal information. Two methods of compression have been explored. One is the now familiar time-compression of auditory verbal materials. The other is a method of compression which involves the dropping of much larger chunks, namely, whole words. The latter procedure appears to involve unexplored territory. In addition, the studies also explore, for the first time, the advantages and disadvantages of transmitting verbal material at high speed simultaneously through both the auditory and the visual channel.

EXPERIMENT I

There have been a number of investigations in the past few years, designed to investigate the effects of varying the speed of presentation of meaningful material upon listener comprehension. There have also been studies which have investigated the differences between the auditory, visual, or audiovisual modes of presentation. There have, however, been few studies which have investigated the inter-relationships between the speed and the mode of presentation. Goldstein (1940) presented connected meaningful material at several rates ranging from 100 to 322 wpm both auditorally and visually. He found an almost linear loss in comprehension as the speed was increased. He also found that for his subjects who ranged in age from 18 to 65 years the auditory presentation resulted in higher levels of comprehension than the visual presentation at the lower speeds but that, as the speed was increased, comprehension by the visual mode of presentation gradually became equal to that of the auditory presentation. Goldstein varied the rate of presentation by training an expert speaker to deliver the material at the various rates used in the study. This material was recorded and minor adjustments in speed were made by varying the playback speed of the recordings. Although Goldstein claimed a high level of intelligibility of the auditory material, there is a possibility that some loss of intelligibility resulted from the speaker's increased rate. Goldstein presented the visual material with motion picture equipment. The rate of presentation could be very accurately controlled so that it matched exactly the rate of the auditory presentation. Goldstein's conclusion that there seemed to be no "optimum rate" at which the material should be presented was based upon a rather straightforward interpretation of the linear relationship between the rate of presentation and comprehension. If some sort of efficiency index had been calculated, an optimum level might have been determined, but this cannot be computed from the data given. Fairbanks, Guttman, and Miron (1957a) did compute an efficiency index based upon the number of comprehension test items answered correctly per unit time. Their study, however, was concerned only with the auditory mode of presentation. The optimum rate for the auditory presentation was reported as about 280 wpm. This rate was twice as fast as the original recording and is considerably faster than everyday speech. In a later study by Fairbanks, Guttman and Miron (1957b) subjects were presented with the material twice instead of just once. The results clearly indicate that the double presentation at the rate of 282 wpm results in higher comprehension scores than a single presentation at the slower rate of 141 wpm ($p < .001$, $N = 36$). In terms of amount learned in a given amount of time, it is clear that the higher speed is more efficient than the lower speed.

The method for speeding the material was developed by Fairbanks, Everitt and Jaeger (1954). This is termed "speech compression." The compression is accomplished by discarding, periodically, small segments of the material to be compressed. The length of the segments is so small that no complete phoneme is cut and the loss of a single segment is not detectable by the human ear. The result is material presented at a faster rate than the original with the speed dependent upon the size and frequency with which the segments are discarded. Although the optimum rate of presentation reported by Fairbanks, et. al. (1957a), is about 280 wpm, they reported that it appears possible for some comprehension to take place at a speed of 470 wpm. Although the comprehension at such a high speed is small, it is provocative to ponder how much effect practice might have.

The present study utilizes the technique of speeding the presentation of the auditory material used by Fairbanks, et.al., rather than that used by Goldstein. It also includes the condition of audiovisual presentation as well as auditory and visual conditions of presentation. It is expected that the results will coincide with those obtained by Fairbanks, et. al., for the auditory condition and that they will approximate those obtained by Goldstein for the visual condition.

Method and Procedure

Subjects. -- The sample used in the present experiment consisted of 220 students, predominately juniors and seniors from introductory courses in educational psychology at the University of Utah. The subjects were "run" in groups of two to six and participation in an experiment was a requirement of the courses.

Learning Material and Comprehension Test. -- The learning material used in this experiment was adapted from the Davis Reading Test Form 1A used by special permission of the Psychological Corporation. The eight passages used ranged in length from 17 to 390 words and the total number of words was 1,152. The Davis tests are designed for grades 11 and 12 in high school and for freshmen in college. The material is of appropriate difficulty for subjects such as those used in the experiment. Although the content of the passages was relatively unfamiliar to the subjects, when a group of 40 subjects were administered the comprehension test without having seen the material, the mean number of items correctly responded to was 11.15 which is significantly different from a chance score of 8 ($p < .01$).

The items used to measure comprehension were also taken directly from the Davis Reading Test Form 1A. The items for each passage used were duplicated on separate pages of response booklets by special arrangement with the publisher, the Psychological Corporation. The subject could thus see only those questions pertaining to the passage which had been presented and could not look at the questions pertaining to the next passage. Forty-five alternative multiple choice items were used. The number of items per passage varied as the length of the passage. The tests for comprehension were scored by tallying the number of correct responses and the number of incorrect responses. A correction was then applied to the number of correct answers to compensate both for guessing and for the ability of the subjects to answer the items correctly without actually reading the passage. The correction was determined empirically from the number of correct responses made by the group given the test items without the passages. The obtained formula was (Rights —.38 Wrongs). A chance score of 11 would thus result in a final score of 0 indicating that being exposed to the material did not raise the comprehension score above the chance level.

Preparation of the Material. -- The material for the auditory presentations was recorded by an experienced male speaker at 150 and 175 wpm. The recordings at 175 wpm were "compressed" to 200, 250, 300, and 350 wpm with a Tempo-Regulator, provided by the University of Utah Research Committee. The device is a commercially produced machine which shortens the presentation time of materials by randomly discarding small bits of the recorded message. The compressed versions of the materials were then rerecorded onto half tracks of tapes and tones were recorded on the alternate tracks to synchronize the slide presentations with the auditory material.

The material for visual presentation was typed in "primer" type on 8-1/2 x 11 white bond paper. This material was then photographed on microfilm and bound in 2 x 2 pasteboard slide frames. Each frame consisted of one or two sentences from the reading passages with a maximum of about 80 words on a slide, although most of the slides contained fewer words. The projected image resulting from this method was sharp and clear with the letters one inch in height which were read by subjects at a distance of 6-8 feet.

Experimental Design. -- Three modes of presentation were used, auditory, visual, and audiovisual. The five speeds of presentation were 150, 200, 250, 300, and 350 wpm. These were arranged in a 3 x 5 factorial design. Twelve subjects were randomly assigned to each of the 15 experimental conditions. The material was presented to subjects in groups of from two to six. The subjects were given instructions in the same mode as the experimental material. After the instructions, the first passage was presented, followed by a time period in which subjects recorded their responses for that passage. The eight passages were presented in this manner. Subjects were told that they would be allowed only a certain amount of time in which to record their responses and when the time was half over, a signal was given. Sufficient time was allowed for all subjects to complete every item.

The material was presented to subjects via tape recordings and 2 x 2 slides with a LaBelle Maestro II tape-slide projector. A tone recorded on one track of a two track tape triggered the slide-change mechanism. This was synchronized precisely with the auditory recording for the audiovisual presentation. The presentation times were controlled precisely for each of the experimental conditions in this manner.

Results

Table 8.01 presents the comprehension scores for the three modes of presentation and the five ratesof presentation. These scores are also presented in graphic form in Figure 8.01. It is clear that there is an almost linear loss in comprehension as speed is increased. The audiovisual mode of presentation is generally superior to both the auditory and the visual modes. The mean for performance at each speed for each sensory mode is also plotted in Figure 8.01. An extrapolation of the mean performance curve would cut the ordinate at about 400 wpm, a point which would represent zero learning with the materials used. The analysis of variance on these data shown in Table 8.02 resulted in significant $\underline{F}$s for the main effects of mode of presentation ($p < .05$) and rate of presentation ($p < .001$). As was mentioned earlier, the comprehension scores were corrected on the basis of the empirical adjustment for guessing.

Efficiency scores were computed as the adjusted comprehension score per unit time of presentation. The mean efficiency scores and standard deviations are presented in Table 8.03 for the three modes and five rates of presentation. The scores are presented graphically in Figure 8.02. It is apparent that the audiovisual presentation results in the highest efficiency level. The audiovisual presentation is also more efficient for the higher three of the five speeds than either the auditory or the visual presentation. At 150 wpm the three modes of presentation are essentially equal but as the rate of presentation increases, the audiovisual presentation clearly reaches a higher efficiency level with a peak at 300 wpm. At this point, the auditory presentation becomes least efficient.

TABLE 8.01

MEAN ADJUSTED COMPREHENSION SCORES AND STANDARD DEVIATIONS BY RATE AND MODE OF PRESENTATION (N = 12 PER CELL)

Rate in wpm	Mode of Presentation							
	Auditory		Visual		Audiovisual		Total	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
150	14.68	3.58	15.54	5.71	14.73	7.68	15.00	5.74
200	14.24	7.96	10.75	6.20	13.68	6.69	12.90	6.96
250	7.32	5.74	9.08	7.06	12.98	7.80	9.80	7.16
300	4.89	5.10	10.11	6.12	12.31	6.53	9.11	6.58
350	5.22	3.62	5.86	7.85	6.75	5.76	5.94	5.86
Modality	9.27	7.09	10.27	7.58	12.10	8.24	10.55	7.14

TABLE 8.02

ANALYSIS OF THE VARIANCE OF ADJUSTED COMPREHENSION SCORES

	SS	df	MS	*F*	P
Mode	247.39	2	123.70	3.05	$p < .05$
Rate	1771.84	4	442.96	10.92	$p < .001$
M x R	406.93	8	50.87	1.25	----
Within	6694.91	165	40.58		
Total	9121.07	179			

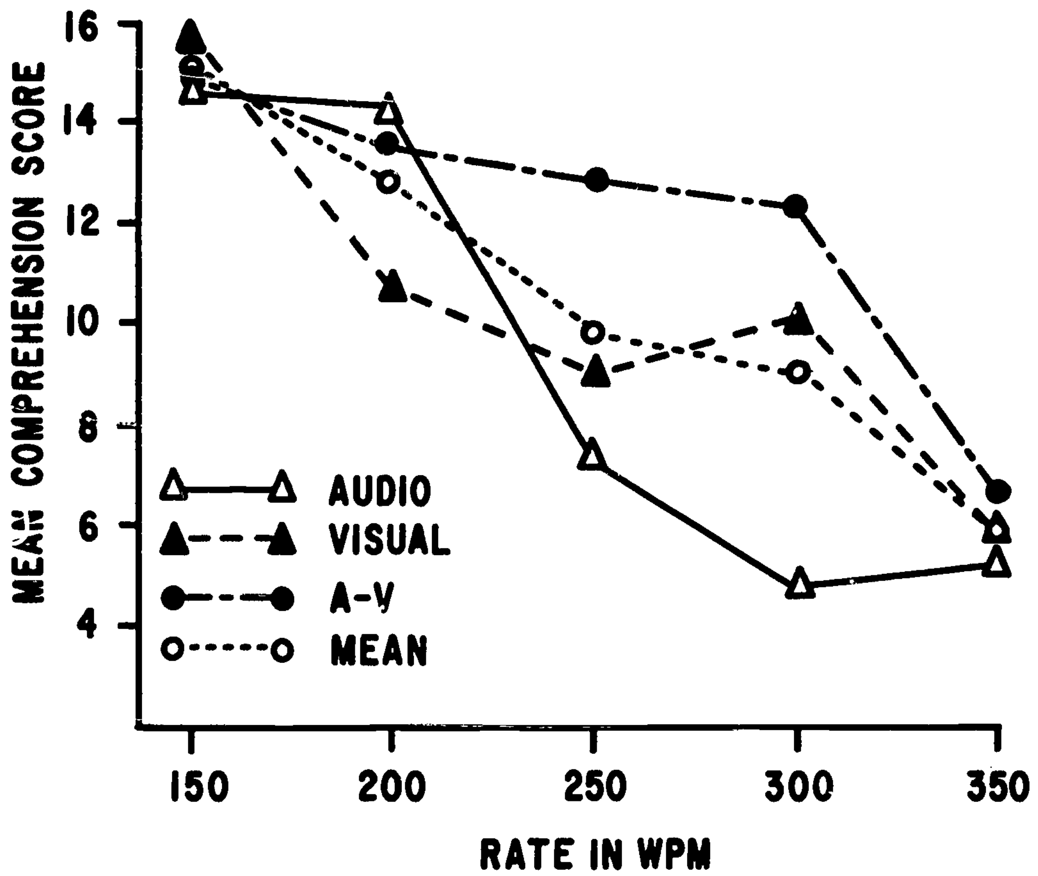

Figure 8.01. The effect of rate and mode of presentation upon comprehension.

TABLE 8.03

MEAN EFFICIENCY SCORES AND STANDARD DEVIATIONS
BY RATE AND MODE OF PRESENTATION
(N = 12 PER CELL)

Rate in wpm	Mode of Presentation: Auditory $\bar{X}$	Auditory SD	Visual $\bar{X}$	Visual SD	Audiovisual $\bar{X}$	Audiovisual SD	Total $\bar{X}$	Total SD
150	1.91	.47	2.02	.74	1.92	1.00	1.95	.75
200	2.47	1.38	1.87	1.08	2.38	1.16	2.23	1.21
250	1.59	1.25	1.97	1.53	2.82	1.69	2.12	1.55
300	1.27	1.33	2.63	1.60	3.20	1.70	2.37	1.72
350	1.59	1.10	1.78	2.39	2.05	1.75	1.81	1.78
Modality	1.77	1.28	2.05	1.59	2.48	1.71	2.10	1.45

Since it is evident from Table 8.03 that there is a wide range among the variances of the experimental groups, Cochran's test for the homogeneity of variance was made. On the basis of the result the hypothesis of homogeneity of variance is untenable ($p = .05$). It must be pointed out that the *F* test is more conservative where there is lack of homogeneity of variance than when there is homogeneity of variance in the data. The result is fewer significant *F*s than would otherwise be expected. The interpretation of the analysis should be considered in light of the above. The analysis of variance on these data shown in Table 8.04 presents a significant *F* only for the mode of presentation ($p < .01$). The graphic representation is, of course, consistent with the statistical analysis and shows little consistent interaction effects. The distributions involved also show some departure from normality. Since there is some evidence that the Cochran test is oversensitive to departures from normality and that small departures from normality do not seriously effect the overall analysis (Boneau, 1960) the analysis of variance on these data was performed.

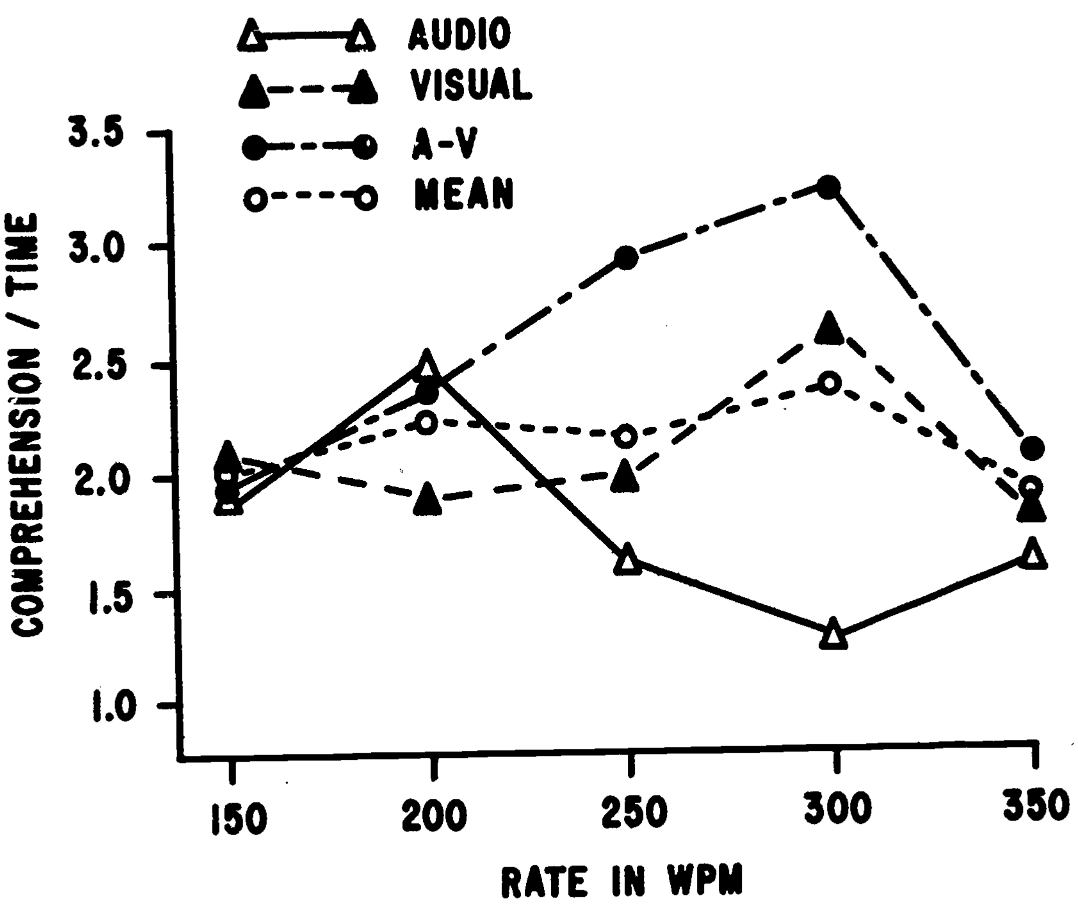

Figure 8.02. The effect of rate and mode of presentation upon efficiency.

TABLE 8.04

ANALYSIS OF THE VARIANCE OF EFFICIENCY SCORES

	SS	df	MS	F	Sig.
Mode	15.22	2	7.61	3.79	$p < .01$
Rate	7.22	4	1.80		n. s.
M x R	21.86	8	2.73	1.36	n. s.
Within	331.60	165	2.01		
Total	375.90	179			

The distribution of the auditory efficiency scores is of essentially the same shape as those obtained by Fairbanks, et. al. (1957a) and by Foulke, Amster, Nolan and Bixler (1962). Although Foulke, et. al., used much younger subjects, the fact that the distributions are essentially the same shape supports the contention that there is, indeed, an optimum speed for the presentation of auditory material. The curves presented in Figure 8.03 compare the present results with those of Fairbanks, et. al., (1957a) and of Foulke, et. al. (1962). It can be seen that the points where a maximum efficiency is reached are different but that the shapes of the curves are essentially the same. The fact that the optimums appear at different rates could be a result of the material used, the type of testing instrument used, or the way in which the tests were scored. When the test used in the present experiment was scored as the number of correct responses per unit time, the results were more nearly like those obtained by Foulke, et. al. (1962) than when the correction formula was applied. By using correct responses only, for the computation of the efficiency score, a level is eventually reached where further decrement in efficiency is impossible because of the individual's capability of arriving at some of the answers without reading the passage. This probably accounts, at least in part, for the leveling off of the scores reported by

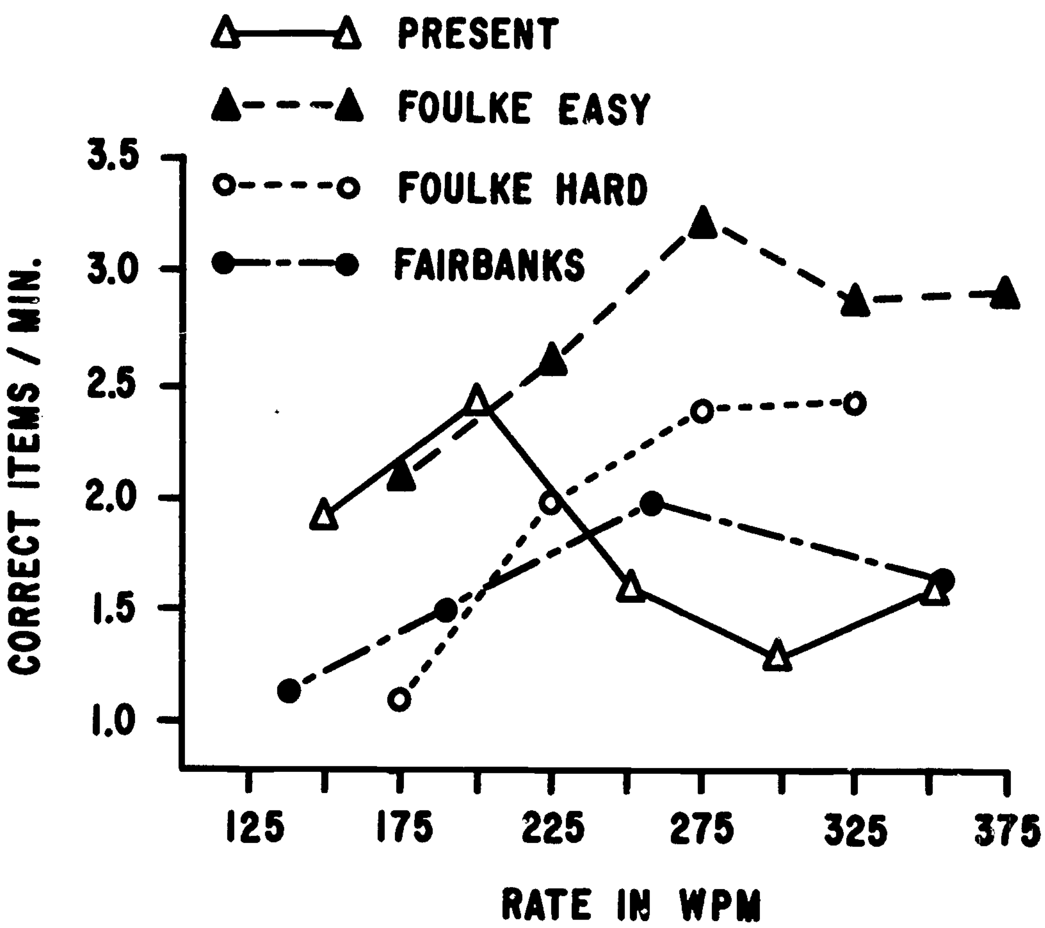

Figure 8. 03. Correct items per minute with rate of audio presentation for the present study compared with results of two other studies.

Foulke. For this reason, in the present study a correction was applied to the comprehension scores.

Discussion

The results clearly indicate an almost linear loss in comprehension as speed is increased. This is in agreement with the results reported by both Goldstein (1940) and Fairbanks, et al., (1957a). The loss appears approximately linear for all modes of presentation. The fact that the auditory presentation was superior to the visual for the lower speeds and that the visual was superior to the auditory for the higher speeds is in agreement with the results reported by Goldstein. This is not surprising since people typically have not had experience with the high-speed sound presentation but have had experience with reading at speeds approaching those used in the present experiment. The superiority of the audiovisual mode of presentation could be accounted for by individual differences in capability to handle one or the other mode of presentation. Assuming that some people are better able to comprehend material by one or the other modality, then it is quite likely that the individual's preferred mode of receiving information would be used in the audiovisual presentation. This would permit many to do better when they had such a choice than when no choice of sense modality was available. This interpretation is further substantiated by the experimenter's observation that some subjects tended to cover their ears or eyes during the high-speed dual-modality presentation. Following the experimental sessions, subjects were asked their reactions to receiving information at such high speeds. Most of the subjects expressed the opinion that it was confusing and that they had to pay particular attention in order to comprehend the material. In addition, subjects in the audiovisual group reported that they had to exert particular effort to "block" one channel so that the other could be used and understood.

It is interesting that the audiovisual efficiency scores more nearly match those reported by Foulke, et al., (1962) and by Fairbanks, et al. (1957a), than do the scores for either of the other modes of presentation used in the present study. As mentioned earlier, the higher audiovisual scores may simply be an artifact and further investigation must be conducted to clarify this matter.

Conclusions made on the basis of the data obtained in the present study must be tentative in the sense that there appear to be individual differences in capability to use either auditory or visual modes of presentation. This must be further investigated. The comprehension scores obtained on auditory and visual modes of presentation correspond roughly with those obtained by Goldstein. That is, at the lower rates of presentation the auditory is superior, gradually giving way to the visual at the higher speeds. At the highest rate of presentation, comprehension by the visual mode is markedly higher than that by the auditory mode. The conclusion which seems most reasonable in terms of presenting material to groups of subjects is that the audiovisual mode of presentation should result in better comprehension than either of the other modes. The question of how individual scores are affected by the differing modes of presentation has not been answered.

One limitation in the ability to interpret highly speeded auditory presentations seems to lie in the amount of experience a person has had with this sort of presentation of material. An observation made as a result of the preparation of the speeded auditory material for the present experiment offers some support regarding the effects of experience. The material used in the passages was completely intelligible to the writers at the higher rates although staff members new to the project were unable to understand much of the material. Obviously, if the material is very familiar, it would be easier to understand than if it were completely unfamiliar. However, unfamiliar material presented at the very high rates of speed was subsequently much easier for the writers to understand. This phenomenon has been reported by other members of the staff. The question of whether or not this observation holds remains to be investigated. The evidence cited by Klump and Webster (1961), Fairbanks and Kodman (1957), Sergeant (1961) and other studies concerned with the intelligibility of words at high rates of presentation tends to indicate that individual words are intelligible at extremely high rates. Since the individual words are intelligible, the difference in comprehension probably lies in the inability to process the information rather than in the inability to recognize the words which convey that information.

Summary and Conclusions

The passages from the Davis Reading Test Form 1A were administered at rates from 150 to 350 words per minute through the visual modality, the auditory modality and through both modalities simultaneously. The higher speeds of the auditory transmissions were produced from speech at 175 words per minute which was compressed by means of the Tempo Regulator. Subjects were tested on a printed version of the items following each passage. Twelve subjects were run under each modality condition at each of five speeds of presentation. The data were analyzed in a 3 x 5 analysis of variance design which showed significant *F*s for the main effects of rate ($p < .001$) and mode of presentation ($p < .01$). At the higher speeds, the audiovisual presentation generally produced the best performance on the test items.

The scores were then converted into efficiency scores representing amount learned per unit of time involved in the presentation. Such efficiency scores appeared to attain a peak of efficiency at about 300 words per minute both for the visual and the audiovisual presentations. At the higher speeds, the audiovisual mode of transmission showed itself to be superior to the other two.

EXPERIMENT II

The findings of the previous study generally indicated that there was an advantage to the simultaneous presentation and that this advantage was more pronounced at the higher rates of presentation than at the lower rates. The observation was made that many individuals attempted to block one or the other modality in the high-speed simultaneous presentations. Upon questioning individuals following the experiment, it was also found that many individuals reported that they had made an effort to block one channel and to receive the information primarily through the other. On the basis of these observations, it was speculated that the superiority of the simultaneous presentation was a function of individual differences in ability to receive information via the auditory or visual channel. This difference should become increasingly apparent as the speed of presentation is increased since the system becomes increasingly more likely to be overloaded. The present experiment was designed to test this hypothesis.

Individual differences should adequately account for any advantage inherent in simultaneous auditory and visual presentations of connected meaningful material. The effect of increasing the rate of presentation should be to force the individual to select one or the other modality. In order to test this hypothesis each individual must be measured on the three modality presentation conditions. That is, measures must be made following an auditory, a visual, and a combined audiovisual presentation. The result at the lower speeds of presentation should show little difference among the three presentation conditions. As the speed is increased, the simultaneous presentation conditions should produce a higher mean score and concurrently a decrease in the correlation coefficient between the single channel presentations until at the highest rate of presentation the relationship between the auditory and visual comprehension scores should approach zero. The relationship between the single channel presentations and the dual channel presentations should remain somewhat higher. The correlation coefficient between any individual's highest single-modality comprehension test score and his simultaneous-presentation test score should be somewhat higher than any of the other correlations at a given rate of presentation. .

The relationship between listening comprehension test scores and reading comprehension test scores had been variously explored. Goldstein's (1940) conclusion that the variability in test scores is the result of a central rather than a peripheral process has been supported by more recent research where it was found that the correlation between reading and listening comprehension test scores was reduced by holding constant or partialing out the effects of intelligence test scores. Spearill (1962) however concluded that a factor of listening could be identified which was separate and unique from a factor of reading, thus indicating that the methods of measuring comprehension are, indeed, measuring distinct though overlapping characteristics. It appears that the highest relationships between reading and listening comprehension are found when equivalent forms of established reading tests are used and the presentation modality is varied.

Method

Description and Analysis of The Davis Reading Tests. --The Davis Reading Tests, Forms 1A, 1B, and 1C were used in the present experiment. The reason for selecting standardized reading tests was that different forms were available, which were roughly equivalent in level of difficulty. In addition, the items used to measure the level of comprehension of the material following the reading passages had a reasonably high reliability level. This, of course, resulted in an appreciable savings of time since the materials were essentially "ready to go." The experiment was performed using the Davis materials with the assumption that the three test forms were equivalent and that the level of difficulty of the three forms was relatively constant. Actually, equivalence of the forms lies partially in the scaled scores used for interpretation of test performance. In this experiment, however, it seemed necessary that the forms be examined in more detail in terms of equivalence of reading and listening difficulty.

The test forms were studied in an analysis of the reading level as estimated with the Dale-Chall (1948) formula and in an analysis of the listening difficulty as estimated by Roger's "G" (1962). The Dale-Chall formula was based on the results of material from grades three to twelve and appears to be adequate for the levels of difficulty of the Davis materials.

The reading difficulty levels estimated from the Dale-Chall formula are presented in Table 8. 05 by test form and by passage number. It can be seen from an examination of the table that the three test forms are not strictly comparable in terms of the difficulty level of the material used in the construction of the test passages. The overall totals, although in close agreement, are not indicative of the number of items which are to test comprehension of the material at each of the levels of difficulty. Form 1B samples more difficult material than the other two forms. Furthermore, Form 1B contains a higher percentage of more difficult material with a higher ceiling than do the other forms.

The Roger's Listenability indexes are shown in Table 8. 06. Again the level of difficulty is not constant from passage to passage nor from test to test. Form 1B has more variability than the other forms, ranging

TABLE 8.05

DALE-CHALL READABILITY INDEX FOR EACH PASSAGE

Passage Number	Readability Index		
	Form 1A	Form 1B	Form 1C
1	6.82	6.87	5.25
2	7.17	5.67	8.18
3	7.94	7.43	7.71
4	6.37	9.14	6.98
5	7.71	7.46	5.72
6	6.49	8.96	6.01
7	5.65	7.24	5.95
8	6.23		
Overall	6.91	7.44	6.94

TABLE 8.06

ROGER'S LISTENABILITY INDEXES FOR THE DAVIS READING TEST

Passage Number	Roger's "G" Index		
	Form A	Form B	Form C
1	16.36	14.68	9.62
2	13.83	7.00	17.90
3	17.83	16.60	19.62
4	15.29	20.22	15.02
5	16.81	13.29	10.09
6	12.31	23.56	9.52
7	10.45	25.77	12.02
8	21.49		
Overall	14.95	15.62	15.12

from a level of 7.00 to 25.77; while Forms 1A and 1C range from a low of about 10.00 to a high of about 21.50. Although the overall Roger's estimate indicate that Form 1B is slightly more difficult than the other two, the indexes are very nearly the same for the three forms.

The reading test passages were recorded at a rate of 200 wpm by an experienced male speaker. The recordings were made on a full track Roberts recording machine (Model FT190) at 15 inches per second (ips). The recordings were then time compressed by use of the Time and Tempo Regulator.

The compressions used in this study were undertaken at 80, 67, 57, and 50 percent of the original time. This resulted in speeds of 250, 300, 350, and 400 wpm plus the original of 200 wpm. Since the regulator produces distortion in the recording at the very high rates of compression, two consecutive lower percentage compressions were made to produce the 350 and 400 wpm materials. The double compressions were more clear and intelligible than the single compression when considered in relation to the rate of presentation.

The compressed tapes were dubbed onto one track of a two-track tape. The tapes were cut and spliced according to the following sequence: signal tone--3 second blank--passages--instructions to answer questions--blank leader tape 2 seconds--announcement, "time half over"--blank leader tape 2 seconds--announcement, "stop"--blank leader tape 2 seconds --signal tone, etc. The blank leader tapes were for the purposes of allowing the experimenter sufficient time to stop the playback machine while the subject recorded his responses to the comprehension questions. After the tapes were edited, signal tones were dubbed onto the second track of the two-track tape to activate the relay which changed frames for the visual presentation.

The passages from the reading tests were divided into segments which would conveniently fit onto one frame of a 35 mm film strip for visual presentation. For the most part the segments consisted of one or two sentences. The material was then typed on 5 x 8 inch white cards with an IBM electric typewriter (letters are Artisan 12 type, numbers are Manifold 12 type) and photographed with Kodak M417 high contrast copy film. Since the negative was to be used in the visual presentation, no printing was necessary.

Apparatus used for Presentation. -- The auditory material was presented to subjects via Koss headsets. By using individual headsets for presentation, background noises were eliminated almost completely.

A Rheem Caliphone two-track stereophonic recording machine was used for playback of the tapes. The experimenter could monitor both outputs from the tape while the subject received only the verbal presentation. In addition, a switch was installed which controlled the output to the subject's headset so that the auditory verbal signal could be switched off during the presentation of only visual material. The control signal from the second track was passed to a transistor controlled relay which in turn advanced the visual frames. A Victor Soundview Model PS65 automatic filmstrip projector was used for presentation of the visual material.

The visual material was presented to subjects by projecting the image onto the back of a fine grain sandblasted plate glass screen. A special projection box was constructed so that the experiment could be conducted in a lighted room. The arrangement was such that no back light was allowed to strike the screen except that produced by the projector. The front of the apparatus was shaded so that a minimum of front light was allowed to strike the screen. The result of this arrangement was a sharp white image on a high contrast black background. The letters were about 0.1 inch in height. The material was viewed at a distance of about 18 inches.

Procedures Used In Presenting Material. -- The subject was seated across a table from the experimenter in a lighted, relatively quiet room. The apparatus was placed on the table and on a small adjoining stand. When the subject entered the room he was given a booklet containing the questions for the passages, instructed to fill in the identifying data, and then was given the appropriate instructions (see Jester, 1966 for details).

The recording machine was stopped after each passage and the subject then responded to the questions. The entire operation took 40-60 minutes depending upon the rate of presentation.

The sample included students at all undergraduate grade levels and the subjects were assigned at random across all of the experimental conditions. A total of 90 subjects was used.

Experimental Design. -- The experiment was arranged in a 3 x 3 x 5 x 6 factorial design. The principle factors of concern were modality of presentation (3 categories) and rate of presentation (5 categories). In order to assure that adequate control was maintained for possible differences in the three forms of the Davis test (3 categories), this was considered as a main effect. Further, since the order of presentation of the materials could conceivably effect the modality main effects, the experiment was counterbalanced in two ways. First, all possible sequences of presentation of modality were used as a main effect factor and second, the three forms of the Davis Test were latinized within the sequence of presentation. As an aid to understanding the basic layout, the design is presented in Figure 8.04. It can be seen from an examination of the pictorial representation of the design that as a result of the counter-balancing employed, the presentation modality by test form interaction (MF interaction) is split between the "between subjects" and the "within subjects" variance classifications. This is not serious since the components are balanced and can be partioned and tested in the analysis of variance. The major disadvantage in the design is involved only in the variance analysis. The disadvantage is that since each subject receives a unique treatment combination, there is no within cell source of variance which can be used as an error term. The fourth order interaction (modality x form x sequence x rate) must be considered as the best estimate of the error variance and is thus used to test the main effects and interactions. Since the main effects are considered as fixed rather than random factors, this is in line with the general model used for the analysis.

Test Scoring. -- The correction for guessing used was the same as that developed for the earlier study reported in this chapter.

Results

Reliability of the Reading Comprehension Tests. -- Although the Davis Reading Tests are reported to have high reliability (Davis Reading Test Manual, 1962), these reliability coefficients are not completely relevant to the present study in which the tests were administered in a somewhat unorthodox fashion. The standard administration of the Davis Reading Tests allows the examinee to return to the reading passages while answering the related items. The manner of presentation of the passages in this study did not permit the subjects to do this. One would therefore expect that subjects would achieve better mean scores in the standardized situation with larger SDs and also that the passages involving specific numbers of things (e.g. How many plants did Europe receive from America?) would produce higher scores in the normal testing than in the present experiment.

Reliability coefficients were computed using the split-half method for each of the three test forms within each rate of presentation and modality of presentation. The coefficients were then corrected by the Spearman-Brown formula and averaged by means of Fisher's z transformation to obtain the reliability coefficients by modality and rate of presentation. As can be seen in Table 8.07 these coefficients are relatively stable across all modalities of presentation and across all rates when groups are combined. However, some individual coefficients are extremely low. Since each of the coefficients presented in Table 8.07

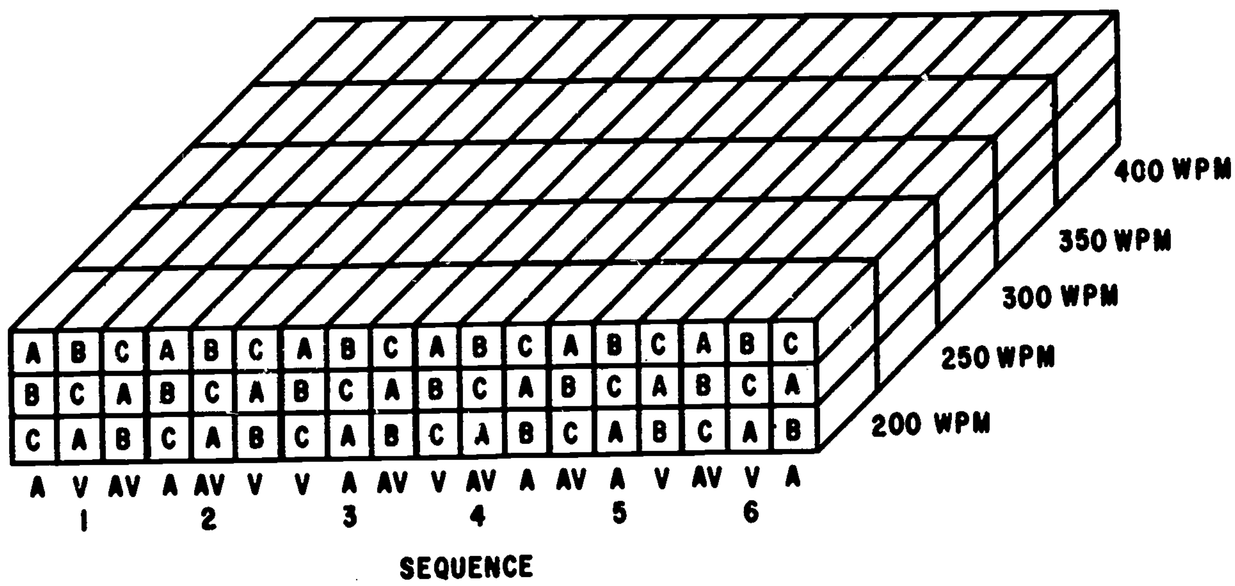

Figure 8.04. Representation of the basic design.

TABLE 8.07

SPLIT HALF RELIABILITY COEFFICIENTS FOR EACH TEST FORM AT EACH RATE OF PRESENTATION (N = 6 PER CELL)

	200			250			300			350			400			Means by Form and Modality			Means by Form	Test Only
Mode	A	V	AV	A	V	AV	A	V	AV	A	V	AV	A	V	AV	A	V	AV		
Form																				
A	.86	.72	.77	.95	.98	.68	.55	.89	.82	.81	.00	.96	.13	.75	.63	.76	.81	.75	.80	.08
B	.91	.66	.37	.48	.64	.93	.75	.17	.82	.43	.52	.89	.64	.32	.46	.69	.48	.77	.66	.27
C	.20	.63	.37	.00	.73	.96	.75	.88	.91	.00	.00	.73	.62	.87	.00	.36	.71	.74	.63	.16
Means by Mode	.77	.81	.53	.65	.87	.90	.69	.76	.86	.49	.19	.89	.49	.71	.39	.63	.69	.78		.17
Means by Rate		.67			.83			.78			.62			.54					.71	

is based upon an n of only six, this might be expected. The overall picture of the reliability of the instruments used is, happily, more encouraging than these few coefficients would indicate. The overall average reliability of the tests approaches the level of the reliabilities reported in the Davis Reading Test Manual of from .76 to .83.

For purposes of evaluating the amount actually learned as a result of the presentation conditions, it was important to know how many of the test items an individual could answer without having seen the information. This condition is the test only condition. Three groups of twenty subjects each were administered the test questions without seeing or hearing the passages. Scores obtained in the test only condition represent the ease with which correct responses could be guessed on the basis of information contained within the questions themselves. The reliability coefficients for the test only condition are low, as would be expected.

As an aid in seeing the relationship of the reliability coefficients to the rate of presentation, the coefficients are plotted by rate and modality of presentation in Figure 8.05. The highest reliability coefficient appears at rates of 250 and 300 wpm. It is interesting that the reliability coefficients for the auditory presentations appear to be the most stable across all rates of presentation. Jensen (1930) computed the reliability coefficients in an experiment investigating the differences between testing by visual and auditory presentations. He reported reliability coefficients ranging from .51 to .88 with the averages around .74 to .79, but highest reliability coefficients were for the auditory presentations ($r = .63$ to $.88$).

Basic Analysis of the Data. -- An analysis of variance was performed on the data following correction for guessing. Summary tables of means and standard deviations are presented in Table 8.08. The summary of the analysis is presented in Table 8.09. It is important that the overall analysis be examined carefully at this point since it forms the basis for some subsequent adjustments of the data. It can be seen that, contrary to expectation, differences in the three test forms produce variance far beyond that expected by chance ($p < .001$). The effect of this variance will be felt in subsequent analyses primarily where individual differences in ability to make differential use of the auditory and visual channels of information input is examined. The reason for the effect lies in the counterbalancing employed since each subject received only one test form through one modality of presentation. The result of this is that the individual differences in ability to use the auditory and visual channels are, in effect, confounded with the test form by modality interaction.

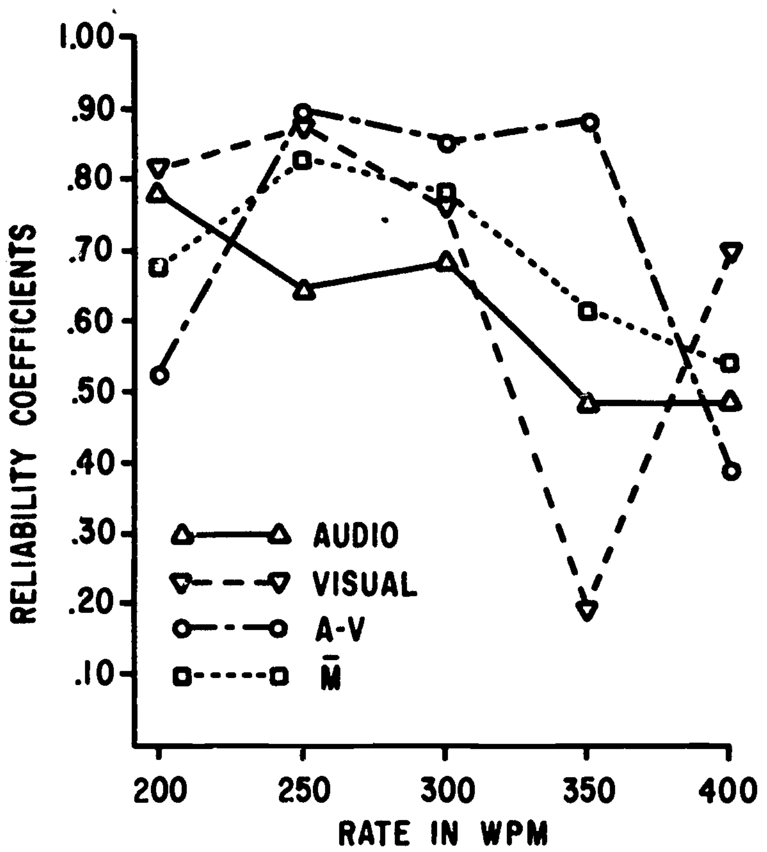

Figure 8.05. Split half reliability coefficients by rate and mode of presentation (n = 18 per cell).

TABLE 8.08

MEANS AND STANDARD DEVIATION OF COMPREHENSION TEST SCORES
(SCORES CORRECTED FOR GUESSING. N = 6/CELL.)

Rate		FORM 1A		FORM 1B		FORM 1C			
WPM	Mode	Mean	S.D.	Mean	S.D.	Mean	S.D.	Means	S.D.
200	A	12.50	8.07	11.50	7.21	13.67	9.33	12.56	7.80
	V	14.50	6.57	9.84	7.34	12.84	11.28	12.39	6.40
	AV	13.17	9.68	11.17	5.28	11.00	5.68	11.78	6.80
		13.39	7.88	10.85	6.32	12.51	6.69	12.24	6.90
250	A	14.00	10.13	10.17	3.88	8.84	4.23	11.00	6.71
	V	12.00	6.89	8.84	10.89	7.67	7.25	9.50	8.24
	AV	12.17	8.26	10.17	10.98	10.34	10.36	10.89	9.38
		12.74	8.07	9.73	8.67	8.96	7.32	10.46	8.05
300	A	11.34	5.42	9.50	4.47	12.34	8.13	11.06	5.95
	V	12.67	7.71	6.17	5.85	10.50	8.94	9.78	7.67
	AV	12.84	5.39	13.17	6.62	9.34	7.65	11.78	6.47
		12.29	5.93	9.62	6.13	10.73	7.86	10.87	6.66
350	A	4.67	3.60	3.00	2.74	7.17	2.88	4.95	3.40
	V	10.67	4.07	-1.66	2.32	-.33	3.06	2.89	6.45
	AV	8.00	4.42	7.34	8.54	-.66	5.12	4.89	7.16
		7.79	4.56	2.89	6.29	2.06	5.17	4.24	5.87
400	A	4.34	4.88	1.50	5.14	.34	3.25	2.06	4.57
	V	6.00	7.56	2.17	5.13	5.00	7.06	4.39	6.48
	AV	8.50	6.96	8.17	7.31	1.67	4.07	6.11	6.68
		6.29	6.41	3.78	6.27	2.34	5.17	4.19	6.09
Grand	A	9.37	7.58	7.13	6.16	8.47	7.45	8.32	7.07
MEANS	V	11.17	6.86	5.07	7.75	7.13	7.72	7.79	7.80
& SDs	AV	10.93	7.05	9.90	7.73	6.33	8.12	9.05	7.82
Total		10.49	7.13	7.37	7.44	7.31	7.73	8.39	7.56

TABLE 8.09

SUMMARY OF ANALYSIS OF VARIANCE PERFORMED ON SCORES CORRECTED FOR GUESSING

Source	S.S.	d.f.	M.S.	F	p
Between Ss	10,968.00	89			
Rate (R)	3,274.82	4	818.70	9.58	<.01
Sequence (S)	394.05	5	78.81	<1.00	--
R x S	1,829.36	20	91.47	1.07	--
M x F	217.01	2	108.50	1.27	--
M x F x R	1,235.00	8	154.38	1.81	--
M x F x S	598.41	10	59.84	<1.00	
M x F x R x S	3,419.35	40	85.48		
Within Ss	4,406.67	180			
Mode (M)	72.80	2	36.40	2.26	<.13
Test Form (F)	595.49	2	297.74	18.50	<.01
M x R	182.61	8	22.83	1.42	--
M x S	397.82	10	39.78	2.47	<.05
F x R	160.36	8	20.04	1.25	--
F x S	224.46	10	22.45	1.40	--
M x R x S	747.21	40	18.68	1.16	--
F x R x S	736.80	40	18.42	1.14	--
M x F	225.72	2	112.86	7.01	<.01
M x F x R	310.50	8	38.81	2.41	<.05
M x F x S	109.30	10	10.93	<1.00	--
M x F x R x S	643.59	40	16.09		
TOTAL	15,374.67	269			

The Effect of Rate of Presentation Upon Comprehension. -- The effect of rate of presentation upon comprehension is shown very clearly in Figure 8.06. Consider first the effects of rate of presentation upon the auditory comprehension scores. There appears to be very little decrement in the mean comprehension scores from 200 to 300 wpm. This is consistent with the earliest studies in listening comprehension where the conclusion was drawn that there is no difference is listening comprehension due to rate of presentation. It appears that they did not increase the rate enough to produce differences. But to conclude that the rate of presentation does not effect listening comprehension, under these conditions, is like saying that temperature does not effect the melting rate of ice as long as the temperature is held below 25° F. There is a rather sudden and sharp drop in comprehension at speeds in excess of 300 wpm, but even at 400 wpm the comprehension is still above zero.

The mean comprehension scores for the visual presentations results in approximately the same curve as does that for the auditory presentations. The decrement in comprehension as a function of speed of presentation is very slight up to a speed of about 350 wpm where there is a very sharp drop in comprehension. The auditory presentations result in higher mean comprehension scores at all rates up to 400 wpm at which point the visual presentation results in a higher mean score.

The audiovisual presentation conditions present approximately the same relationship of comprehension to rate of presentation as do the single modality presentation conditions. There is very little difference in comprehension between the auditory and the audiovisual presentation conditions. The exception to this occurs at 400 wpm where the audiovisual presentation clearly results in higher comprehension scores than either the auditory or the visual presentation conditions. Some of the time honored practices designed to increase comprehension by the simultaneous reading by teacher and student, by testor and testee, and of a commentator reading the information on films while the viewer simultaneously reads the same information deserve questioning. Perhaps if the material were to be presented at extremely rapid rates this practice would increase comprehension but it appears that the simultaneous presentation offers little advantage at the slower rates of presentation.

Order Effects. -- The orders of presentation are an indication of the effects of practice upon the comprehension of the material. The comprehension scores as a function of order and rate of presentation are presented in Figure 8.07. It can be seen that there is a marked difference in almost all cases from the first to the second presentation. There is, however, very little increment from the second to the third presentation. The indication appears to be that following relatively little practice subjects reach a plateau. One could certainly interpret the initial rapid

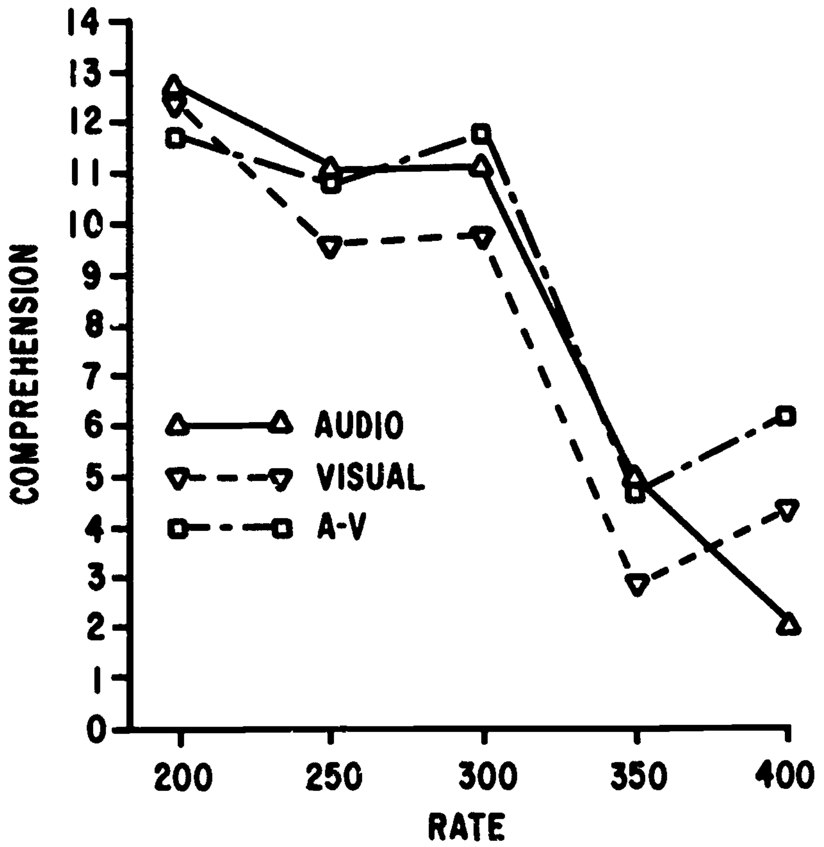

Figure 8.06. Modality of presentation by rate of presentation.

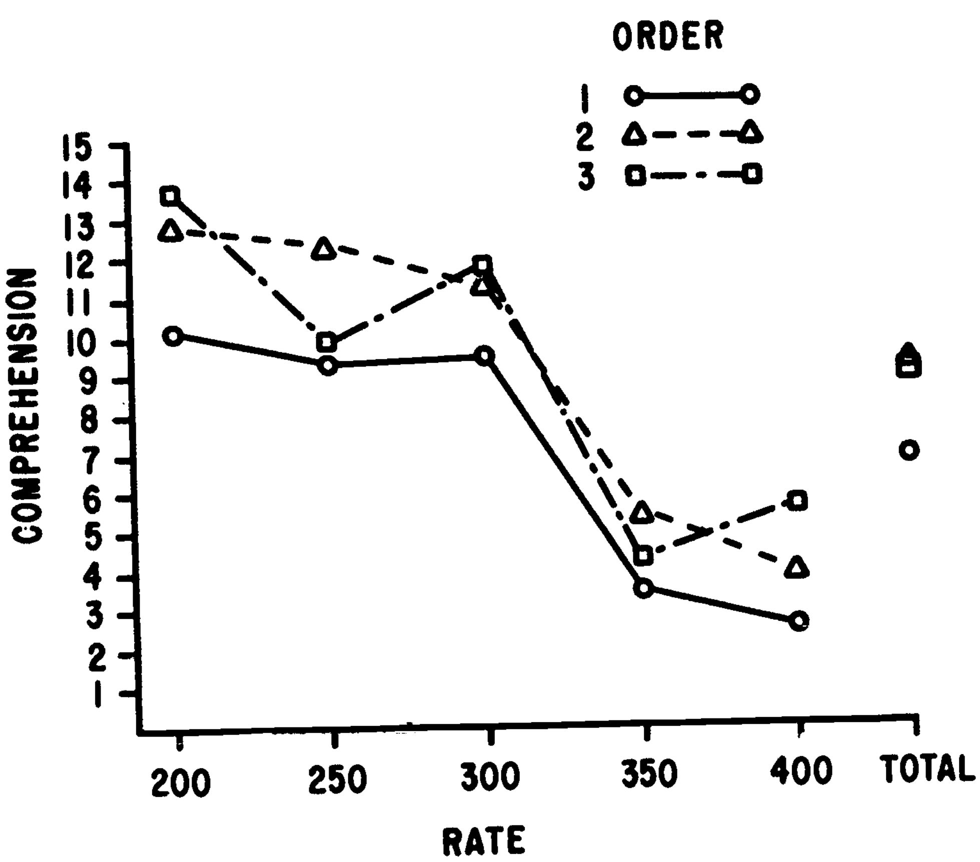

Figure 8.07. Effect of presenting material first, second, or third.

improvement as simply an adjustment effect which would imply that all subjects should be given some practice prior to the experiment proper. How much practice should be given, however, is not estimable from the data collected in this experiment. The fact that the order effect at 400 wpm produces differences between the second and third presentations as well as between the first and second is probably an indication that practice has its greatest effect at this speed. It is likely that were subjects given considerable practice at high speeds of presentation that performance would improve even more.

Individual Differences and Correlational Analyses. -- One of the hypotheses formulated prior to the experiment was that subjects would differ in their ability to make use of information presented through the auditory and visual modalities. It was further hypothesized that the relationship expressed in correlation coefficients among the three presentation conditions would result in the following. First, the relationship would be higher for the single channel presentation conditions with the audiovisual condition than it would be for the two single presentation conditions with each other. Second, these relationships would become more pronounced as the speed of presentation was increased.

The correlation coefficients are presented in Table 8.10. They follow very closely the expected pattern. At the lower rate of presentation (200-300 wpm) they are of the magnitude of the alternate form reliability coefficients of the Davis Reading Tests. As the rate of presentation increases the relationship between the visual and auditory presentations decreases until at 400 wpm it is slightly negative and may be considered indicative of no relationship between the auditory and visual scores. This is in accord with expectations and the most reasonable interpretation is that the similarity between a given subject's performance with auditory and visual presentations deteriorates as the rate of presentation is increased. What this probably means is that a given subject does indeed make better use of one modality than of the other and that when pressured by the rate of presentation or density of information he tends to select or to use that modality which works best for him. The correlations between both of the single channel presentations with the dual channel audiovisual presentation maintain relatively high levels across all rates of presentation. When the correlation coefficients are corrected for attenuation, approximately the same relationships are maintained. The corrected correlations are presented in Table 8.10. At the lower rates, the intercorrelations tend to resemble the alternate form reliability coefficients of the Davis Tests which are reported in the test manual. The high correlation between the auditory and the visual presentations at the lower rates of

TABLE 8.10

CORRELATIONS BETWEEN PERFORMANCE IN EACH MODALITY CONDITION, BOTH CORRECTED AND UNCORRECTED FOR ATTENUATION BY THE SPEARMAN FORMULA. CORRELATIONS CALCULATED AFTER EACH SCORE WAS ADJUSTED FOR FORM DIFFERENCES AND ORDER OF PRESENTATION EFFECTS.
(N = 18 PER CELL)

	200 wpm	250 wpm	300 wpm	350 wpm	400 wpm
Uncorrected					
A with V	.77	.78	.63	.20	—.12
A with AV	.53	.77	.70	.37	.30
V with AV	.52	.61	.60	.47	.66
Corrected					
A with V	.97	1.00	.88	.65	—.20
A with AV	.83	1.01	.91	.56	.70
V with AV	1.00	.69	.74	1.00	1.00

speed certainly substantiate the results of earlier studies where high relationships between reading and listening skills were obtained.

Efficiency Scores for Comprehension. -- Since the comprehension scores, when examined by rate of presentation, are based upon different total presentation times, the time taken for learning can be assumed to be less at the higher rates of presentation than at the lower rates. It is thus important to consider the comprehension scores in terms of the time taken for presentation of the material. Efficiency scores were computed by dividing the comprehension scores by the time taken for presentation of the material. The resulting efficiency scores represent the amount learned per unit time of presentation. The mean efficiency scores are shown represented in Figure 8.08 as a function of rate and modality of presentation. It can be seen that the highest efficiency occurs in the audiovisual condition at 300 wpm. As a matter of fact, the highest efficiency for all modalities of presentation occurs at 300 wpm. This is consistent with the results obtained by Fairbanks, et al. (1957) who found 282 wpm to be the most efficient rate for the presentation of auditory material. If presentations which are made at speeds of approximately 300 wpm are the most efficient for learning or comprehension, it is all too obvious that we have been wasting time communicating at 140 wpm. The speaking rate of 300 wpm is extremely difficult to achieve without the aid of mechanical processes but the speed might be very profitable when presenting recorded material either alone or with simultaneous film presentations. In the case of the material used in the present study, however, there appears to be no real advantage to the use of simultaneous audiovisual presentations over the use of auditory presentations alone. It should be noted, however, that both the auditory and the audiovisual presentations resulted in a higher peak efficiency than did the visual presentation.

Analysis as a Greco-Latin Square Design:--The counterbalancing employed resulted in the splitting of the modality by test form interaction. Although this presents no real problems, it does produce a rather complex factorial analysis of variance. In addition, there is no entirely satisfactory estimate of error variance and the assumption must be made that the fourth order interaction consists of random or error effects and thus is appropriate for testing the other sources of variance. Upon careful examination of the design it can be seen that the counterbalancing produces six Greco-Latin squares which can be used in a slightly different analysis of variance procedure. The means and standard deviation for this analysis are presented in Table 8.11. The sources of variance and F ratios for both procedures are shown in Table 8.12. As would be

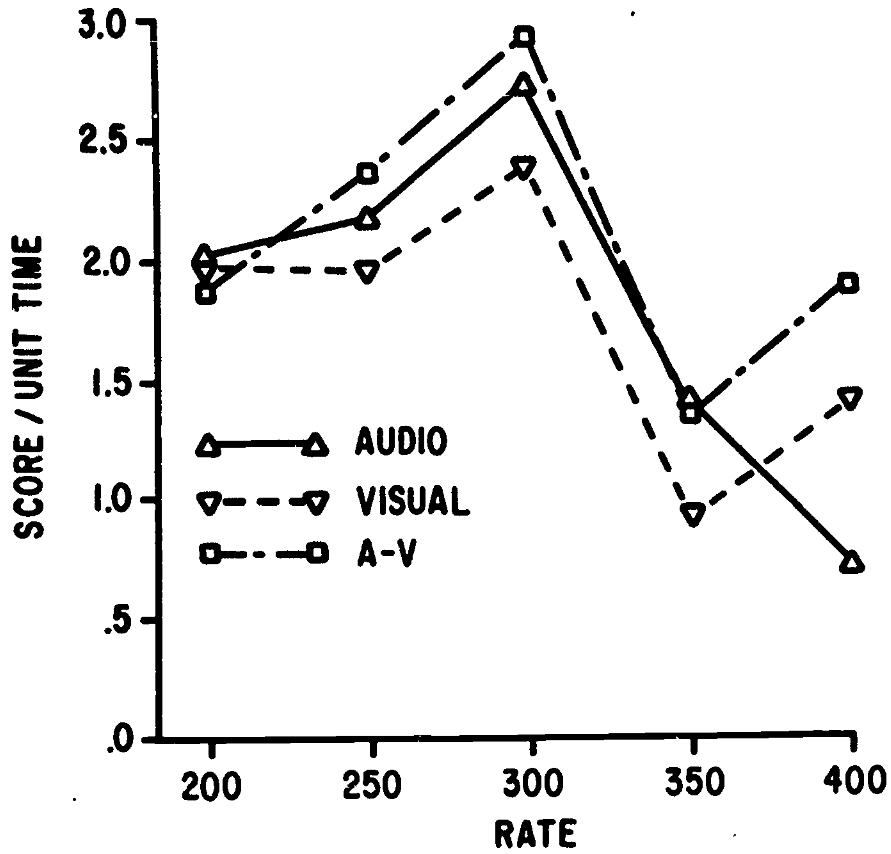

Figure 8. 08. Efficiency ratings by modality and rate of presentation.

TABLE 8.11

MEANS AND STANDARD DEVIATIONS FOR GRECO-LATIN SQUARE ANALYSIS OF VARIANCE (SCORES CORRECTED FOR GUESSING N = 18/CELL)

Rate	Mode			Test Form			Order		
		$\bar{X}$	S.D.		$\bar{X}$	S.D.		$\bar{X}$	S.D.
200									
	A	12.56	7.80	1A	13.39	7.88	1	10.05	6.08
	V	12.39	6.40	1B	10.83	6.32	2	12.94	7.55
	AV	11.78	6.80	1C	12.50	6.69	3	13.72	6.81
		12.24	6.90		12.24	6.90		12.24	6.90
250	A	11.00	6.71	1A	12.72	8.07	1	9.33	7.92
	V	9.50	8.24	1B	9.72	8.67	2	12.33	8.21
	AV	10.89	9.38	1C	8.94	7.32	3	9.72	8.15
		10.46	8.05		10.46	8.05		10.46	8.05
300	A	11.06	5.95	1A	12.28	5.93	1	9.50	5.65
	V	9.78	7.67	1B	9.61	6.13	2	11.22	7.01
	AV	11.78	6.47	1C	10.72	7.86	3	11.89	7.35
		10.87	6.66		10.87	6.66		10.87	6.66
350	A	4.95	3.40	1A	7.78	4.56	1	3.39	3.71
	V	2.89	6.45	1B	2.89	6.29	2	5.17	6.12
	AV	4.89	7.16	1C	2.06	5.17	3	4.16	7.38
		4.24	5.87		4.24	5.87		4.24	5.87
400	A	2.06	4.57	1A	6.28	6.41	1	2.61	6.15
	V	4.39	6.48	1B	3.78	6.27	2	4.00	6.41
	AV	5.94	6.68	1C	2.33	5.17	3	5.78	5.59
		4.13	6.09		4.13	6.09		4.13	6.09
Overall									
	A	8.32	7.07	1A	10.49	7.13	1	6.98	6.77
	V	7.79	7.80	1B	7.37	7.44	2	9.13	7.91
	AV	9.05	7.82	1C	7.31	7.73	3	9.05	7.83

TABLE 8.12

GRECO-LATIN SQUARE ANALYSIS OF VARIANCE

Source	d.f.	SS	MS	F	p
Between Ss	(89)	10,968.00			
Squares (Sq)	5	365.65	73.13	1.00	--
Rate (R)	4	3,274.82	818.70	9.94	.01
Sq x R	20	2,384.20	119.21	1.45	--
Ss/Sq/R	60	4,943.33	82.39		
Within Ss	(180)	4,406.67			
Orders (O)	2	269.09	134.54	5.88	.01
Modes (M)	2	72.80	36.40	2.41	.11
Tests (T)	2	595.48	297.74	15.21	.01
R x O	8	135.09	16.89	<1.00	--
R x M	8	182.61	22.83	1.51	--
R x T	8	160.35	20.04	1.02	--
S x O	10	337.40	33.74	1.47	--
S x M	10	152.75	15.28	1.01	--
S x T	10	198.07	19.81	1.01	--
Sq x R x O	40	915.09	22.88*		
Sq x R x M	40	605.17	15.13**		
Sq x R x T	40	782.76	19.57***		
Total	269	15,374.67			

*error term for Order effects.
**error term for Mode effects.
***error term for Test effects.

expected, both analyses produce approximately the same results. Since the Greco-Latin Square analysis uses a slightly higher estimate of error variance, the *F*s are slightly lower for this analysis than for the factorial design analysis.

There are two very basic differences between the two analyses. First, the factorial design analysis takes into account the modality by test form interactions while the Greco-Latin square analysis does not, and, second, the Greco-Latin square analysis takes into account the effect of order of presentation while the factorial design analysis does not. Although these differences are not crucial they are important. Since both of these effects produce statistically low probabilities in the *F* ratios, each analysis is obviously being affected by a source of variance which cannot be appropriately tested in that analysis. Thus, both analyses provide information worthy of discussion.

The Greco-Latin square analysis provides information relative to the variance which can be attributed to the order of presentation. This source of variance results in an *F* of 7.01 (df = 2, 120) which is statistically reliable beyond the .01 level. It can be seen that the most pronounced effect of order of presentation occurs at 400 wpm. This is not unreasonable since it is the rate of presentation which would be expected to be most foreign to the majority of people. The lower (200-300) rates of presentation are not so different from those of everyday communication that individuals would experience too much difficulty adapting to them. The data supports this interpretation by virtue of the fact that the second and third presentations are nearly the same in most cases. The factorial design analysis of variance permits the modality by testing form interaction to be evaluated. Examination indicates that, generally, most of the variance occurs from the first to the second presentation and that there is very little difference between the second and the third presentation. The indication is that subjects profited much more from the practice afforded by their first contact with the information than by subsequent contacts.

An interesting and unexpected phenomenon occurred in the modality of presentation by sequence of presentation interaction. The variance attributable to the interaction produced an *F* ratio of 2.47 (df = 10, 40) which is statistically reliable ($p = .05$). The audiovisual presentation is superior except when it occurs in the first position. This superiority is consistent with the findings of the previous study where the audiovisual presentation condition produced higher comprehension scores than did either of the single modality presentation conditions. The fact that the Greco-Latin square analysis provides evidence that the order of presentation effect is reliable accounts for the finding that all of the presentations occurring in the first position are low. This order effect partially accounts for the fact that the present study did not produce large differences among the modality of presentation conditions. The interaction may also shadow any real differences between the auditory and the visual presentations. Careful examination of the interaction leads one to suspect that the effects of order of presentation produce a higher increment when the visual presentation is followed by the auditory than when the auditory presentation is followed by the visual. That the increment in the second and third presentation is a result of practice cannot be denied but the fact that the increment in comprehension is differential according to which modality of presentation is first and the order in which modalities follow the first, can scarcely be disputed. The primary implication of this effect is that studies which investigate this phenomenon be designed so that the main effects are not obscured or the study should be so designed that the interaction can be more systematically investigated. This could, of course, be done by providing an initial practice session with similar material prior to the presentation of the experimental materials. The exact amount of practice necessary to eliminate the effects of order or sequence of presentation is not known nor can it be estimated with absolute accuracy from the present data. Further study where the effects of multiple sequential presentations are systematically explored will help to clarify this issue.

Discussion

This study has provided not only some knowledge concerning factors that influence the transmission of visual and auditory verbal information but it has also identified many of the problems that are associated with research of this kind. Reliability of measurement presents no great problem though one might well have anticipated that therein would lie difficulties. Even at the highest speeds of transmission, the reliability coefficients cluster around the 0.70 level and cannot be attributed to the fact that some students are better at guessing than are others. The portion of the reliability that can be attributed to consistency in guessing alone is small, as is evident from the performance of the group that attempted the test questions without seeing the passages.

While the speed of presentation which provides maximum learning per unit of time is about 300 wpm for both the auditory and the visual transmissions, the auditory transmission tends to be consistently inferior to the visual. One may well suspect that this inferiority is due to the fact that the mechanical analysis of sound at the level of the cochlea is inferior to the resolution of visual information at the level of the retina. The possibility also exists that if improvements could be made in both the original sound recordings and in the mechanics of the compression process that the difference in the results of the auditory and visual presentations might be reduced, if not eliminated. While one can draw conclusions about the effects of the present materials, one cannot generalize them to say that the same would be found with different materials as far as differences between auditory and visual modalities are concerned. However, the fact that the peak for efficiency comes at approximately 300 wpm for both modalities appears to represent a finding from which generalizations can be more readily made.

There appear to be individual differences in the ability to use verbal auditory and verbal visual information, particularly at the higher speeds. This is consistent with the well-established fact that with the subjects used, namely, college students, there are some who have not learned to use reading materials with any high level of proficiency. Whether the same is true with listening as with reading is a matter which still needs to be more adequately explored, but the present study showed large individual differences in the ability to comprehend and retain the auditory verbal materials used. In addition, a study reported in an earlier chapter of this report brought out much larger individual differences in using auditory information than in using visual information.

The superiority of the audiovisual transmissions at the higher speeds of presentation is probably a result of the fact that this condition permits the subject to select that modality which he finds most acceptable to him under the given circumstances. At ordinary rates of speech presentation this effect does not occur and cannot be used as an endorsement of the practice of reading aloud the directions to tests while the examinee reads them to himself. One presumes that differences in the ability to use auditory and visual information are learned, but the origins of these differences need to be explored.

A major difficulty in conducting research in this area is that there is an interaction of passage and modality. Some passages are easier when the transmission is through one modality rather than through another. This is a problem which frequently recurred when nonsense syllables were used. Some syllables which are highly ambiguous when transmitted auditorially are readily recognized when transmitted visually. We have speculated that a good point to begin research of this nature might be to develop a set of syllables equally recognizable through both modalities but, then again, speed of transmission probably also produces an interaction effect with modality. Syllables may be equivalent at lower speeds, but not equivalent at higher speeds.

EXPERIMENT III

The high degree of redundancy of verbal discourse makes it possible to reduce in length the presentation of verbal materials without reducing the amount of information available to the receiver. The Time and Tempo Regulator removes some of the redundancy within phonemes by cutting very small amounts at random from a sound recording. This procedure is effective in reducing the time required for presenting speech without loss of information because any single phoneme includes substantial redundancy which can be partially eliminated. In addition to the redundancy within each phoneme, language involves a high degree of word redundancy. The latter is clearly demonstrated by the fact that if a word is omitted from a prose passage, a knowledgeable person can generally supply the missing word without much difficulty. When this can be done, the implication is that the missing word adds no information which was not contained in the original passage.

Thus, messages can be compressed either by the partial elimination of either intra-phoneme redundancy or inter-word redundancy or by a combination of both of these methods of redundancy reduction. Both of these methods of compression, however, are likely to do more than eliminate mere redundancy, for a level is soon reached in the dropping of material when further elimination results in the reduction of the information available. For example, the phonemes in a particular word can be cut only so far and still retain intelligibility; beyond that point the word becomes unintelligible and information is lost. Again, some words can be dropped from a typical sentence without loss of information, but the dropping of additional words reduces the amount of information available to the receiver. This study explores the relationship of degree of compression by both of these procedures to level of comprehension and, in addition, attempts to determine the optimum combination of these two compression processes for producing material from which there will be a maximum amount of learning in a given time.

Method

Design. -- Materials from the first half of the Davis Reading Test Form 1A were presented to subjects in one of a combination of compressions by time and words. Five levels of time and word compression, making a total of twenty-five treatments, were used with ten subjects per treatment. The treatment used as a base contained 100 percent of the words in the first half of the Davis Reading Test, and was presented at 200 wpm. This latter speed was chosen because it is reasonably within the experience of subjects, and in keeping with other studies in the series. This speed established the base time for subsequent time compressions.

Compression by words was undertaken by requesting a group of thirty-five undergraduate students at the University of Utah to eliminate those words from the passages which would not alter their essential meaning. Compressions were obtained by this method so as to have remaining 80, 60, 40 and 20 percent of the original material. Each of these word compressions, and also the 100 percent version of the original material, was presented at each of the five time compressions produced by a Tempo-Regulator. These time compressions removed 20, 40, 60, and 80 percent of the material and, hence, reduced the time taken to present each passage to a corresponding percentage of the original time. Thus, treatments ran from 100 percent of the material at 100 percent of the time to 20 percent of the material at 20 percent of the time, organized in a 5 x 5 design. The rate of presentation in words per minute is shown in Table 8. 13.

Subjects. -- Subjects were derived from two sources. The original intent was to draw subjects entirely from English classes designed for non-college oriented seniors in an academic high school. A sample of 125 boys and 125 girls was thus selected with a mean Pintner I.Q. of 103. These were divided into 25 groups of 10 subjects each. However, since the performance of the last ten of the groups tested involving 100 subjects showed outstanding inconsistencies with other available data, these groups were replaced with subjects from pre-admission remedial reading classes at the University of Utah. These latter subjects were selected because of their similarity to the subjects in the original group in terms of I. Q. level. Two of the treatments of 12th grade subjects, which provided satisfactory data, were also rerun to check some of the original data against the new data. On these two groups the new data and the original data showed a close correspondence as will be indicated later in the presentation.

Apparatus. -- Short sections of the passages about 20 words in length were shown to the subjects by means of a remotely controlled Victor Soundview filmstrip projector, model No. PS65, which was controlled manually by the experimenter who timed changes of frame by means of a Hunter Clockcounter.

Procedure. -- The investigator sat behind the subjects, who were seated eight feet four inches from a screen onto which slides containing the test passages were projected. The height of the letters on the screen was 0. 75 inch. The subjects were assigned at random to one of the twenty-five treatments. The projection time for each slide was determined by the word-per-minute rate for each treatment. After each passage, the subjects were asked to answer the questions concerning that passage derived from the original test. Subjects were given an explanation of the

TABLE 8.13

TIME RATES IN WORDS PER MINUTE

Per Cent of Words	Per Cent of Original Time				
	100	80	60	40	20
100	200	250	333.33	500	1000
80	160	200	266.67	400	800
60	120	150	200	300	600
40	80	100	133.33	200	400
20	40	50	66.67	100	200

task and subjects were first exposed to a sample passage and a set of sample items. The subjects were instructed to answer every item in the test. Ample time to answer all items was given.

Results

Efficiency scores were computed by correcting the raw scores for guessing (rights minus one-fourth the wrongs) and then dividing the time for presentation by the scores. The means and standard deviations of these scores are shown in Table 8.14. The means are graphically represented in Figure 8.09. The distribution represents a smooth surface indicating internal consistency of the data. While the data were derived from two separate classes of subjects, on two groups data were collected from both classes in order to check on the comparability of the two sources of subjects. The duplicated data is shown in parenthesis in two cells in the table. In these two cells the means for the 12th graders and the remedial reading students correspond very closely, a fact which validates our subject selection procedure.

Discussion

The data presented indicate that the most effective form of compression of verbal information, in terms of a short-term retention criterion, is one which combines both time compression and compression through the elimination of words. It was a matter of considerable surprise to the present authors to discover that the optimum rate of presentation was one in which material was presented at a rate of 400 wpm. This peak was clearly not a product of some freak operation of error factors operating in our particular group, for the distribution showed an overall tendency to peak in that particular category. The three-dimensional distribution represented a fairly smooth surface with an asymptote where the coordinate representing 80 percent of the words crossed the coordinate representing time compression to 40 percent. There would be considerable interest in determining whether the same asymptote would be achieved if the subjects were exposed to the material for more than one trial. An interesting question is whether the asymptote would move towards higher levels of compression if the subjects were derived from groups having higher scores on intelligence tests.

TABLE 8.14

MEANS AND STANDARD DEVIATIONS OF EFFICIENCY SCORES

Per Cent of Words		Per Cent of Time Compression				
		100	80	60	40	20
100	M	1.678 (1.606)*	1.511	1.566	1.739	1.196
	SD	.513 (2.395)*	1.122	.968	1.863	2.202
80	M	1.432	1.430	1.957	3.027 (2.772)*	1.739
	SD	2.114	.746	.623	1.9 (5.992)*	4.704
60	M	1.280	1.437	1.633	2.065	2.174
	SD	.584	1.435	1.245	1.772	3.904
40	M	.828	.990	1.377	1.033	1.304
	SD	.527	.639	.868	1.159	2.574
20	M	.608	.634	.847	.660	.761
	SD	.745	.698	.945	1.148	2.178

*The means and standard deviations in parenthesis are for those cases in which acceptable data were available for both the 12th grade students and for the students in the University remedial reading classes. Note that the standard deviations were larger for the 12th grade group than the remedial reading group as would be expected.

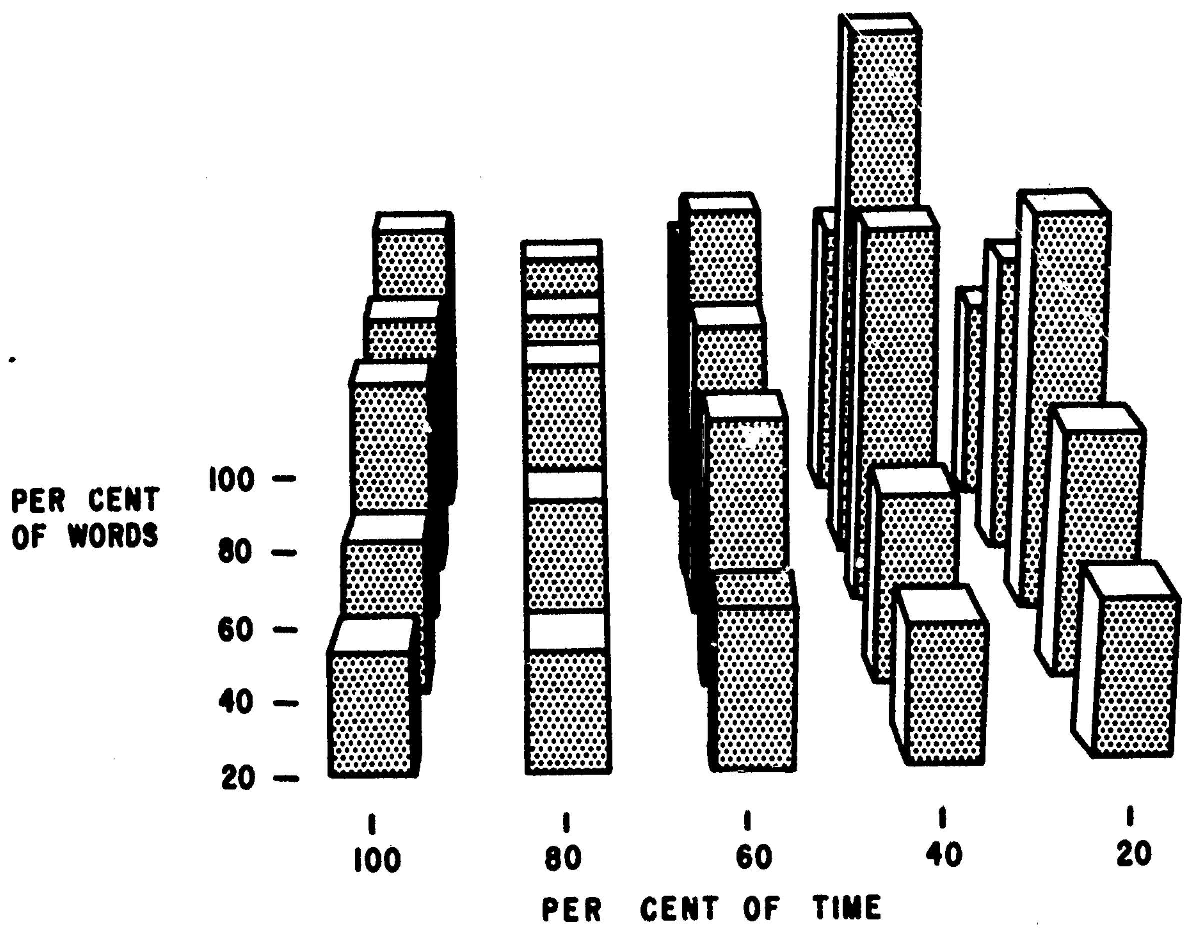

Figure 8.09. Graphical representation of mean performance at each level of compression.

CONCLUSIONS AND IMPLICATIONS OF THE EXPERIMENTS REPORTED IN THE CHAPTER

The experiments reported in this chapter have been concerned with determining; (1) the extent to which compression of verbal material changes level of comprehension, (2) the relationship of degree of compression to learning per unit of time, insofar as comprehension, as measured in a reading test situation measures learning from the paragraphs, and, (3) the optimum combination of compression processes for producing maximum learning per unit of time.

While comprehension generally declines as speed of presentation is increased, and the relationship in terms of reading test scores approximates a linear function, a similar relationship is not observed when learning per unit of time is plotted against speed of presentation. When the latter is done, the peak of efficiency is approximately at the 300 wpm level in the case of our data derived from time-compressed material. This optimum speed is considerably above that which is commonly used for presenting lectures. Indeed, a human speaker would have difficulty in maintaining this speed of communication for more than a few sentences. However, one cannot generalize and say that this speed would be optimum under all conditions or with all kinds of materials. In the case of difficult technical material a much slower speed might be the optimum. The material used in the studies was quite comparable to that to which college students are exposed in a typical freshman English course.

Time compression removes redundancy inherent within phonemes, but this is not the only redundancy present in verbal material. As large a unit as a word may be partially or entirely redundant with another word or words within the same context. An alternative method of compressing verbal material is through eliminating units as large as words. While various criteria can be used for the elimination of words, for the purpose of removing redundancy, in the study reported here the relatively crude one of judgment had to be invoked. The material in the Davis reading tests was compressed by the latter procedure so that they contained 80, 60, 40, and 20 percent of the original material. These versions were then each time compressed so as to provide 25 different combinations of compression by word elimination and compression by phoneme segment elimination. When each of these presentations was given to subjects, the optimum rate of presentation was found to involve the elimination of 20 percent of the words and the compression of the remaining material to 40 percent of the time. This compressed version involved a presentation speed of approximately 400 wpm. That comprehension is possible at all at such high speeds is surprising in view of the fact that lectures are typically presented at less than half this speed and students do not generally complain at the slow speed which the presentation involves. Whether this optimum would remain stable if subjects were to be given several trials with the material remains to be seen. There is also a question whether high speed of presentation would continue to be effective if the material were to be substantially lengthened. Longer passages might involve difficulties in maintaining attention. A final question is whether a group of college students might not have an optimum speed of presentation far above that found in the study reported here.

There are marked differences in the ability of the students included in the sample studied to utilize auditory and visual verbal information. Such differences become progressively more marked as the speed of presentation of the material is increased. This is shown by the fact that the correlation between performance on an auditory presentation and performance with a visual presentation steadily declines with increasing presentation rate until it becomes virtually zero. The latter occurs despite the fact that the reliability of measurement remains surprisingly high. One may well presume that such differences are largely due to accidents of training or lack of training in the individual's background. The extraordinary permanence of reading deficiencies suggests that an early lack of training in related perceptual skills may leave a relatively permanent mark. We are inclined to believe that the individual differences in effectiveness in using a particular sensory channel which have been noted here may arise early in life. Perhaps Madame Montesorri, when she insisted on the importance of early sensory training, was showing insight into the long-term effect which the omission of such training might bring. There would be interest in determining whether those who have difficulty in receiving verbal information through the visual channel also have difficulty in receiving other forms of visual information. Perhaps the same might also be found in the case of receiving auditory information. An incidental observation may be introduced at this point. The two subjects who were most effective at receiving auditory information at the highest speed used were a music major and a speech major, both fields in which auditory skills must be highly developed.

A very marked practice effect occurred from the first to the second trial with the highly speeded material. One presumes that the subject's lack of experience wi''. the high speeds of presentation used required that an initial adaptation be made to the novelty of the situation. This finding does not imply that individuals can learn to use highly speeded materials as a part of an instructional program. As a matter of fact attempts to train subjects to use high-speed auditory presentations have not so far produced consistent results.

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CHAPTER IX

RETROSPECTIONS AND EXPECTATIONS

5

This volume began with the presentation, once more, of a model that was previously described in an earlier publication arising out of the project. The studies that follow are mainly concerned with testing hypotheses implicit in various aspects of the model. The model, like all useful models, has been rich in the hypotheses it suggests and the present series of studies has not exhausted the various ideas for research which it can yield.

A central idea incorporated in the model of audiovisual information transmission which has guided the research is that when the information-processing capacity of the individual is fully utilized then his transmission system functions as a single channel. This is in direct contrast to classical audiovisual theory of information transmission found in all current textbooks in the field. Our suspicions that the researches which are commonly cited to substantiate this point of view are thoroughly unsound have been fully confirmed by the studies that are cited in Chapter 3 of this report. These studies indicate, clearly and unequivocally, that the transmission of information through more than one sense modality provides <u>no</u> advantages at the rates of information transmission which were used in the experiments. This does not mean that two sense modalities cannot be used for the simultaneous transmission of information for obviously they can, but they can be used to advantage only when the rate of transmission of information is relatively low. Even under the latter circumstances, whenever conditions are arranged to attract the learner's attention to one channel then he is likely to learn more from that channel but at the expense of the material learned through the alternate channel. The information processing system appears to be of very limited capacity at the highest levels, where the bottleneck in information processing occurs.

The fact that the highest levels of the nervous system, where the most complex analyses of incoming information occur, are limited in capacity, does not mean that the lower levels are not capable of analysis of information at a much cruder level and on a wider front of sensory inputs, for obviously this occurs. Incoming information is obviously monitored at a low level for broad categories of information which can be of the greatest value to the receiver. However preoccupied a person may be with the information derived from a particular source, as a person is when reading a completely fascinating book, he is still capable of turning immediately to information with even higher priority. A shout of "fire" will immediately divert his concentration from the book, and yet he is able to pick up this signal only because the information was analyzed at a crude level and given priority in the main information processing channel.

In the case of young adult subjects that have been used in the series of studies, and who have at least moderately good skill in reading, one can find virtually no advantages in using two sensory modalities for transmitting information in contrast with one. In learning associations between words and visual presentations the word can be presented visually along with the object with which it is to be associated. No advantage is gained by using the auditory modality. Indeed, the use of the auditory modality for transmitting verbal material would appear to have disadvantages rather than advantages, for auditory information tends to have an ambiguity which printed material does not have. The only case where there is likely to be a clear-cut advantage in using both the auditory and visual is that in which names in a foreign language are to be associated with pictures of objects and the learner is to be tested later with an instrument in which the names are also to be presented in the auditory mode. One may infer from the data presented in Chapter 5 that there would be an advantage in using two channels under such circumstances. This fits the well-known fact that students perform best when the testing modality is the same as the modality in which the learning has occurred. There are, however, limitations on the latter generalization, for studies in Chapter 4 have shown that where associations are to be developed between familiar words and familiar objects that there is, for all practical purposes, perfect transfer across modalities.

In the development of either word-object or word-word associations either across or within a single sense mode, time conditions are of considerable importance. Such associations develop most readily when there is a simultaneous input of the two items to be associated. Why this is so is open to speculation. Our own preferred interpretation is the one that fits the model we have used. This interpretation is that in order for an association to be developed, the learner must identify particular meanings or particular attributes of the two elements that have to be responded to. This cannot occur until both elements have been received by the learner. For example, suppose the task of the learner is to associate two words and the first word of the two presented is chest. Now in order to form an association with a second word the learner may have to decide whether the word is to be interpreted as in tool chest or as in chest X-ray. He cannot determine which one of these meanings of chest permits him most readily to form the association until the second word has been presented. The task of making an association between chest and wood is different from making an association between chest and cough. If the association is with wood it involves one meaning but if with cough another and thus he must wait until the second word arrives before the task of making the association can begin. The advantage of presenting the two words simultaneously to the learner is that this permits him to identify each with a minimum delay and leaves as much time as possible for forming the association. An alternative hypothesis is that mere time contingity alone may be the key factor in facilitating the formation of associations, but this hardly seems likely since in another experiment by Mueller (1965) the simultaneous presentation was equal in effectiveness to that sequential presentation in which the most meaningful word of a pair arrived first. When the first word is thoroughly familiar and unambiguous less advantage would be expected from a simultaneous presentation if our interpretation is sound.

A particularly interesting phenomenon which has been ignored by those who specialize in audiovisual education is the time lost in channel switching. Since every contemporary book on audiovisual education takes the position that learning will occur most effectively when both the auditory and the visual channels are being, so to speak, saturated with information, the channel-switching phenomenon has been completely ignored. It is a phenomenon which occurs because of the single-channel nature of perception. Time loss in switching can be observed when the information density is such that it has reached the limit of the capacity of the organism to handle. This, of course, is a typical rather than an exceptional state of affairs. It is worth reflecting at this point that the educational sound motion film can hardly be used economically unless it is transmitting information at a rate near the limit at which information can be received by the learner. It is under just such conditions that the loss of learning through channel switching becomes most evident. This problem has not even been considered by the designers of those sound motion pictures which are to be used as teaching devices. From what has been learned in the studies presented in this report there would appear to be much in favor of educational motion pictures designed after the pattern of the old silent pictures which alternated print with visual displays. One alternative is the use of visual displays with subtitles. But this would appear to place too much strain on the viewer who must frequently change from the pattern of eye movements required for reading to the pattern of eye movements required for inspecting a complex visual display. Our investigations have not been extended to cover the latter type of shift which is analogous to shifting from one message to another, in contrast to shifting from one sense modality to another.

Finally, the principal investigator would like to voice his own optimism concerning the value of the approach illustrated here to problems of designing audiovisual teaching materials. The approach to the improvement of these materials that is presented here takes place through the discovery of general principles, discovered in a laboratory situation, which are then applied to the design of teaching materials. This is similar to the way in which advances in engineering have been typically achieved. For example, the basis of the design of engineering truss structures is Newtonian mechanics which, within limits, permits the calculation of the forces operating at each junction in such a structure. Newtonian mechanics permits the design of structures in which the forces operating are well within the strength of the materials used. An analogous set of psychological principles, derived from laboratory experimentation, should permit the design of audiovisual materials with some assurance that they are within the learning capability of the pupils for whom they are intended. Bridges are not improved to any extent by the procedure of building a number of them and then seeing which ones stand up best. Audiovisual materials are also unlikely to be improved by producing this one and that one and then determining which one is most effective as a learning device. While much of the latter activity has been undertaken, the main outcome has been to discover that certain things do not matter. For example, many studies have shown that color in a sound-motion picture does not matter unless the learning involves knowledge of color. The formulation of a set of principles useful for audiovisual design is unlikely to be derived from experimentation with actual teaching devices but must be the product of laboratory research.

This research project has made considerable use of the concept of compression in the development of studies related to problems of audiovisual instruction. This concept related to information transmission and processing has previously found no place in the literature on media although deference has always been paid to the dimension of realism-abstraction which sometimes has been used to reflect what we have called degree of compression. Our preference for the concept of compression stems from the fact that it is vastly more valuable as a scientific concept than are any of the related concepts found in the literature of the audiovisual field. It refers to an identifiable physiological process, in the case of visual information, and also to a way of reducing the information or redundancy in particular visual displays. While methods of measuring degree of compression are still primitive in the case of visual information, what is involved is sufficiently well understood that more precise methods of determining compression would appear to be possible. In contrast, such dimensions as realism-abstraction are at the best fuzzy notions which bear no relationship to any body of organized knowledge.

Studies of the value of compressing visual information prior to its transmission which are presented in Chapter 7 have helped to clarify the advantages and disadvantages of compressing information in educational displays. While our original thought was that compressed information should facilitate the transmission of knowledge, this does not necessarily seem to be the case. The value of what are termed realistic presentations appears to lie in the fact that such presentations provide some useful information in the presence of a large quantity of irrelevant information. The acquisition of the information to be acquired,through teasing it out from an entanglement of irrelevant information,provides experience which is later valuable in applying the information in a different context. Learning through the use of compressed visual information does not provide the learner with experience in making this discrimination.

The data on visual compression do not rule out the value of using highly compressed forms of visual displays in all situations. There is the interesting suggestion in these studies that if the learner is given the opportunity to tie the compressed information to some realistic situation he will assimilate it more effectively and use it more efficiently later than when it is presented without any such tie-in. There is also the possibility that, after a learner has observed the effects of a phenomenon in a number of realistic and complex situations, he may perhaps then benefit from the presentation of the information in a compressed form. However, learning to apply, say a physics principle, to a range of new situations may draw heavily on the person's ability to discriminate the relevant from the irrelevant in the new situations.

The extensive use in education of visually compressed information in typical classrooms, as is evident from the use of maps, globes, diagrams, and so forth, emphasizes the importance of the class of problems considered here. The absence of any attack on these problems, despite the proliferation of audiovisual materials that use them, reflects the absence in the audiovisual field of constructs which can be used as a basis for scientific enquiry.

Visual information can sometimes be compressed by coding it in verbal terms. Thus when one makes the statement that a certain house is "modern" in style, the word "modern" represents a highly compressed form of the visual information presented by the house. The advantages of thus coding information need to be extensively explored. It was only touched upon in this report in the single study involving the value of naming visually presented shapes on the subsequent recognition of the shapes. We still do not know whether a detailed verbal description of a complex visual display results in a better retention of its features than does the mere inspection of the display without any verbal description.

Our explorations of the verbal compression process had to begin at a different point from the studies of visual compression. Our immediate concern was to determine the value of presenting redundant information both visually and auditorily since this kind of redundancy has been both recommended and practiced. Test users have long required that verbal materials be read aloud by the examiner while the person taking the test reads them aloud. The value of such redundancy is a matter of theoretical as well as of practical interest since, in terms of the model presented here, one would expect that it would achieve no advantage. Our investigations permitted a study of the effect of redundancy not only at normal speeds but also at speeds far higher than are ordinarily encountered (in the case of auditory materials). The high speeds for the auditory materials were achieved through the use of a speech compressor.

At speeds typical of vocal communication, the college students used as subjects gained no advantage from the simultaneous auditory and visual presentation of the verbal material. This was strictly in accordance with predictions. However, at higher speeds a definite advantage was found for the audiovisual transmissions. This could be interpreted as representing a finding that might be considered to run contrary to the model of information transmission, but other explanations are also possible which are consistent with the model. One explanation is that some individuals, through accidents of training, are more effective at taking information in through the eyes while others use their ears more effectively. In the situation involving audiovisual transmissions, the learner can choose whether to attend to the auditory or to the visual transmission. Indeed, he is free to choose the transmission which he can most effectively use. If he did this, and if there were genuine differences in the ability to use visual or auditory information then the effect noted would take place. An informal observation tends to support this interpretation. At the highest speeds, some subjects tended to close their eyes while others placed their hands over their ears, indicating that only one transmission was being received.

The model implies that the main restriction on the amount of information that can be handled is derived from the fact that the highest processing level is a limited capacity system. If this is so then one might expect that as much information could be received through the ear as through the eye. The data from the chapter on verbal compression show that at the higher speeds of presentation more information was received, per unit of time, through the eye than through the ear. This is an interesting finding which needs to be explored further. One explanation for the inconsistency between the finding and the model is that the subjects had had experience in receiving high-speed printed information through the eye, but that they had had no experience of doing this through the ear. It would be of considerable interest to determine, through the use of compressed speech and practice with high-speed auditory material whether the eye and the ear could transmit equal amounts of information.

Next Steps

The position of the investigators who produced this report was that experimental investigations of audiovisual problems through the use of actual teaching materials had produced significant knowledge, but that most of the knowledge which still had to be acquired would have to be derived from a different kind of experimental enquiry. Research with actual teaching materials was successful in producing evidence concerning the worth of particular techniques used by film producers, but it had not developed a set of principles which would be of value in designing new teaching materials. It did not, for example, examine any of the principles which are stated in textbooks in the field such as that the use of two sense modalities produces more learning than the use of one. Our position is that the "principles" of audiovisual information transmission voiced in texts need to be questioned and examined for validity. Our questioning approach has raised serious doubts concerning the validity of those principles that are most commonly emphasized. In the case of multiple channel versus the single channel transmission issue, what is commonly stated in textbooks is clearly wrong and based on research which for many obvious reasons is clearly worthless. A questioning and experimental attitude towards some of the other cornerstones of audiovisual education also need to be questioned and studied before the field can be expected to emerge from its present state in which practice is determined largely by authority.

In conducting our studies we have been encouraged by the support and interest displayed by persons who have a close connection with audiovisual education. We have also been discouraged by the fact that simple experimental studies, of the kind we have conducted, have never been undertaken by audiovisual specialists. Indeed, such studies are almost wholly absent from the publications of the field such as the Audiovisual Communication Review. This absence is partly explained by the training given to the audiovisual specialist which generally omits the areas of substantive knowledge from which we have drawn such as physiology, communication, perception, and information theory. The training also omits any experience in experimental design. Graduate schools of education must take the full share of the blame for such a situation.

Until those who receive degrees in the audiovisual area are better prepared for research activities, the task of conducting studies of audiovisual problems will remain in the hands of psychologists. The last few years have seen an encouraging growth of interest among psychologists in problems of information transmission using more than one sense modality. Recent issues of such journals as Perceptual and Motor Skills have shown an increasing number of studies in this area. In addition, some of the work undertaken in the Research and Development Centers is focussed on such problems. Some of those who have participated in the enterprise represented by this volume will also continue research in the area. Interest is sufficiently widespread to anticipate a substantial growth in the kind of research represented by this report.