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THE UNIVERSITY OF ALBERTA

# THE EFFECT OF INTERPOLATED INFORMATION REDUCTION ON KINESTHETIC AND VERBAL SHORT-TERM MEMORY

by

© GERALDINE TANNIS

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Effect of Interpolated Information Reduction on Kinesthetic and Verbal Short-Term Memory" submitted by Geraldine Tannis in partial fulfilment of the requirements for the degree of Master of Science.

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Date August 2, 1972

## ABSTRACT

The purpose of this study was to determine the nature and requirements of a task which would cause the kinesthetic and/or verbal STM systems to lose information. In doing so, any consistent differences or similarities which may be exposed may help to define the nature of the kinesthetic STM system. There were three factors of experimental interest: modality of the input, modality of the interpolated task and amount of information reduction in the interpolated task. The experimental task involved the subjects receiving input information (verbal or kinesthetic) and recalling after a period of delay in which the subject engaged in a interpolated transform (verbal or kinesthetic) of increasing levels of information reduction.

The experimental design was treatment by subjects, factorial, replicated ten times for each subject. The dependent variables were the number of digits incorrectly recalled or forgotten and the absolute error in reproduction accuracy. The methods used to analyse the data were an analysis of variance and measure of information transmission.

It was concluded that:

1. Verbal information loss was a function of the amount of information reduced in the interpolated transform.
2. K information loss was unrelated to the amount of information reduced in the interpolated task.

3. The STM systems for K and verbal information were separate.
4. Storage of K information, unlike verbal information, was not by verbal labels and K and verbal information have different central processing requirements.

The analysis of data and the use of STM paradigm also allowed for discussion of information loss.

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# CHAPTER 1

## STATEMENT OF THE PROBLEM

### Introduction

To quantitatively investigate skilled human performance, an analytical framework was needed that would handle the individual components of performance and the interaction between components. Under the influence of a series of developments in engineering, communications and computer science, experimental psychologists moved towards explaining performance in terms of information and communication theory. Because of the number and complexity of the processes involved in human performance, computer analogies were utilized in order to define more simply the interactions of the processes.

From these trends a theory was developed to account for skilled performance in human beings in an information processing framework. The human was viewed as a cybernetic system in the sense that control functions may be more important in the understanding of performance than energy conversion or power generation function (Pew, 1970). Attempts were made to formulate and describe stages of information processing within the organism as well as their limitations and performance capacities.

The processing of information in the organism was broken down into three major stages: input, central processing and output. The main features of an input stage seems to be a selective attention mechanism and a short-term sensory store (buffer). In the processing stage, the input information is coded and stored in memory. This stage, also, includes a stimulus recognition and identification process, involving memory scanning and a decision mechanism. The output stage involves an effector mechanism and some type of feedback system, functioning to inform the organism of the results of his output so he may organize his behavior.

Because skilled performance is comprised of a systematized sequence of activities, (Fitts and Posner, 1967) information, once past the input stage, must be temporarily stored while operations are being carried out on the ongoing input. This immediate storage function could be carried out by a short-term memory system (Posner and Rossman, 1965).

Short-term memory has been the topic of extensive research since it is thought to play such a key role in information processing in sequential tasks (Broadbent, 1958). The suggestion has been made that the computer analogy for information processing breaks down at this point (Posner and Rossman, 1965). Unlike a standard computing system, the human operator is susceptible to loss of information from short-term memory when computing operations are being carried out on the input. To fully specify the characteristics of a human information processor, the laws governing the loss of information in short-term memory must first be understood.

From studies, dealing with the rate of information loss from short-term memory and factors affecting the rate, there appears to be a discrepancy among sensory modalities. Results from studies concerned with a short-term memory for kinesthesis, have led researchers to conclude that kinesthetic information does not conform to the laws of information loss for verbal and visual information stored in short-term memory (Adams and Dijkstra, 1966; Posner and Konick, 1966b; Sharp, 1971). The difference between the kinesthetic modality and the verbal or visual modalities seem most evident when an interpolated task is introduced. The effect of an interpolated task on recall is analogous to the effect on material in store from operations on ongoing input in a sequential task.

This difference is partially accounted for in Broadbent's (1958) information processing model. In this model, short-term memory, or the rehearsal mechanism, is considered to be a recycling process. When rehearsal is in use, it demands a part of a limited central processing system in a given subject. Consequently, accuracy in immediate recall could possibly be reduced if there was an interruption of this recycling process, or if a sufficient part of the central processing capacity was not available.

To stimulate this interruption of this rehearsal process in a research situation, a paradigm was used containing an interpolated task between the input and recall stage. Further to this, studies have been done to determine the effects of varying types of interpolated tasks and their difficulty on recall (Posner and Konick, 1966; Posner and

Rossman, 1965).

Posner (1964b) showed that the amount of information reduced in an information transformation was a quantitative predictor of task difficulty. This reduction relates to the amount of the central processing capacity used in carrying out the transform. From this fact, the inference could be made that as the difficulty of an interpolated task was increased, the portion of the central processing capacity available to rehearsal of information in store would be correspondingly reduced. As a results, short-term retention would be decreased as a function of the increasing difficulty of an interpolated task. Posner and Rossman (1965) found this to be true with verbal recall. However, when a kinesthetic recall task was used and the interpolated task was in the verbal modality, there was no significant decrement in recall accuracy as the difficulty of the interpolated task increased (Posner and Konick, 1966). These results tend to intimate that kinesthetic information was not centrally processed but was stored in a separate short-term memory system.

However, task difficulty was compared across sensory modalities solely on the basis of the amount of information reduced, which is related to the amount of the central processing capacity used. But Broadbent (1958) suggested that processing demands of verbal skills are different from those of motor skills. He based this on the amount of conscious awareness which exemplifies these two types of input and the manner in which they were coded. For the retention of verbal material, verbal labels would probably be used, whereas, as it has been suggested (Posner and Konick, 1966), the retention of motor movements is not completely coded through the storage of verbal labels but rather as an image form which may require less central processing (Sharp, 1971).

Because a kinesthetic task seems to put less demand on the central processing capacity than a verbal task, it would seem that difficulty of tasks could not be compared directly across modalities only on the basis of the amount of information reduced in the task.

Researchers (Posner and Konick, 1966; Williams, et al., 1969) investigating the interference effects on short-term memory between sense modalities, and the related difficulty of a task across modalities do not seem to have considered this phenomena. Consequently it is possible that they may have overlooked some of the reasons why kinesthetic recall does not conform directly to the laws concerning verbal recall. Therefore, to meaningfully investigate the nature of, and the interactions between the verbal and kinesthetic modalities in short-term memory, equivalences, in terms of task difficulty should be made between these two operational systems. In doing so, it was felt that once equivalences in task difficulty were established, that nature of short-term memory, and consequently the characteristics of the human performer as an information processing system, might be more fully defined.

## The Problem

The present study was an attempt to determine equivalences, in terms of task difficulty between verbal and kinesthetic information transforms from their effect on recall. In addition, there was an attempt to determine if there were any consistent differences between the verbal and kinesthetic short-term memory systems, from the interference effect of an interpolated task on recall within the same modality.

## Definition of Terms

Kinesthesis (K). Howard and Templeton (1966) define K as ". . . the discrimination of positions and movements of body parts based on information other than visual, auditory or verbal."

Information. A gain in knowledge due to the reduction of uncertainty (Fitts and Posner, 1967).

Bit. The unit used in the measurement of information and uncertainty. The amount of information (Binary digit) in a "yes-no" decision (Attneave, 1959).

Information transformation. The process of translating a stimulus code to a response code (Fitts and Posner, 1967).

Information reduction. A process which results in the amount of information in the output being less than the amount of information in the input. This implies that there is information loss and as a result the original stimulus cannot be recovered from the response (Fitts and Posner, 1967).

<u>Short-Term Memory (STM)</u>. ". . . a system which loses information rapidly in the absence of sustained attention" (Fitts and Posner, 1967). It involves processes which only operate for approximately sixty seconds after the input. Beyond this interval information will be lost or transferred to long term memory.

<u>Interpolated task</u>. An information transformation task which the subject is required to perform in the interval between the input phase and recall of a memory task.

## Limitations

The task used for the K modality was restricted to a unidimensional replacement accuracy task. This task has been used by several researchers (Ascoli and Schmidt, 1964; Patrick, 1971; Stelmach, 1969). But, because of their singular nature such tasks may not be indicative of all similar tasks.

# CHAPTER 2

# RELATED LITERATURE

The concept of task difficulty in the short-term memory (STM) literature has only been considered as to its functional use in defining the nature of this system. As a result, there are certain key issues which must be considered, in order to specify task difficulty within two different sensory modalities. Essentially these problems are: the coding of verbal and kinesthetic (K) information; the processing of these types of information and the factors leading to the loss of the information in STM.

## Coding of Information

"One goal of an informational analysis of behavior is to specify the codes involved in human behavior including neurophysiological processes, as well as, the inputs to man's sensory channels and his response codes" (Fitts, in Melton, 1964).

A code, which is central to the view of man as an information processor, consists of a population of symbols and a system of rules or constraints governing them (Fitts and Posner, 1967). The purpose of a code is to provide a more readily remembered unit than would be the case if a direct representation was stored in memory. It is believed that man uses a discrete coding process, in that, he categorizes his input information.

Coding is directly related to the maximum possible rate at which the human system can transmit information. The concept of a channel capacity includes specification of the code to be used. Therefore, if the code is changed, the capacity of the human system to transmit information may be changed also (Fitts and Posner, 1967). As a result, one cannot apply the theorems of information theory to human performance without first considering the types of codes used.

Coding of verbal information. For auditory presentations, evidence for verbal encoding is very strong (Wicklegren, 1965). Sperling (1963) has suggested that aurally presented information is read into an auditory information storage storage system and stored in the form of verbal labels. This notion is supported by studies by Conrad (1964) and Wicklegren (1965, 1966) in which acoustic interference was found to be the main reason for information loss.

The notion of an auditory information storage system would suggest that aurally presented information, which has verbal labels for storage directly available, is subject to simpler encoding than another type of information which has to be given a verbal label. This recoding of non-verbal information into verbal form could be called a type of strategy which may effect the rate and amount of non-verbal information which can be processed. As predicted by this view, verbal coding is very efficient for storing information in STM (Pollack, 1963).

Coding of K information. Posner (1967) suggested that in motor skill learning, one may consider the concept of a representational memory. He based this suggestion in part on the results of several studies (Adams & Dijkstra, 1966;) Posner and Konick, 1966) which led the investigators to conclude that K information was not stored in the form of verbal labels.

Adams and Dijkstra (1966) using a blind lever positioning task, obtained rapid forgetting for unfilled intervals from 5 to 120 seconds. Posner and Konick (1966) followed these findings a little further. They used two tasks: retention of a position on a line (visual location) and the retention of a distance of a motor movement, conducted without visual information (kinesthetic distance). Rehearsal was prevented by an interpolated task of varying levels of difficulty as measured by the amount of information reduction required in the task. Both visual location and kinesthetic distance showed systematic forgetting as measured by a decrease in accuracy of replication over the delay interval. However, K-distance produced forgetting over an unfilled interval and the rate of forgetting over the filled intervals was completely independent of the level of difficulty of the interpolated task. Visual location showed the opposite results. They concluded that K information was not stored by an active process, such as verbal rehearsal, and made the suggestion that the information wqs stored in some non-rehearsable form such as an image.

This notion of an image, in Sperling's (1963) terms, is used to refer to an extremely brief and complete representation of a prior visual image. However, it may be applied to the K modality. This type of storage code would then contain more information than a straight verbal code. Posner (1967) stated that the code for K involves the storage of all information which is not in the form of verbal labels. However, he indicated that this code refers to the types of information available in the task but not necessarily to what the S is subjectively experiencing or attending to.

It is possible that K information is recoded into a crude verbal label for storage as was suggested by Greenwald's (1970) ideo-motor mechanism. Consequently, in this theory, the verbal code for the K information may require decoding back to the initial response image in order to be employed. Because of these transformations the fidelity of the K response may be affected. However, it would seem that there is strong evidence for a representational image for K in STM supporting the view that perhaps K information is not codable (Wilberg, 1969).

Channel capacity of the STM system. The capacity of an S to receive and retain information on a short-term basis is the measurement of the immediate memory span defined as the number of discrete units that can be replicated in series after one exposure (Postman in Melton, 1964). It has been found that there really is no constant when using information theory statistics to describe the capacity (Miller, 1956). For example, it is as easy to recall eight random letters as it is to recall eight random digits even though the information value, in bits, of the former, is much greater than the latter. Miller (1956) suggests that there is no maximum value on the amount of information that can be transmitted but rather the limiting factor is the number of conceptual units or "chunks." Chunking or recoding may be the result of attaching labels or differential response to a group of discrete units (Postman in Melton, 1964) which may constitute a type of strategy for learning.

If labels are readily available due to the way the information is processed (e.g. digits coded by verbal labels) it would seem that this type of stimulus information, could be packaged into "chunks" with more ease than would information such as K which does not seem to be coded in verbal form. Perhaps it is the properties of the stimulus information and subsequent coding which causes the variability in the channel capacity of STM.

## Information Processing in STM

In an information processing model of the human performer, the central processing mechanism has been shown to be of the serial type (Norman, 1970). That is, the system is capable of performing one, or at maximum, several very elementary processes at a time. The limitations of the processing capacity are dependent on the type of transformation process involved. The human, performing an easy or highly learned task, such as walking, is able to attend to other stimuli in the environment. As the primary task increases in difficulty, it demands more attention of the limited processing capacity and consequently the capacity available for dealing with other stimuli is reduced (Posner, 1966).

Processing in STM could, perhaps, be viewed as a recycling or rehearsal of the stored information which demands part of this limited processing capacity (Broadbent, 1958). This demand may come about as a result of attempting to apply rules and strategies from a permanent store to the information in STM, for improved retention. In this respect, STM could be looked upon as an "operational" memory system (Hunter, 1964; Posner, 1967a). To investigate information processing in STM, an experimental paradigm was utilized in which there was no opportunity for rehearsal over a delay interval. Rehearsal was eliminated by the insertion of an interpolated task which would control the attention of the central processing capacity. The rationale behind the paradigm is that, with rehearsal prevented, there should be a decrement in recall, if processing in STM requires a part of the limited processing capacity.

It has been readily shown that verbal material in STM requires a part of the limited processing system. Peterson and Peterson (1959) found that retention of a "CCC" trigram was greatly decreased when the <u>S</u>'s were required during the delay interval, to count backwards by 3's from a number presented immediately after the trigram. Supportative evidence was given by Posner and Rossman (1965). They found a linear relationship between the amount of information reduction in the interpolated task which defined its difficulty, and retention of numeric digits. As the difficulty of the task increased, the capacity available to the rehearsal of the digits was accordingly reduced.

Although K information, as suggested above, may be stored as a representative image, it may be meaningful to consider rehearsal or recycling of this non-verbal material, if it too, was shown to require a part of the central processing capacity (Posner and Konick, 1966). Posner and Konick found that a K distance recall task was independent of the amount of central processing capacity available. With this task, forgetting was not a function of task difficulty.

Taking these results one step further, Williams et al. (1969) conducted four experiments on the effects of similar interpolated activity on the retention of digits and specific K events. In their first experiment, they tested the effect of interpolated digital activity (rest, recording, adding, and classifying of digit pairs) on the retention of a six digit sequence. They replicated Posner and Rossman's (1965) findings that short-term forgetting of digits is an increasing function of the size of the information reducing transform in the interpolated task. In their second experiment, they used the same interpolated task to test the effect on K recall. They confirmed Posner and Konick's (1966) results that STM, for K information, does not depend on the central processing capacity for rehearsal. Experiment III, using a K interpolated task conceptually similar to the digital task, showed that K recall can be interfered with by K interpolated task. In their final experiment, K interpolated activity interfered with digital recall only when it was of an information reducing type. The conclusion from these results was that STM for K and verbal material were based on independent neural mechanisms; i.e. different locations for processing in STM. Sharp (1971) found that K recall was not affected by the interpolation of a redundant K task and concluded that central processing demands of K information in STM were minimal perhaps due to the type of coding. The conflicting results between this study and Experiment III of the Williams study may rest on the fact that the K interpolated task in the Williams study was much more similar to the material in store and perhaps similarity is a critical variable in K STM.

In summary, researchers have shown the verbal material in STM requires the availability of the limited processing capacity, whereas this is not so for K information in STM. It has been further suggested that K information is not codable (Wilberg, 1969). If this is so, the concept of an "operational" STM which is readily applicable in the verbal modality is not functional in the K modality since rehearsal may not be possible.

Rates of Information Loss From STM

Two major theories for information loss which have been applied in research on verbal and K STM are the trace decay and interference theories. The basic premise of the decay theory is that learning deteriorates over a retention interval and as a result, recall is reduced (Adams, 1967). Several investigators found a loss on recall of a subspan series of verbal items if rehearsal was prevented (Brown, 1958a; Conrad, 1957). Peterson and Peterson (1959) showed that the retention of a single trigram was reduced as the retention interval, in which the subject counted backwards, was correspondingly increased. There has been some dispute as to whether or not these losses can be attributed to decay (Moray, 1960; Norman, 1969).

Decay theory, applied to K STM, has been given more support (Adams and Dijkstra, 1966; Pepper and Herman, 1970; Stelmach and Barber, 1970). One of the major studies in this area was done by Adams and Dijkstra (1966) who attempted to extend the findings of Peterson and Peterson (1966) to the K modality. They tested STM for simple linear, graded motor responses, with length of retention interval and number of reinforcements as basic variables. The retention interval was from 5 to 120 seconds. They found error to be an increasing function of the retention interval and was interpreted to be the result of trace decay.

However, Sharp (1971) has pointed out that performance in the Adams and Dijkstra study was as good after

15 seconds delay as after zero seconds delay. This observation is supported by results of several other studies (Posner and Konick, 1966; Stelmach, 1969b; Wilberg and Sharp, 1970a and 1970b). Therefore, it appears that K information may not be susceptible to decay within a 20-second delay (Sharp, 1971).

The second theory is that of interference. This theory holds that responses learned before the criterion response is learned (proactive inhibition) or in the retention interval (retroactive inhibition) causes a decrement in recall (Adams, 1967). Studies utilizing a retroactive inhibition paradigm are most relevant to this study, so these, alone will be reviewed. In the verbal area, Wickelgren (1956) found that recall was reduced, due to retroactive inhibition, with the number of interpolated items and with increasing phonemic similarity to that of the material in store. However, with the interval held constant, acoustic similarity does not seem to completely account for a decrement in recall. Posner and Rossman (1965) found that, the difficulty of interpolated processing, with the interval and acoustic similarity held constant, had a large effect upon retention of digits. As the difficulty of the interpolated task increased, recall decreased. Although interference, using a retroactive inhibition paradigm has been demonstrated, exactly what factor precipitates it, does not seem to be very clear.

In the area of K STM, several of the earlier studies done were concerned with the effects of non-motor information reduction tasks on motor recall (Posner, 1967; Posner and Konick, 1966; Williams et al., 1969). In each of these cases, only one movement was given for the criterion task. The general conclusion was that K recall was not affected by a lack of opportunity for rehearsal. However, it may have been that the capacity of the S to handle such information was not stressed.

Further research was done on the effects of interpolated motor task on recall. Stelmach and Barber (1970) investigated the retention of K information from blind positioning responses. The two conditions used were a 30-second rest interval and a 30-second interval in which the subject engaged in an antagonistic interpolated task. They found that both conditions showed significant amounts of forgetting but the mean differences between conditions was not significant. The results were supported by several other findings (Patrick, 1971; Schmidt and Stelmach, 1969; Sharp, 1971) and consequently provide little support for interference theory in motor STM. However, Boswell and Bilodeau (1960) gave some supportative evidence to this view. They found that zeroing a lever did not cause a decrement in recall but disengaging from the equipment and retrieving a pencil did. It has been argued that the results may have caused a loss in "cognitive set" (Sharp, 1971) but on the other hand, this may give an indication of the type of task needed to interfere with K STM.

Recently, in a study done by Pepper and Herman (1970), it was shown that interference could be demonstrated in K STM. In their study, dealing with a force estimation task, they found that the relative magnitude of the interpolated motor task had a significant effect on retention. By reanalyzing previous data and showing this interference effect was present when algebraic error was taken, they provided support for their conclusions.

Conclusive evidence has not been produced to support either the decay theory or the interference theory. Dual theories of forgetting have been proposed for both verbal STM and K STM (Pepper and Herman, 1970; Stelmach, 1969a; Wicklegren, 1966). Representative of this view is Posner's (1966) "Acid-Bath" model, in which it is proposed, similar items, in competition, intermingle during the retention interval and destroy the trace. This theory would then hold that interference depends both on the time in store and the similarity between the stored material.

## Measurement

Although information theory is not a psychological theory, the concepts when applied to skilled performance are useful in quantifying the processes involved in skills. The purpose of this section is to consider types of tasks and the measures of performance in order to evaluate the techniques of measurement in information theory that are connected with this study.

Types of tasks. It has been stated (Coombs et al., 1970) that tasks in the study of human performance may be classified in terms of "what constitutes error." Posner (1964) proposed a taxonomy of information processing tasks, distinguished on the basis of task requirements with psychological implications. The three types of tasks proposed were: (i) a creation model in which S is required to map a single point to more than one response (Coombs et al., 1970 would classify this as an "equivocation intolerent task," i.e. given the response, any uncertainty about the stimulus is error;) (ii) a reduction model in which the S must map more than one stimulus point into a single response (the error classification for this would be as an "ambiguity intolerant task," i.e. given the stimulus any uncertainty associated with the response is error;) (iii) a conservation model in which the S must preserve all the stimulus information in the response (this would be referred to as a "pure transmission task" because it is both equivocation intolerant and ambiguity intolerant).

To date, the major concern in human performance has been with the pure transmission task. Memorization is of this type, since the S is presented with a stimulus and the response consists of recalling all of the information in the stimulus. However, as Posner (1964) suggested, information conservation is not the only and perhaps, not even the most representative process, of information processing in humans. He has shown further, that an ambiguity intolerant task involving information reduction is related to the difficulty of a task. In such a way, he has provided a tool for more concisely investigating the capacity and nature of the STM system as evidenced in the studies by Posner and Rossman (1965) and Williams et al. (1969).

However, as Coombs et al. (1970) point out, when Posner talks about information reduction, he is referring to what the S has to do to the stimulus in order to arrive at his response. Statistically, he also uses the term to refer to the resultant of subtracting the stimulus uncertainty from the response uncertainty using the "bit" unit. Although using informational measures to quantify and classify the thought process is useful, one cannot infer as to the type of psychological processes taking place such as tactics and strategies. In some cases, it may even be more difficult to reduce certain types of information, such as K information, because of a lack of useful strategies.

Coombs et al. (1970) do suggest why the information reduction measure, as Posner used it, provides information. In the task, the response should be predictable from the stimulus because these are correct answers. But the statistic measures the degree to which the type of stimulus is unpredictable from the response. Therefore, they conclude that the degree to which the stimulus is unpredictable from the response would seem to be a reasonable measure of the independence of the stimulus and response, if the task was correctly carried out. They, then, hypothesize that as the independence between the stimulus and response increased a greater number of mediation processes would be required to produce the response. This may break down however, when it is extended to K information which may not involve any of the mediating process, if, as it has been suggested is not processed in the central processing capacity (Posner and Konick, 1966; Williams et al., 1969).

Measurement of Performance. In order to meaningfully measure performance, Fitts and Posner (1967) have proposed several criteria that the measurement should fulfill: (i) it should indicate the extent to which the output reflects the input or the contingency between the two; (ii) it should allow for comparisons between tasks with varying temporal patterns (i.e. discrete, serial, continuous); (iii) it should be responsive to the accuracy of the response, taking into account other aspects of performance other than the standard used to specify success; (iv) the measure should be sensitive to the time required to perform the task. However, as they conclude, no single measure appears to meet all these requirements. So the researcher must choose a measure which is most appropriate for the task at hand and will be sensitive to the critical variable which will affect performance within the context of that skill.

In a memory task, measurement of the amount of information transmitted seems most applicable. This measure (T) may be used whenever it is possible to separate the input into a set of discrete responses, each with a probability associated with it (Coombs et al., 1971).

The information transmitted (T) is the amount of input information represented in the output. In a memory task, when T is measured, the response is conceptualized as a message. Since the responses each have a probability associated with it and because these probabilities are in part dependent on what the input is, then there is uncertainty associated with the response of the S. As a result, information is transmitted from stimulus set to response set. Since a memory task constitutes a pure transmission task, any conditional uncertainty related to either the output, given the input, or the input, given the output, is error. Therefore, with perfect recall, uncertainty in the input set equals the uncertainty of the output set which equals the maximum amount of information which would be transmitted. T represents, therefore, the conditional constraints or correlation between the stimulus and response.

This measure, however, is statistical by nature and cannot describe performance completely. T does not reflect the pattern of responding; that is, a response is either right or wrong, and there is no accountability in the measure for the "goodness" of the response.

This measure is useful for comparing performance in the sense that information transmitted is a dimensionless quantity. Since the information in a discrete statistical distribution does not rely on a unit of measure, the concept can be used in comparing results from different experimental situations, which would normally be useless since they are based on different metrics (Miller, 1956).

Like other measures, it handles some aspects of performance and disregards others. But for this study, the measurement of T fulfills the main criteria in that the measurement reflects the covariance or correlation between the input and output. In addition, it allows for comparisons to be made because of its non-metric quality which might have otherwise be meaningless.

# CHAPTER 3

# PROCEDURES

## Experimental Design

The experimental design was a treatment by subjects, factorial design, replicated ten times for each subject. The three factors of experimental interest were: the sensory modality of the information input, the sensory modality of the interpolated task, and the amount of information reduction carried out in the interpolated task. The sensory modality of the information input factor had two levels (visual and kinesthetic). The sensory modality of the interpolated task had two levels (visual and kinesthetic). The difficulty of the interpolated task had four levels (Reversal, Addition, 2-Classifications, 1-Classification).

The levels of the first and second factors were to assess the nature of the STM systems for both sensory modalities from the effects of an interpolated task of the same and different modality.

The levels of the third factor were chosen to represent an increasing size in the information reduction which has been shown to be a quantitative predictor of task difficulty (Posner, 1964b; Posner and Rossman, 1965). The four levels were used to determine the effect of an increasingly difficult interpolated task in both the verbal and K modality on recall of verbal and K material stored in STM.

## Apparatus

The apparatus (See Figure I) consisted of a 1 inch by 48 inch metal rule used as a track, mounted on a baseboard. A metal cursor, 1 inch by 1.5 inches was constructed to fit the metal track, with a knob on the top for fingertip grasping. This was used by the S for making simple linear motor responses and was designed so that friction and inertia were minimized. Two blocks 2 inches by 2 inches by 48 inches, were mounted on the baseboard on either side of the track. On these blocks, 10 intervals of 1.5 inches each, were marked off; 5 on each side of the midpoint of the track. Each of the intervals was then scaled in quarters of an inch. The size of the intervals were chosen on the basis of the results of a pilot study (Appendix A). Sets of holes were drilled into the blocks, such that a physical stop could be positioned at each interval so that it defined the length of a response required of the S on any trial. Two sets of holes were made at either end of the 10 intervals so that a stop could be positioned as a starting point on the left and right side of the total working space. The apparatus was fixed to a table top, at right angles to the line of vision of the S, for left and right movements. The S sat on one side of the table with the midline of his body in line with the midpoint of the track (Figure II). The E sat on the opposite side of the table. In order to eliminate any relevant visual cues,

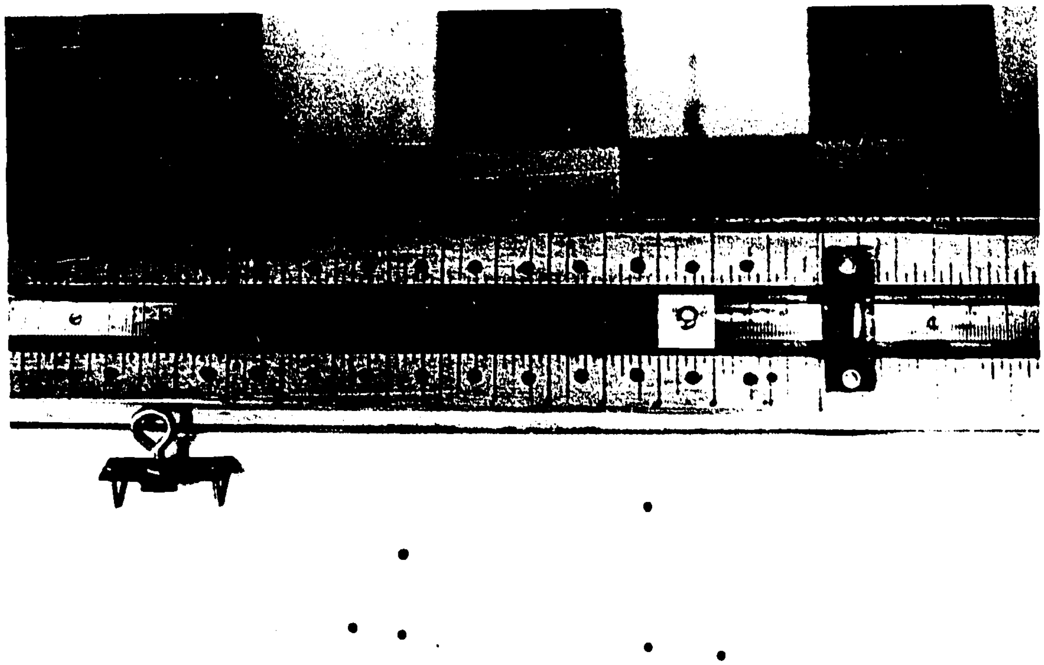

FIGURE I. OVERHEAD VIEW OF APPARATUS

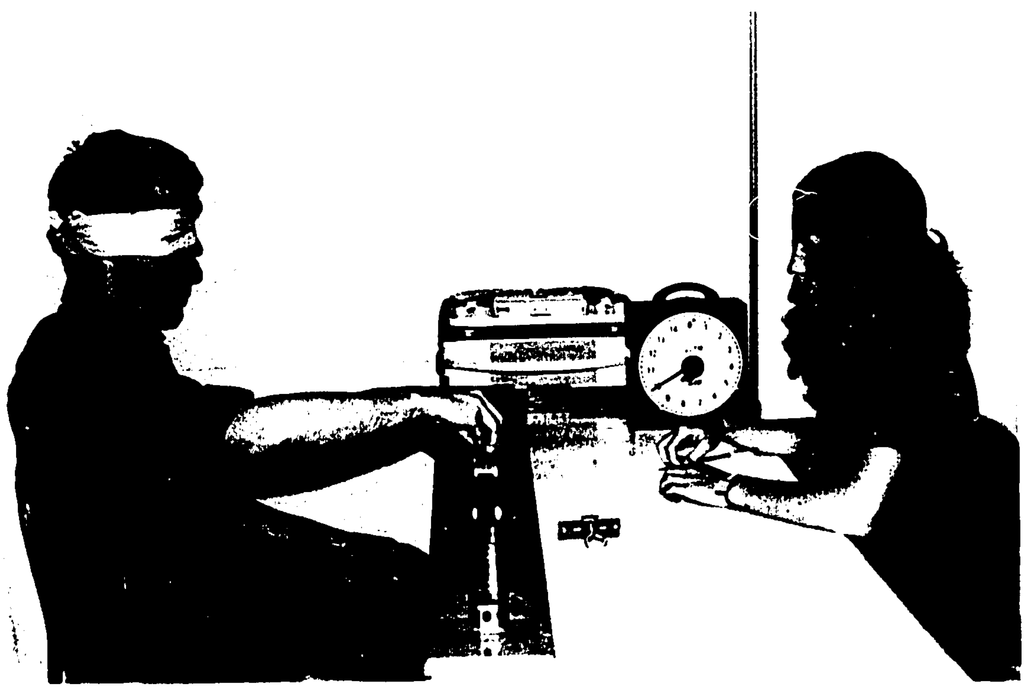

FIGURE II. VIEW SHOWING POSITION OF S, E AND APPARATUS

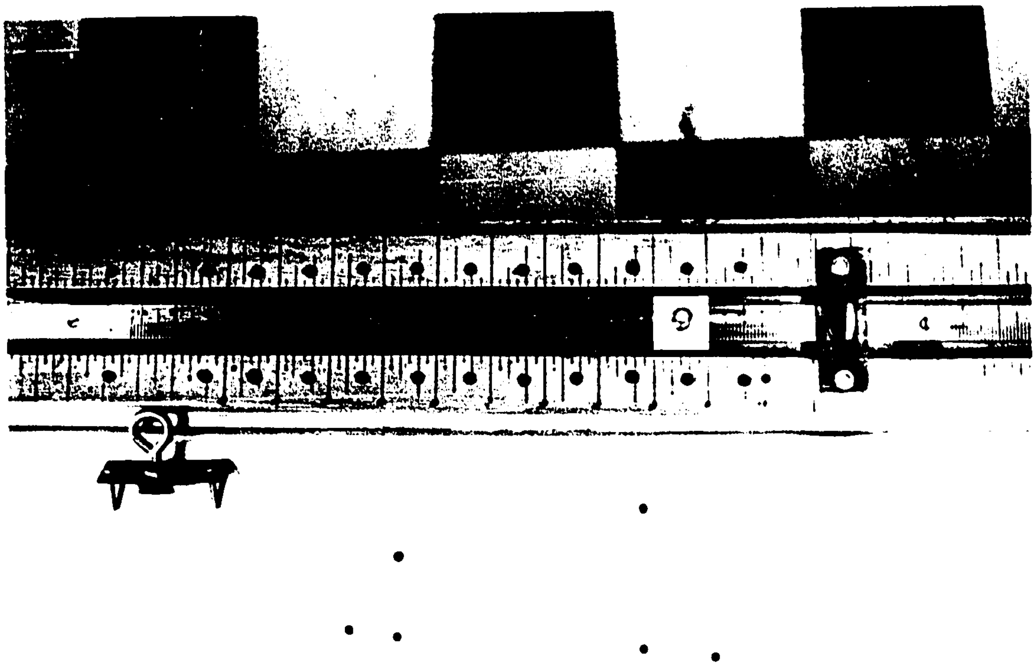

FIGURE I. OVERHEAD VIEW OF APPARATUS

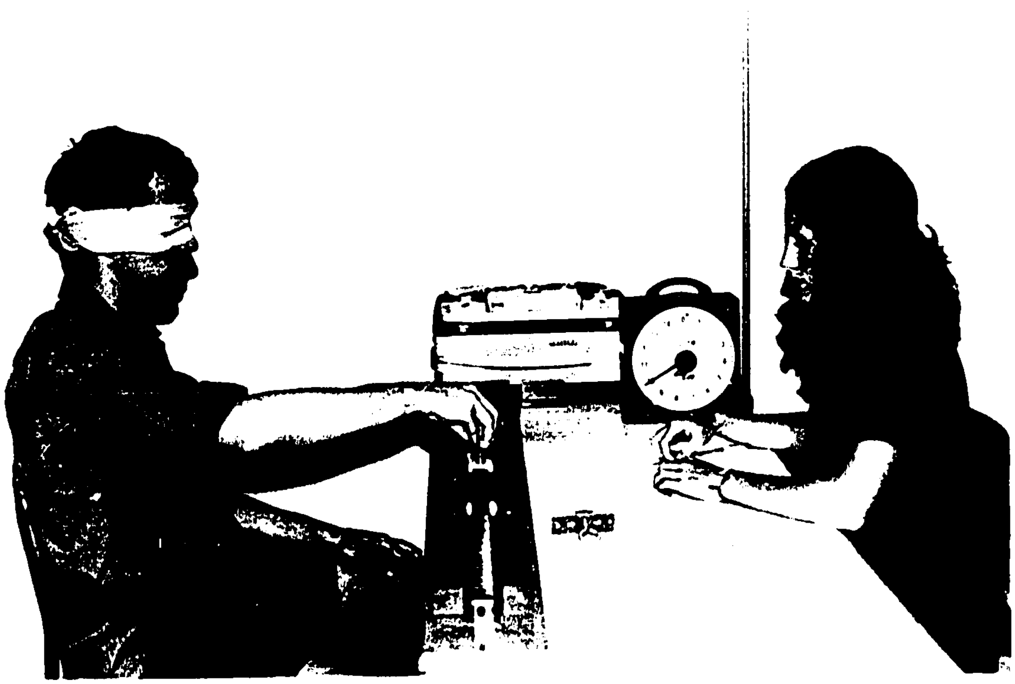

FIGURE II. VIEW SHOWING POSITION OF S, E AND APPARATUS

S was blindfolded throughout the experiment.

Instructions and input information for the verbal conditions were all pre-recorded on magnetic tape on a Phillips magnetic tape recorder, type EL 3549A/54. Since the S produced K responses at varying speeds, the E provided verbal instructions for the K condition. A Gralab Universal Timer, model 172, was used to time the 20 second interval in which the K interpolated task was carried out.

## Recall Task

Verbal modality. S was presented with a series of 8 numeric digits from 0 to 9 recorded one at a time at a rate of 30 digits per minute. Each S received 40 such series per session. The digits were randomly chosen and assigned to each series. The task was to recall verbally, the 8 digits, in order, after a 20 second delay interval. During this interval the S was engaged in an interpolated task.

K Modality. The S was required to make a series of 5 movements all in one direction, the distances of which were determined by a physical stop positioned by the E before each move. Each S was given 40 such series per session. The length of the movements were randomly chosen from the 10 possible alternatives marked out on the apparatus and were randomly assigned to a series. The task was the recall of the five movement lengths, in order, as accurately as possible after a 20 second interval in which the S engaged in an interpolated task.

Interpolated Task

The following four types of interpolated tasks were adapted from the study by Posner and Rossman (1965), so that they could be carried out in both verbal and K modalities. Each task represented varying amounts of information reduction and consequently varying levels of task difficulty (Posner, 1964b).

1. Reversal:
   (a) Verbal Modality: The S was presented with a pair of digits and was required to recall them in reverse order.
   (b) K Modality: The S was presented with two linear movements and was required to replicate them in reverse order.

   The transformation was such that the input and output information were equal and therefore was zero bits reducing (Posner and Rossman, 1965).

2. Addition:
   (a) Verbal Modality: The S was required to add, verbally, the two digits with which he was presented.
   (b) K Modality: The S was given two movements and was required to indicate the total length of the two moves on the track by a linear movement.

In both cases, each digit or length given, was one of 10 alternatives. Therefore, each had an information load of about 3.3 bits and so the total input information of the pair had 6.6 bits.* The sum of the digits and lengths, however, contains only 3.8 bits. Therefore, this task required 2.8 bits reduction (Posner and Rossman, 1965).

3. 2-Classifications:

(a) Verbal Modality: The S was to classify the pair of digits as high (50 or above) or low (below 50) and as odd or even.

(b) K Modality: The S was required to classify the pair of lengths as long (total length of the two movements pass the midline of the body) or short (not past the midline) and as same or different depending on whether the S could discriminate between the two lengths or not. (The categories were represented by linear responses. A "long" response was represented by a long movement on the track and a "short" response by a short move. "Same" was represented by a short movement and "different" was represented by a short movement with a slight forward-backward movement of the cursor at the end of it.)

In this condition, the input information was, again 6.6 bits but the output was only 2 bits, resulting in a 4.6 bit reduction task (Posner and Rossman, 1965).

4. 1-Classification:

(a) Verbal Modality: The S was required to respond "A" if the pair of digits was high and even or low and odd. The S responded "B" if the pair

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*Information theory, from which these computations are derived, are fully explained in Attneave (1959).

of digits was high or odd or low and even.

(b) K Modality: The S responded with a "long" movement (past the midline of the body) if the pair of movements was long and the same or short and different. S responded with a short move (not past the midline of the body) if the reverse was true.

This condition called for a 1 bit response. With the input information the same as the previous tasks, this was a 5.6 bit reduction task (Posner and Rossman, 1965).

## Subjects

Eight male graduate physical education students, ages 22 to 45 years old were used as subjects. They were selected on the basis of availability and freedom from any handicaps which may have impaired their performance.

## Method

Each S was tested individually in 4 sessions of approximately 60 minutes each. The testing in each session contained 1 level of the sensory modality of the input and 1 level of the sensory modality of the interpolated task and all 4 levels of information reduction carried out as the interpolated task (V-V-V, K-K-K, V-K-V, K-V-K) (Figure 3).

Order of testing sessions were randomly assigned to the Ss. At the beginning of each session, the S was presented with a series of instructions. They were told what type of

| INPUT PHASE | INTERPOLATED TASK | RECALL PHASE |
| --- | --- | --- |
| VERBAL (8 digits) | VERBAL (3 pairs of digits)<br>-reverse<br>-add<br>-2 classifications<br>-1 classification | VERBAL |
| VERBAL (8 digits) | K (3 pairs of movements)<br>-reverse<br>-add<br>-2 classifications<br>-1 classification | VERBAL |
| K (5 movement lengths) | V (3 pairs of digits)<br>-reverse<br>-add<br>-2 classifications<br>-1 classification | K |
| K (5 movement lengths) | K (3 pairs of movements)<br>-reverse<br>-add<br>-2 classifications<br>-1 classification | K |

Figure 3: Method of task presentation.

input they would receive (either digits of movements) and how they were to recall it. The Ss were, also, informed as to the type of interpolated task to be used and received instructions on how to handle the pair of digits or pair of movements that would be given in the interpolated task phase. Before each session the Ss received six practice trials on the interpolated tasks. Each trial consisted of three phases: the input phase, the interpolated task phase and the recall phase.

Input phase. In the verbal condition, the S heard a pure tone followed by the presentation of eight digits. In the K condition, the S was seated in front of the apparatus. The command "Grasp," followed by "Left" or "Right," indicated to the S which starting point on the track the cursor was positioned. The S moved his preferred hand to the knob on the cursor and grasped it between his fingers and thumb. On the command "Move," S moved the cursor out to meet a physical stop, placed by the E. On the command "Return," the S returned the cursor to the starting position. (Boswell and Bilodeau [1964] showed that allowing S to return the control lever on his own had no effect on recall.) This procedure was repeated 5 times. The starting position was to the left or right of the midpoint and was assigned randomly to each trial.

Interpolated phase. Immediately after the last digit or movement was given, the S was presented with a command to "Reverse," "Add," "2-Classifications" or 1-Classification."

In the verbal condition of the interpolated task, the S was then, immediately, presented with the first of three pairs of digits with the appropriate information reduction task to be carried out verbally after each pair was given. In the K condition of the interpolated task, the S was, immediately, given the command to "Move." The S then moved the cursor out to the physical stop positioned by the E and returned it to the starting point. This procedure was repeated again. Then the S carried out the appropriate transformations on the movements. This process was repeated 3 times so the S received 3 pairs of movements.

The order of interpolated task difficulty was assigned randomly to the 40 trials with each difficulty condition appearing 10 times. The length of the interpolated phase was set at 20 seconds. However, in the K condition the E had little control over the speed at which the S made his movements. Therefore, on twelve trials, the interval was extended by 2 seconds. An interval of 20 seconds was chosen on the basis of the conclusions drawn in the literature (Sharp, 1971). It was felt that after this time interval the K memory trace would be susceptible to decay. In this study, there was an attempt to control for the decay factor by using a 20 second interval, so that it would not confound the interference effect of the interpolated task. Therefore, in the previously mentioned 12 trials, the decay factor may account for some of the decrement in recall.

Recall phase. On the termination of the interpolated task interval, S was given the command to "Recall." In the verbal condition, the S repeated verbally, in order, the 8 digits presented in the input phase. In the K condition, the S was then given the command "Grasp" followed by either "Left" or "Right." Recall was always from the opposite end of the track at which the input information was given. The S then proceeded to grasp the cursor and replicate the five movements given in the input phase. The cursor was returned to the starting position after each movement.

## Dependent Variables

To measure performance decrement, the following variables were chosen:

(a) Verbal Modality: The number of digits which were not recalled or incorrectly recalled.

(b) K Modality: The absolute error in reproduction accuracy measured in inches on each of the five movements lengths to be recalled.

## Statistical Analysis

The data was analysed using one-way, two-way and four-way analyses of variance. A Fortran IV ANOV80 program (an N-way analysis of variance program) was computed on an IBM 360/67 computer at the University of Alberta Computing Science Department. Duncan's New Multiple Range Test was used as a test between means for main effects. A repeated measures design was utilized in order to reduce error variability due to individual differences (Myers, 1969). Because carry-over or practice effects are prevalent in a repeated measures design, replications was treated as a factor. A conservative rejection level of .01 was chosen to reduce the probability of a Type I error.

Also, the amount of information transmitted in each condition was determined from the data according to a procedure described by Garner and Hake (1951, pp. 447-451). In the verbal condition, the inability of the Ss, in some instances, to recall necessitated the inclusion of a "missing data" row in the averaged joint probability matrices (Appendix E). Because it was felt that the Ss lack of recall was reflective of the interference effect of the interpolated task, the inclusion of the missing data seemed necessary in order for the measure to be meaningful. In addition, the percentage of non-recalled stimuli was calculated to further clarify what was contained in the verbal information transmission measure.

In the K condition, it was necessary, for the creation of a joint probability matrix, to classify a response as correct or incorrect. Therefore, it was decided that any response within +1 or -1 inch of the actual movement stimulus would be considered correct. This decision was based on the results of the pilot study reported in Appendix A, in which it was concluded that 1.5 inches between movements from the range of 0 to 15 inches was easily discriminable 100% of the time.

# CHAPTER 4

## ANALYSIS

Following a review of related literature as presented in Chapter 2, two hypotheses were formulated. However, some of the pertinent problems in the present study have only been the concern of limited research. Therefore, a series of questions were formed to deal with these specific issues.

### Hypothesis

$H_1$: Verbal recall performance following a reversal interpolated task > verbal recall performance following an addition interpolated task > verbal recall performance following a two bit classification interpolated task > verbal recall performance following a one bit classification interpolated task (V-V-V, V-K-V).

### Questions

1. Is there any difference between verbal recall performances when a verbal interpolated task is used as an interference factor or when a K interpolated task is used as an interference factor?

The first hypothesis was substantiated by Posner and Rossman (1965) using a subspan digital recall task and interpolated verbal tasks increasing in amounts of information reduction. In this hypothesis, decrement in recall was considered to be directly related to the difficulty, measured in terms of information reduction, of the interpolated task.

The first question was formed in order to investigate the statement by Williams et al. (1969) that "if the proposition of the independence of verbal and kinesthetic retention mechanisms is true then [a K interpolated task] should not interfere with the recall of digits unless it includes some type of information transform." They found using Rest, Record and Add conditions, only a slight tendency (not statistically significant) for the K interpolated task to interfere with the recall of digits. It was noted that a t-test ($p = .05$) showed that the effect was mainly due to the difference between the Rest and Add conditions.

The question was also posed in order to determine the type of interpolated task and related difficulty that would interfere with a verbal recall task.

## Degrees of Freedom

Greenhouse and Geisser (1958) have shown that when the assumption of covariance is not met, conservative degrees of freedom can be used which will correct for this. In this study, a repeated measures design was used which requires all pairs of repeated measures to have equal covariance in order for the conventional F ratios, for tests involving the repeated measures, to have an F distribution (Wilson, 1971). Therefore, it was considered necessary to draw conclusions based on Greenhouse and Geisser conservative degrees of freedom in order to control the artificially inflated degrees of freedom prevalent in a repeated measures design and to test for the assumption of covariance. Conventional degrees of freedom were used where the conservative test was not applicable and for multiple comparisons between means.

## Verbal Modality

Primary analysis. A two-way analysis of variance, employing conservative degrees of freedom and a four-way analysis of variance, were computed on the error scores (Table 1 and Appendix C, Table 9, Respectively). Significance of the main effect of task difficulty indicated that mean error, under each level of task difficulty, differed greatly ($p. > .001$). Since the interaction term failed to reach significance there did not seem to be any difference between recall error after a K interpolated task under each level of task difficulty and after a verbal interpolated task under the four levels of task difficulty. The effect of subjects did not reach significance at the .01 level. Replications were considered as a factor in order to assess fatigue or learning effects but it did not reach significance. Mean error scores for the two main effects are presented in Appendix C, Table 10.

Duncan's New Multiple Range test was used for the difference between means for the error scores over the four levels of difficulty for both modalities of the interpolated task (Table 2). Using mean error scores as the criterion, the Reverse condition for a K interpolated task

TABLE 1

TWO-WAY ANALYSIS OF VARIANCE
VERBAL MODALITY

| Source | Sum of Squares | d.f. | Conservative d.f. | Mean Squares | F |
|---|---|---|---|---|---|
| Interpolated Task Modality (TM) | 129.60 | 1 | 1 | 129.60 | 31.86** |
| Level of Difficulty (D) | 584.59 | 3 | 1 | 194.862 | 47.91** |
| TM x D | 48.69 | 3 | 1 | 16.230 | 3.99 |
| ERROR | 2570.62 | 632 | 7 | 4.067 | |

** Significant at the .01 level (Greenhouse and Geisser)

TABLE 2

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO DIFFERENCES BETWEEN K=8 MEANS FOR THE VERBAL MODALITY

| | | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|---|
| | Means | K-Reverse | K-Add | V-Add | V-Reverse | K-2-Classi-fications | K-2-Classi-fications | K-1-Classi-fication | V-1-Classi-fication |
| A | .98 | | .62** | 1.44** | 1.50** | 2.07** | 2.30** | 3.03** | 3.32** |
| B | 1.6 | | | .82** | .88** | 1.45** | 1.68** | 2.30** | 2.70** |
| C | 2.42 | | | | .06 | .63** | .80** | 1.48** | 1.88** |
| D | 2.48 | | | | | .57** | .80** | 1.42** | 1.82** |
| E | 3.05 | | | | | | .23 | .85** | 1.25** |
| F | 3.28 | | | | | | | .62** | 1.02** |
| G | 3.90 | | | | | | | | .40 |

SHORTEST SIGNIFICANT RANGES

$R_1$ = .36
$R_2$ = .38
$R_3$ = .39
$R_4$ = .40
$R_5$ = .404
$R_6$ = .41
$R_7$ = .413

** Significant at the .01 level.

A B C D E F G H

was found to be significantly different (p. = .01) from the Reverse condition for a verbal interpolated task. For all other conditions of difficulty, there were no significant differences between a K and a verbal interpolated task.

A further analysis was carried out on the effect of the levels of interpolated task difficulty within the separate interpolated task modalities (V-V-V and V-K-V) to fully clarify the effect of level of difficulty on recall. Therefore, the main effect of interpolated task modality was partitioned into verbal interpolated task over four difficulty levels and K interpolated task over the four levels of difficulty.

<u>V-V-V</u>

The one-way analysis of variance was calculated with the absolute error scores as the criterion (Table 3). The main effect of level of difficulty of the interpolated task was significant at the .01 level of confidence. The effect of replications was not included in this analysis since it was found not to reach significance (p = .01) in the four-way analysis of variance for the verbal modality condition (Appendix C, Table 9). The mean error scores over the four levels of difficulty were reported in Appendix C, Table 10. The graph for these mean error scores was illustrated in Figure 4. As shown in this graph mean error in recall of digits increased as the difficulty of the interpolated transform increased. A trend analysis (Appendix C, Table 11)

TABLE 3

ONE-WAY ANALYSIS OF VARIANCE VERBAL MODALITY
VERBAL INTERPOLATED TASK

| Source of Variance | Sum of Squares | d.f. | Conservative d.f. | Mean Square | F |
|---|---|---|---|---|---|
| Level of Difficulty (D) | 19.19 | 3 | 1 | 6.39 | 13.89** |
| Subjects (S) | 8.96 | 7 | 7 | 1.28 | 2.72 |
| S x D | 9.7 | 21 | 7 | .46 | |
| TOTAL | 37.85 | 31 | | | |

** Significant to the .01 level (Greenhouse and Geisser)

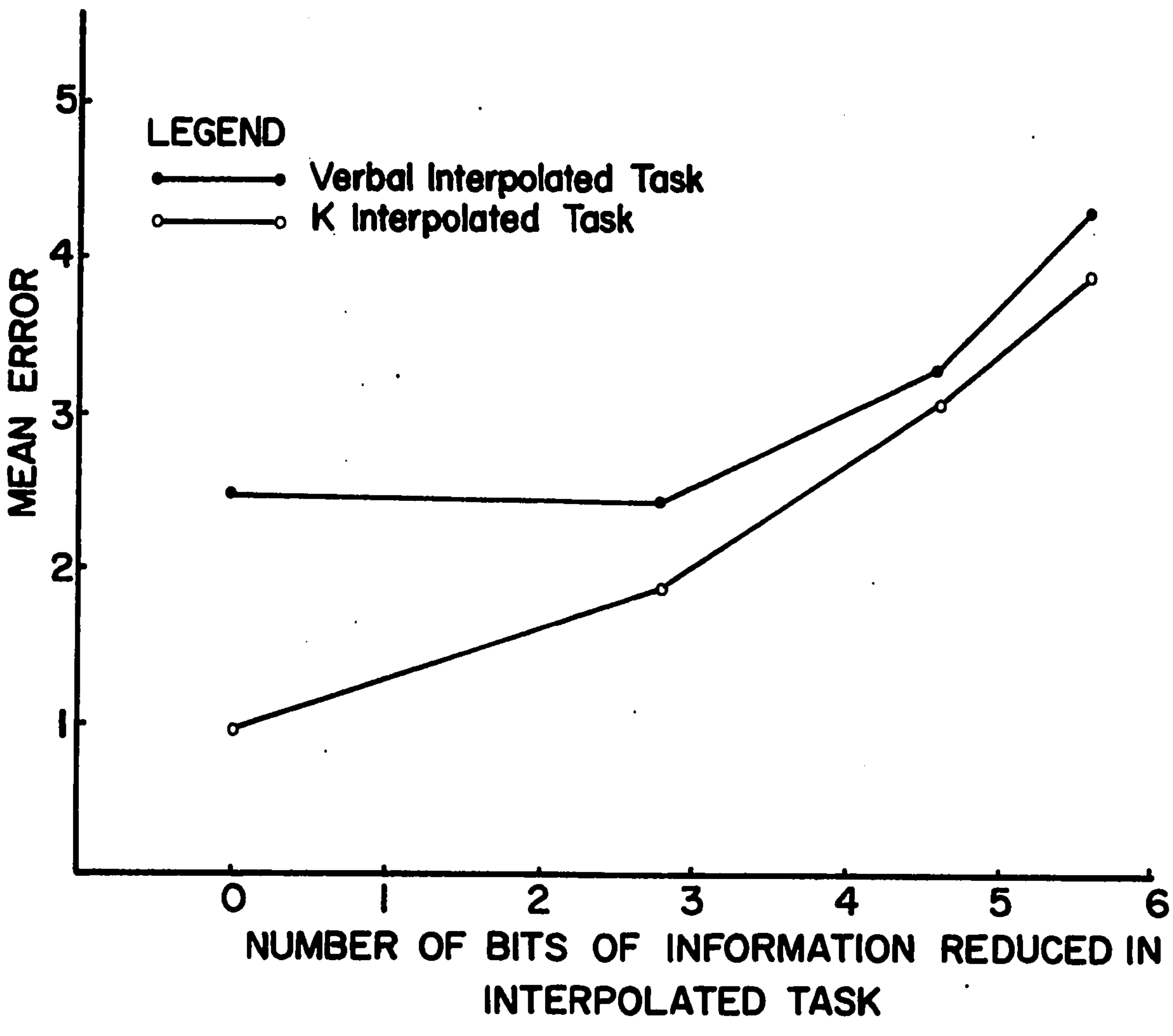


Figure 4: The mean error over four levels of interpolated information reduction for the V-V-V and V-K-V conditions.

was carried out on these data to determine the form of the function which would best describe the relationship between the level of difficulty and the mean error score. The error score was found to vary linearly (p = .01) with the number of bits of information reduced in the verbal interpolated task.

Duncan's New Multiple Range test was applied to the mean error scores (Table 2). The mean error score for the Reverse condition failed to differ from the mean error for the Add condition. The Add condition differed from the 2-Classifications and 1-Classification condition and 2-Classifications condition differed significantly from 1-Classification condition (p = .01).

V-K-V

The one-way analysis of variance was completed on the absolute error scores (Table 4). The main effect of level of difficulty of the interpolated task was significant at the .01 level of confidence. The effect of subjects failed to reach significance (p = .01). The effect of replications was not calculated since it failed to reach significance in the four-way analysis of variance for the verbal modality condition (Appendix C, Table 9). The mean error scores of the four levels of difficulty were reported in Appendix C, Table 10. The mean error were graphed over the four difficulty conditions (See Figure 4) and a test of linearity (Appendix C, Table 12) was carried out on the data. The

TABLE 4

ONE-WAY ANALYSIS OF VARIANCE VERBAL MODALITY
K INTERPOLATED TASK

| Source of Variance | Sum of Squares | d.f. | Conservative d.f. | Mean Sqare | F |
|---|---|---|---|---|---|
| Level of Difficulty (D) | 39.69 | 3 | 1 | 13.23 | 19.79** |
| Subjects (S) | 20.00 | 7 | 7 | 2.857 | 4.62 |
| S x D | 14.05 | 21 | 7 | .669 | |
| TOTAL | 73.74 | 31 | | | |

** Significant at the .01 level (Greenhouse and Geisser)

mean error in recall of the digits was found to increase linearity (p = .01) as a function of increasing difficulty of the K interpolated task.

Duncan's New Multiple Range Test was applied to the mean error scores for the four conditions of interpolated task difficulty (Table 2). It was found that all the means differed at the .01 level of confidence.

## Discussion

The results of the V-V-V and V-K-V conditions seem to be consistent with Broadbent's (1958) functional model of human information characteristics. That is, there was definite indication of a limited capacity for processing information in STM. In addition, the results supported numerous other studies which have demonstrated, as Posner (1963) stated "that retention in (verbal) short-term memory is an active process which is extremely liable to disruption."

Coding of Information. Posner and Konick (1966) presented two criteria which they felt, if met, would indicate that retention of information in a task might be accounted for by verbal labels or verbal encoding, alone. If information was stored in verbal labels, they suggested that, little or no forgetting would be expected over an unfilled interval and the amount of forgetting would be expected to increase with interpolated task difficulty. In the present study, only one of these conditions was made available. Verbal recall errors were found to be a linear function of the difficulty of the interpolated transform in the V-V-V and V-K-V conditions. However, it may be of interest to consider the nature of the K reverse task, in which there was no information reduction and required only simple reproduction of the input (a pure transmission task), in light of its interference effect in comparison to the verbal Reverse task. The verbal Reverse task involved a high degree of familiarity with the interpolated stimuli and, like the K task, required no information reduction. However, it caused an average error score of 2.48 digits per 8 digit series as opposed to a .98 digit decrement caused by the K task. The indication was that another variable aside from difficulty and familiarity may have been operating to interfere with recall. In conjunction with the results of Conrad's (1964) study, it may be valid to attribute this to acoustic interference, in which case, one would have to conclude that the digits were stored in the form of a verbal code in STM. Similarly, the suggestion may be made that since the K task did not have a comparable effect, it was not verbally encoded. From this inference, the K Reverse condition may be regarded as analagous to a Rest condition since the input of such information would not prevent the processing of the verbal information. If this is so, both criteria set forth by Posner and Konick (1966) were met, the conclusion may be made that the verbal information was stored in STM in the form of verbal labels.

Information processing. The four types of interpolated tasks were chosen because they involved increasing levels of information reduction which Posner (1966) suggested would demand increasingly more attention of the limited central processing capacity. As a result, the capacity available to other processes, in this case, rehearsal of an 8 digit series, would be correspondingly reduced. If processing of this verbal material did, in fact, require the same processing system as the interpolated task, recall errors would increase, as suggested in the first hypothesis, as the difficulty of the interpolated task increased. The results of the main effects of interpolated task difficulty substantiate this hypothesis (see Figure 4). In the V-K-V condition, only those K interpolated tasks involving information reduction (Add, 2-Classification, 1-Classification) were found to be as effective in reducing recall as their corresponding information transforms in the verbal modality. The K Reverse condition (0 bits reducing) created significantly less decrement in recall than the verbal Reverse task (Question 1). This may indicate that in order to effectively reduce the information contained in the K task, verbal associations were used which may have necessitated the use of the central processing in the same way the verbal interpolated tasks did. Because the interference effect of the K Reverse task was not equivalent to the effect of the verbal Reverse task, it could be inferred that a K task, which does not require verbal transformation, does not require the attention of the central processing system. This conclusion adds support to the hypothesis that K information unlike verbal information is not centrally processed (Posner and Konick, 1966).

Information loss. The results obtained for the main effect of level of difficulty of the interpolated task were in full agreement with the first hypothesis that the accuracy of recall is a decreasing function of the size of the information transform intervening between presentation and recall. The interference effects provided by the verbal interpolated task were consistent with the results of Posner and Rossman (1965) except in the case of the Reverse and Add conditions which showed no significant differences in recall error. This inconsistency was also evident in the results of William et al. (1969) and was attributed to the fact that practice may overcome many of the effects of information load on performance so variations in the effects of these well practiced tasks may be expected from one experiment to another.

The fact that the interference effect of the K interpolated task for the Add, 2-Classifications and 1-Classification condition were comparable to the corresponding conditions in the verbal interpolated task modality suggests that the difficulty (defined by the amount of information reduced) of the interpolated task rather than similarity to that which is in store is the more important variable in interference effects on verbal recall. In the verbal modality, an increasing amount of information reduction causing a corresponding increase in recall error, would suggest an interference model as an explanatory concept for loss of information.

Subjects. The subjects effect was significant at the .01 level. However, the variability between the Ss were consistent across all treatment conditions, since there were no subject by treatment interactions. The fact that the main effects for treatments was still significant even with intersubject variability indicates that the effects of the treatments were extremely powerful.

Replications. The effect of replications was not significant. This indicates that minimal practice or fatigue effects were present over the V-V-V and V-K-V conditions.

Hypothesis

$H_2$: K Recall performance following a reversal interpolated task = K recall performance following an addition interpolated task = K recall performance following a two bit classification interpolated task = K recall performance following a one bit classification interpolated task (K-K-K, K-V-K).

Question

2. Is there any difference in K recall performances when a

K interpolated task is used as an interference factor or when a verbal interpolated task is utilized as an interference factor when both involve increasing amounts of information reduction?

The second hypothesis was formulated, mainly, on the results of studies by Posner (1967), Posner and Konick (1966), and Williams et al. (1969). In each of these studies, no evidence was found that K recall was related to the availability of the limited processing capacity. Therefore, recall should not be affected by increasing amounts of information reduction.

The second question was formulated due to conflicting evidence regarding interference effects in K recall. It was concluded by Posner and Konick (1966) and Williams et al. (1969) that digital information processing has no systematic effect on K recall. As for the effect of a K interpolated task on recall, Blick and Bilodeau (1963), using an arc drawing task which required only a single K interpolated task, found no interference effects. Sharp (1971) demonstrated further, that retention of K information in STM was not affected by the interpolation of a redundant K task. However, other authors, notably Boswell and Bilodeau (1964) and Williams et al. (1969) did obtain an interference effect from the K interpolated task.

The question was also posed in order to determine the type of task and its related difficulty that would cause a decrement in K recall.

K Modality

Primary analysis. A two-way analysis of variance, using Greenhouse and Geisser conservative degrees of freedom and a four-way analysis of variance, to determine the effect due to the factors of subjects and replications, were performed on the data (Table 5, and Appendix D, Table 13, respectively). In the two-way analysis of variance, the effect of interpolated task modality reached significance only at the .05 level of confidence. Similarly, the effect due to level of difficulty failed to reach significance ($p = .01$) indicating that the recall error scores for the four levels of difficulty did not differ. The main effects interaction, also, did not reach significance at the .01 level, but was significant at the .05 level of confidence. In the four-way analysis of variance (Appendix D, Table 13) the subject effect was significant at the .01 level of confidence, whereas, effects due to replications were non-significant. Mean error scores for the main effects of interpolated task modality and level of difficulty were reported in Appendix D, Table 14.

A Duncan's New Multiple Range Test was applied to the mean error scores over the four levels of difficulty for both modalities of the interpolated task. The K Reverse condition was not significantly different from the verbal Add condition. The K Add condition was significantly less than all the verbal difficulty conditions ($p = .01$). The K 2-Classifications condition did not differ from the verbal

TABLE 5

TWO-WAY ANALYSIS OF VARIANCE
K MODALITY

| Source | Sum of Squares | d.f. | Conservative d.f. | Mean Square | F |
|---|---|---|---|---|---|
| Interpolated Task Modality (TM) | 80.106 | 1 | 1 | 80.106 | 9.405* |
| Level of Difficulty (D) | 135.242 | 3 | 1 | 45.081 | 5.293* |
| TM x D | 203.064 | 3 | 1 | 67.688 | 7.94* |
| ERROR | 27188.184 | 3192 | 7 | 8.518 | |

* Significant at the .05 level (Greenhouse and Geisser)

TABLE 6

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE DIFFERENCE BETWEEN K=8 MEANS FOR THE K MODALITY

| | | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|---|
| | Means | K-Add | K-Reverse | K-1-Classification | K-2-Classifications | K-Reverse | V-Add | V-2-Classifications | V-1-Classification |
| A | 2.42 | | .20 | .38 | .50** | .64** | .70** | .78** | 1.14** |
| B | 2.62 | | | .18 | .30 | .44** | .50** | .58** | 1.94** |
| C | 2.80 | | | | .12 | .26 | .32 | .40** | .76** |
| D | 2.92 | | | | | .14 | .20 | .28 | .64** |
| E | 3.06 | | | | | | .06 | .137 | .49** |
| F | 3.12 | | | | | | | .08 | .44** |
| G | 3.20 | | | | | | | | .36 |

SHORTEST SIGNIFICANT RANGES

$R_2 = .36$
$R_3 = .38$
$R_4 = .39$
$R_5 = .392$
$R_6 = .404$
$R_7 = .409$
$R_8 = .413$

** Significant at the .01 level.

A B C D E F G H

(Underlines: B–D; C–G; G–H)

Reverse, Add and 2-Classifications conditions. The difference between the K 1-Classification condition and the Verbal Reverse and Add conditions failed to reach significance at the .01 level of confidence. The verbal 1-Classification condition was significantly greater than all the K conditions of difficulty (p = .01).

To further clarify the effects of the level of difficulty on recall performance, the effect of interpolated task modality was partitioned into the two levels of that factor (K-V-K, K-K-K).

## K-V-K

A one-way analysis of variance was performed with the absolute error scores as the criterion (Table 7). The main effect of difficulty of the interpolated task did not reach significance at the required .01 level of confidence. The effect of subjects was found to be significant (p = .01). Replications was not treated as a factor as it failed to reach .01 level of significance in the four-way analysis of variance for the K modality condition (Appendix D, Table 13). The mean error scores for the four difficulty conditions were presented in Appendix D, Table 14.

A graph for the mean error scores was illustrated in Figure 5.

A Duncan's New Multiple Range Test was applied to the means (Table 6). Using the mean error scores, the Reverse condition did not significantly differ from the Add and

TABLE 7

ONE-WAY ANALYSIS OF VARIANCE K MODALITY
VERBAL INTERPOLATED TASK

| Source of Variance | Sum of Squares | d.f. | Conservative d.f. | Mean Square | F |
|---|---|---|---|---|---|
| Level of Difficulty (D) | 3.78 | 3 | 1 | 1.26 | 4.064 |
| Subjects (S) | 65.18 | 7 | 7 | 9.31 | 30.03** |
| S x D | 6.59 | 21 | 7 | .31 | |
| TOTAL | 75.56 | 31 | | | |

** Significant at the .01 level (Greenhouse and Geisser)

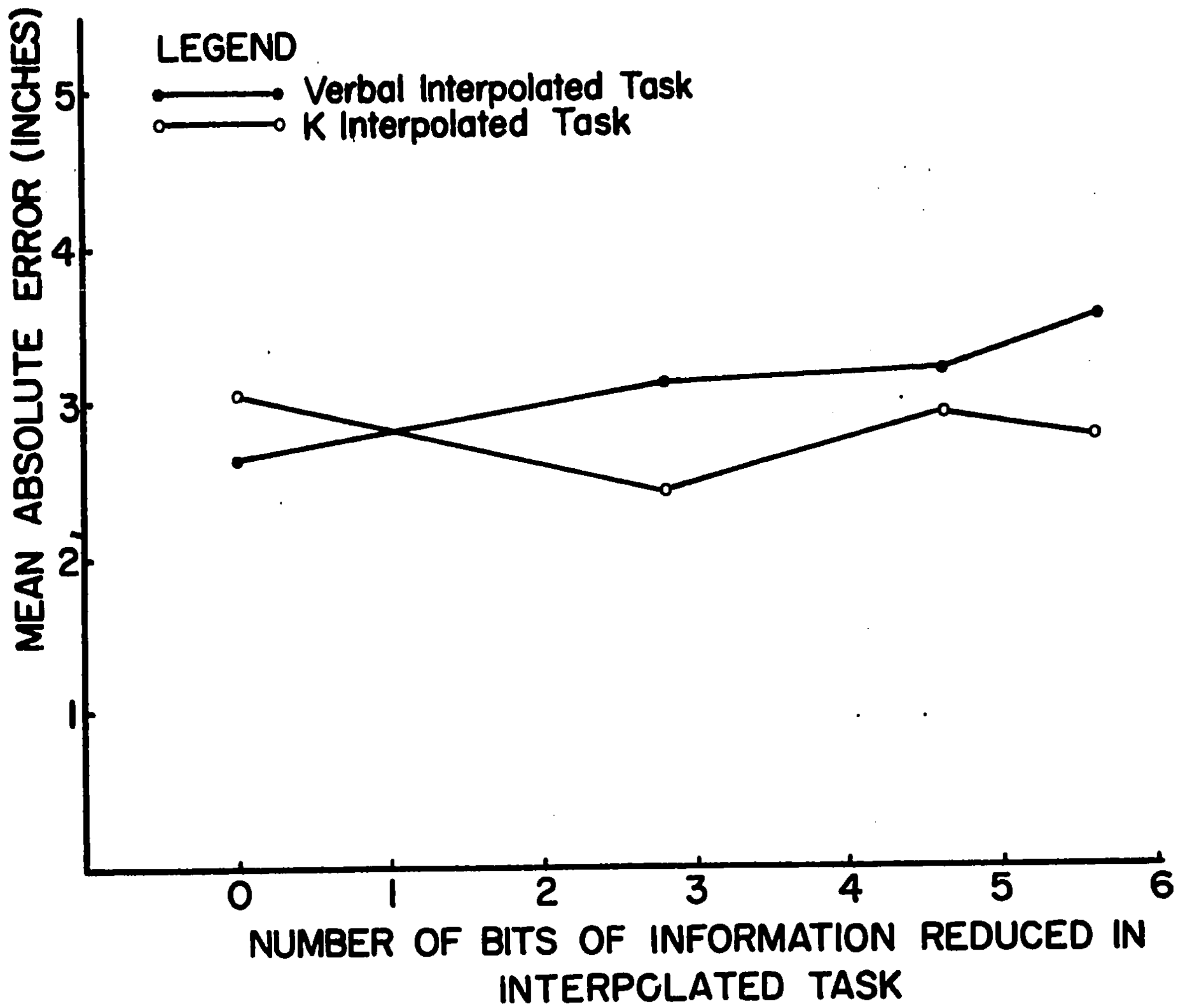


Figure 5: The mean error over four levels of interpolated information reduction for the K-V-K and K-K-K conditions.

2-Classifications conditions (p = .01). The difference between the Add, 2-Classifications and 1-Classification conditions did not reach the .01 level of significance. However, the Reverse condition was significantly less than the 1-Classification condition (p = .01). A test of linearity was carried out on the data (Appendix D, Table 15). The test indicated a linear trend over the four levels of information reduction.

K-K-K

A one-way analysis of variance was carried out on the absolute error scores (Table 8). The main effect of difficulty of the interpolated transform failed to reach significance at the .01 level of confidence. Similarly, the effect of subjects failed to reach the .01 level of significance. The effect of replications was not considered in the analysis since it failed to reach significance at the .01 level in the four-way analysis of variance (Appendix D, Table 13). The mean error scores for the levels of difficulty of the interpolated task were presented in Appendix D, Table 14. A graph for these data was represented in Figure 5.

A Duncan's New Multiple Range Test was applied to the means (Table 6). With the mean error score as the criterion, the Reverse condition did not differ significantly from the 2-Classifications or 1-Classification conditions (p = .01). The 2-Classifications condition did not differfrom the 1-Classification condition. The Add condition was significantly

TABLE 8

ONE-WAY ANALYSIS OF VARIANCE K MODALITY
K INTERPOLATED TASK

| Source of Variance | Sum of Squares | d.f. | Conservative d.f. | Mean Square | F |
|---|---|---|---|---|---|
| Level of Difficulty (D) | 1.85 | 3 | 1 | .616 | 2.12 |
| Subjects (S) | 5.69 | 7 | 7 | .814 | 2.81 |
| S x D | 6.242 | 21 | 7 | .29 | |
| TOTAL | 13.74 | 31 | | | |

** Significant at the .01 level (Greenhouse and Geisser)

less than the other three difficulty conditions at the .01 level of confidence. A test for linearity (Appendix D, Table 16) was found to be non-significant at the .01 level.

## Discussion

Information processing in STM. As Posner and Konick (1966) suggested, it may be meaningful to talk about the rehearsal of non-verbal material if it were shown that it required part of the central processing capacity. However, in the present study, K information showed no significant increase in forgetting with increased interpolated information processing, which was in accord with the second hypothesis. These findings are exactly in agreement with Broadbent's (1958) prediction that a task which is strictly motor and involves less conscious awareness of the information involved seems to be independent of the available central processing capacity.

Sharp (1971) using a redundant K interpolated task found no differential effect on K recall from a task requiring different amounts of non-verbal processing. In the present study, the K tasks containing information reduction (Add, 2-Classifications, 1-Classification) may have involved verbal transformations and, therefore, should have relied less on a non-verbal processing capacity than the Reverse task which was 0 bits reducing. Following up Sharp's argument, if K was rehearsed or recycled in STM, the K reverse task should have had a significantly larger effect on recall than the other 3 interpolated tasks. Analysis of the main effect of task difficulty (Table 5) and the Duncan's New Multiple Range Test (Table 6) indicated that there was no differential effect from the four K interpolated transforms which was in agreement with Sharp's findings. It can be argued, therefore, that K information is not maintained by a recycling or rehearsal process and, thus, does not rely on the central processing capacity.

Coding of information in STM. As discussed in the previous section on the verbal modality, Posner and Konick (1966) proposed two criteria to determine if retention of information could be accounted for by verbal labels alone. In the present study only one of these criteria was dealt with. This criterion, concerning an increase in forgetting with an increase in interpolated task difficulty, was not met. In an analysis of the effect of interpolated task difficulty on K recall, there was no evidence that forgetting was significantly related to the size of the interpolated information transform. These results are consistent with several other studies (Posner, 1967; Posner and Konick, 1966; Williams et al., 1969) in which it was concluded that K information was stored in image form. The analysis of the main effect of level of difficulty of a K interpolated transform (Table 8) was not significant at the .01 level of confidence indicating no difference between the four levels of difficulty. As suggested, in the previous section on processing, it was very likely that verbal transformations were involved in the tasks containing information reduction. Therefore, K recall, if it were rehearsable should have shown the greatest decrement under the Reversal condition since it was completely non-verbal in nature. However, this was not the case, and may have indicated that K STM involved a direct representation of the available information. This would support the hypothesis that K information is non-codable.

Information loss from STM. The interval between presentation and recall of the stimuli was deliberately set at 20 seconds since Sharp (1971) indicated that K information may not be susceptible to decay within this time span. Thus, loss due to decay was thought to be controlled for in the study. An analysis of the main effects interaction, which was significant at the .05 level, indicates that there may have been a somewhat greater interference effect from the verbal interpolated transform involving information reduction than from the K interpolated transforms. It is tentatively suggested that this may be attributable to a type of loss of "cognitive set" resulting from the switching of modalities plus the attention demand of the verbal interpolated task. The results indicated that there was an interference effect in all experimental conditions (i.e. there was definite recall error). The test on the difference between means indicated that there was no difference in the interference effect of an interpolated task containing information similar to that in store (K Reverse, K 2-Classifications, K 1-Classification) and a verbal interpolated task which was dissimilar

(V Reverse, V Add, V 2-Classifications). This finding is contradictory to Sharp's conclusion that only similar material will interfere. However, unlike several other studies (Blick and Billodeau, 1963; Williams et al., 1969) the Ss were thought to be maximally loaded, receiving five movements to replicate instead of one. The K Add condition only required one movement and was only 2.8 bits reducing (as opposed to the other conditions which required either switching modalities, a greater magnitude of movement or greater information reduction) produced a significantly smaller effect than all other conditions. Thus, it may be argued that in the case where the S is maximally loaded, a "set" must be maintained in order to sustain K information in STM. Although the argument is, by no means conclusive, an interference model may be suggested by these results as an explanation for the loss of K information from STM.

Subjects and replications. The subject effects was again, significant indicating that there was inter-subject variability in performance. Replications was not significant, indicating that learning and fatigue effects were minimal.

Questions

3. Is the amount of information transmitted in a verbal recall task, with a verbal interpolated task of increasing levels of difficulty, given between stimulus presentation and recall, comparable to the amount of

information transmitted in a K recall task under the same conditions?

4. Is the amount of information transmitted in a verbal recall task equivalent to the amount of information transmitted in a K recall task when a K interpolated task of increasing difficulty is presented, in both cases, between the stimulus presentation and recall?

Both of these questions have been posed in order that the consistent differences and similarities between the verbal and K STM systems can be further investigated.

The use of the information measure was necessitated by the difference in types of performance scores normally used for evaluation in the separate modalities.

Essentially, by comparing the operational systems, perhaps, more conclusive statements may be made about the nature of the K STM system which is of main concern in this study. In the related literature section on coding, the statement was made that "coding is directly related to the maximum possible rate at which the human can transmit information" (Fitts and Posner, 1967). Therefore, by determining the amount of information that could be transmitted under varying conditions of recall, it may be possible to further specify the types of codes used and their effect on information processing in the STM system.

## Results

In order to compare across modalities, a unit of measure that could be applied to both the verbal and K modalities was needed. Therefore, the amount of information transmitted was calculated from a table of probabilities of joint occurrences of stimulus and response categories (Appendix D, Tables 19 to 26, and 28 to 35). The amount of information transmitted, in bits, over the four levels of interpolated task difficulty for the both modalities of that task was presented in Appendix E, Tables 17, and 18. A graph of the amount of information transmitted for the V-V-V and V-K-V conditions along with the corresponding conditions (K-K-K and K-V-K) were illustrated in Figures 6 and 7. In addition, the percentage of missing data for the verbal modality, due to the inability of the Ss to respond, is reported in Appendix D, Table 27.

On comparing the results of this measure with the metric measure, it seems that the amount of information transmitted in the K modality does not always mirror the mean error scores under each difficulty condition. This may be attributable to the fact that the informational measure does not reflect the goodness of the response, but rather classifies it as "correct" or "incorrect." The verbal data appears to be in agreement with the mean error scores for all the conditions.

## Discussion

Information processing. Because the information transmission measurement used in this study, due to

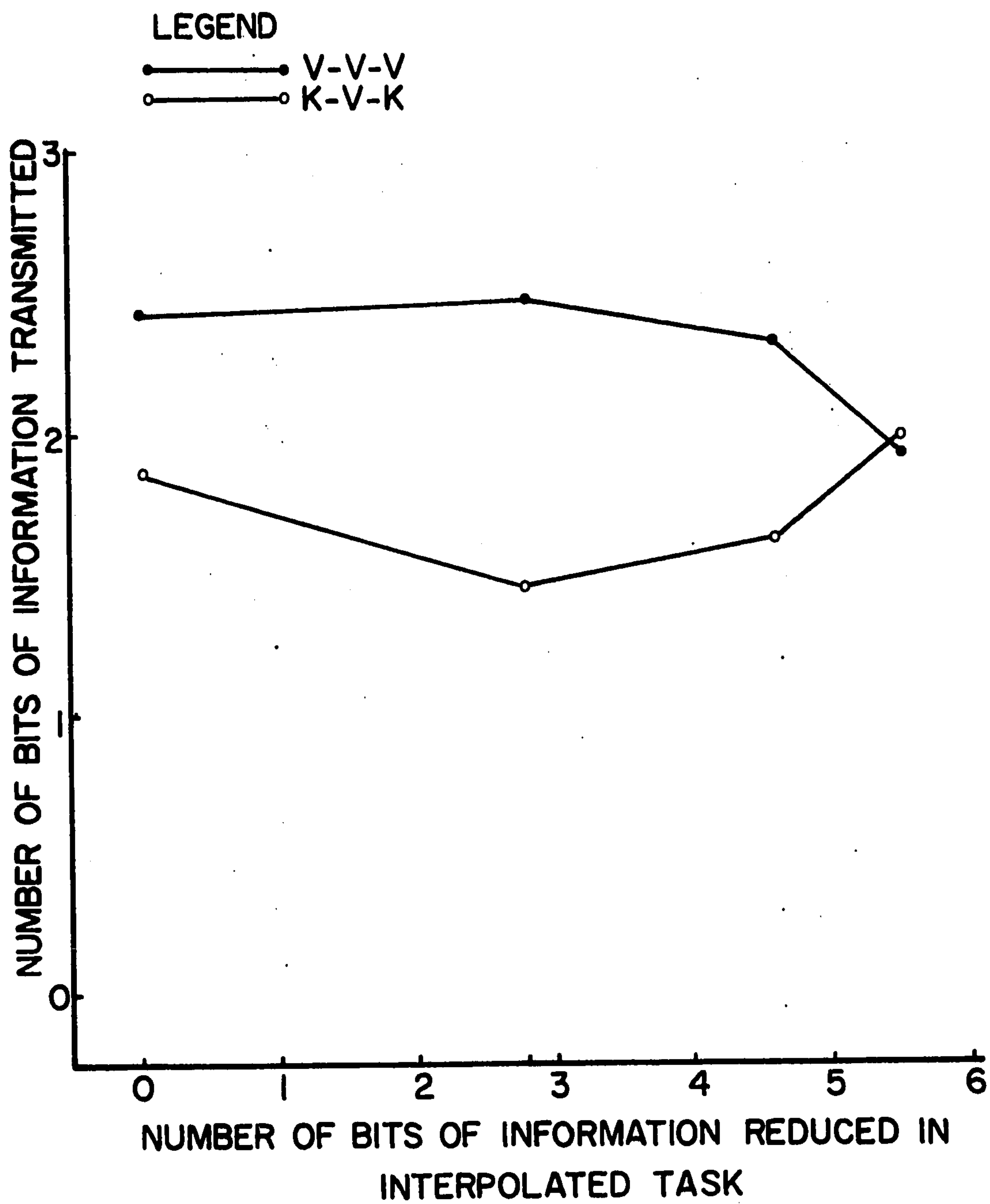


Figure 6: Amount of information transmitted over the four levels of interpolated information reduction for the V-V-V and K-V-K conditions.

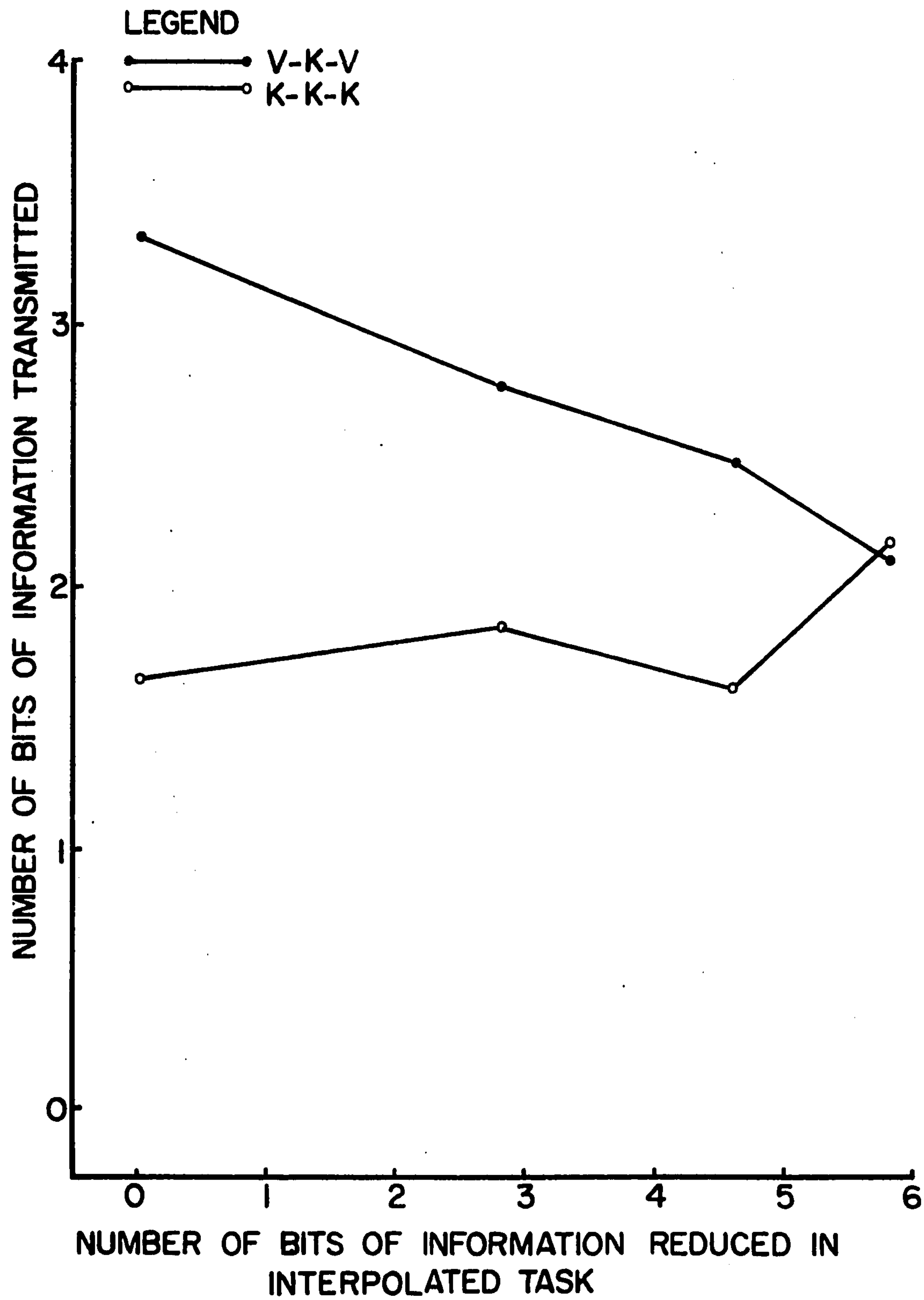


Figure 7: Amount of information transmitted over the four levels of interpolated information reduction for the V-K-V and K-K-K conditions.

alterations in standard procedure of calculations, was not thought to be totally reliable, no legitimate conclusions could be drawn from this data. However, the author felt that it would be worthwhile to use the data to further speculate on issues already discussed.

Processing in STM, Broadbent (1958) stated, may be recycling or rehearsal of information. At this stage the information may be "chunked" or strategies put into use in order to increase the probability of retention. However, if the information was in a non-rehearsable form, such a central operational STM system would not be functional. Information available to an operational STM system would be more likely to be transmitted than information stored in a representational memory. In the present study, if these assumptions are true, more verbal information should have been transmitted than K information. This was found to be true in most conditions (Appendix B, Table 17 and 18). This indicated that K information, unlike verbal information, may not be centrally processed.

Coding of information. In the previous discussions, the suggestion was made that verbal information seems to be stored in STM in the form of verbal labels. Similarly, the proposal was made that the STM system for K is representative and K information may not be codable unless it involved some verbal transformation.

The purpose of a code, in itself, is to provide a unit that will be more easily stored and retrieved in STM than a direct representation (Fitts and Posner, 1967). Therefore, it may be valid to presume that, on the average, in a recall task involving codable information, more information should be transmitted than in recall of non-codable information and perhaps may be less susceptible to interference or decay in STM. From the results in Appendix E, Tables 17 and 18, this seems to be the case, in the present study. On the average, 2.45 bits of information were transmitted in the verbal modality as opposed to 1.76 bits in the K modality. In the Reverse, Add and 2-Classifications conditions, the verbal information appears to be less affected by the interpolated transforms, but the reverse is true with the 1-Classification tasks. No explanation of this trend has been determined. One may speculate that this type of task, the information contained in which would appear also to be verbal encoded, would interfere the most with verbal recall because it utilized the same processing capacity and was the largest information transform. Likewise, it should interfere the least with K recall because it did not utilize any of the suggested representational memory and in terms of the magnitude of movement involved, the K 1-Classification contained the least amount of movement of all four tasks. However, the data on mean error was not in complete agreement with the information transmission measure so no definite conclusions could be made concerning this point.

The results derived from the information transmission measure, however, seem to add support to the hypothesis that K information is non-codable.

Equivalences in task difficulty. If the amount of information transmitted reflects the effect of the interpolated transform on verbal and K recall, it would appear that difficulty cannot be solely defined as the amount of information reduction in an interpolated task. Three interpolated transforms (Reverse, Add, 2-Classifications) were associated with a much lower rate of information transmission in the K modality as opposed to the verbal modality. It is interesting to note that the 1-Classification task was associated with almost equal information transmission in both modalities. However, in the K modality the rate was higher than the previous conditions and in the verbal modality the rate of transmission was decreased in comparison to the other conditions. From the previous analysis of mean error, verbal recall decreased as a function of the increasing amount of information reduction both with a verbal and K interpolated task, the only difference lying in the K Reverse condition. Essentially, K recall was equally reduced under each condition of the verbal and K interpolated task, regardless of the amount of information reduced (verbal 1-Classification caused a slightly larger decrement). It could be inferred that the information reduction measure really has no functional meaning in terms of task difficulty in the K modality and that any task of the same nature may cause equal disruption of recall regardless of the information reduced.

No definite conclusions can be drawn concerning equivalences in task difficulty between modalities. However, it seems that loss of K information from a system which is maximally loaded, results from any type of interpolated task regardless of the amount of information reduced in it.

# CHAPTER 5

# SUMMARY AND CONCLUSIONS

## Summary

The purpose of this study was to determine the nature and requirements of a task that would cause the verbal and/or K STM systems to lose information. In doing so, it was thought that any consistent differences or similarities exposed by the investigation would help to define the nature of these two operational systems. The experimental design was a subject by treatment, factorial design, replicated ten times for each subject. The Ss were 8 graduate physical education students.

The apparatus consisted of a metal track mounted on a baseboard. A metal cursor was mounted on the track. The working space of the subject consisted of ten 1.5 inch intervals marked off on the track. The apparatus was used by the Ss for making simple linear motor responses. Visual cues were controlled by blindfolding the Ss. The experimental task was to receive information input (either 8 digits or 5 movements), store the material for a period of delay during which the Ss engaged in a series of interpolated transforms (either with pairs of digits or pairs of movements) and to recall the information input either verbally or kinesthetically.

There were three factors of experimental interest:

sensory modality of the input (verbal or kinesthetic [K]); sensory modality of the interpolated task (verbal or K); and level of difficulty of the interpolated transform (Reverse, 0 bits reducing; Add, 2.8 bits reducing; 2-Classifications, 4.6 bits reducing; 1-Classification, 5.6 bits reducing).

Two hypotheses and a series of questions were formed, all dealing with recall under the varying conditions of the interpolated information reduction.

The findings of the four related parts of the experiment were as follows:

V-V-V

Verbal recall errors increased linearly as a function of the amount of information reduction in the interpolated task.

V-K-V

Verbal recall error increased linearly as the difficulty of the K interpolated transform increased. The K interference effect was equal to the verbal interference effect only when it contained an information reduction operation.

K-V-K

The decrement in recall accuracy was found to be unrelated to the difficulty of the verbal interpolated transform. The verbal 1-Classification task did cause a slightly larger decrement than any of the K interpolated tasks. This may have been indicative of the type of task difficulty needed to cause a greater decrement than was evidenced in the other conditions.

K-K-K

The decrement in recall accuracy was again found to be unrelated to the information reduction in the interpolated transform. In addition, the results showed that most of the K conditions caused a decrement that was not significantly different than that caused by the verbal transforms of Reverse, Add and 2-Classifications.

From the use of a measure with units common to both modalities (bits of information), it was found that information transmitted in the verbal recall tasks under the varying levels of task difficulty was much greater than the amount of information transmitted in the K recall task under the same conditions.

## Conclusions

On the basis of the results obtained and within the limitations of the study, the following conclusions were proposed:

There appear to be separate STM systems for verbal and K information.

Verbal information is coded and stored in STM, in the form of verbal labels, whereas K information appears to be stored in a non-codable (i.e. image) form.

K information, unlike verbal information, does not appear to be centrally processed.

The amount of K information lost should be greater than the amount of verbal information lost under the same conditions of recall since K information does not seem to be available for rehearsal.

Loss of verbal information is systematically related to the amount of information reduced in a task which follows the presentation of the stimulus.

Loss of K information is unrelated to the difficulty of a task when difficulty is represented by the amount of information reduction. It is tentatively proposed that K information loss may be increased if there is a lost of "set" or "task readiness."

## Recommendations

The study has shown that K information loss in STM is unrelated to the amount of information reduced in an interpolated task. Therefore, it seems that the term "difficulty" defined as the amount of information reduction is not applicable in the K modality. The results of the study concerning K eluded to an increased decrement in recall as a result of a type of "set" change. Whether this is valid or not is a problem that needs to be investigated.

No "Rest" condition was provided in the study in order to determine if delay was really controlled for by the 20 second interval. This condition should be investigated in relation to the intervals containing increasing levels of information reduction.

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# APPENDIX A

## PILOT STUDY

## SIZE OF A DISCRIMINABLE INTERVAL FOR A LINEAR MOTOR TASK

The purpose of this experiment was to determine what size of interval between movements in a linear replacement task was necessary for easy discrimination. The subjects were 3 male graduate physical education students. The apparatus consisted of a cursor mounted on a metal rule which served as a track. The metal rule was scaled in inches. The experimental task involved the Ss moving the cursor along the track to a physical stop. Using the "Method of Constant Stimuli," each S received a standard movement and a comparison movement and was to respond "Same" or "Different." Each S received 30 such trials at 6 different positions. The 6 positions represented long, medium, and short movements in the S's working space on the track. The movements were: 15 inch movements from the right and the left, 7 inch movements from the right and the left, and 2 inch movements from the right and the left. The 6 movements were presented in random order. The percentage of correct responses was calculated for each movement category.

The results indicated that:

1. An interval of 3/4 of an inch was easily discriminable (no error) in the 2 inch movement range, from the right and the left.

2. An interval of 1 inch was easily discriminable (no error) in the 7 inch range, from the right and the left.

3. An interval of 1.5 inches was easily discriminated (no error) in the 15 inch range from the right and the left.

It was concluded that a 1.5 inch interval was necessary for simple discrimination when stimulus lengths, to be presented, would range from 0 to 15 inches in length.

# APPENDIX B

PILOT STUDY

MAXIMUM LOADING IN A KINESTHETIC RECALL TASK

The purpose of the experiment was to determine the maximum number of errorless categories of movements that could be recalled accurately. The subjects were 3 male graduate physical education students. The apparatus consisted of a cursor mounted on a metal track with a scale measured on the side of the track in 1.5 inch intervals. The experimental task involved the Ss, who were blindfolded, moving the cursor along the track to a physical stop, returning it to the starting position and recalling it after the appropriate number of movements were given. The Ss received in one trial, 3,5, or 7 movements to recall. The Ss received 30 such trials, 10 for each number of movements. The number of movements to recall were presented in random order. A movement was considered correctly recalled if it was within +1 or -1 inch of the actual distance. Recall performance was measured as a function of the number of movements correctly reproduced.

From the results and within the limits of the study, it was concluded that:

1. 3 movements were well below the span of immediate memory for reproducing linear movements.
2. 5 movements appeared to be the maximum number of movement categories that could be correctly recalled.

3. 7 movements appeared to be above the span of immediate memory for reproducing linear movements.

# APPENDIX C

TABLE 9

FOUR WAY ANALYSIS OF VARIANCE
VERBAL MODALITY

| Source | Sum of Squares | d.f. | Mean Squares | F |
|---|---|---|---|---|
| Interpolated Task Modality (TM) | 129.59 | 1 | 129.59 | 38.09** |
| Level of Difficulty (D) | 584.58 | 3 | 194.86 | 57.30** |
| TM x D | 48.68 | 3 | 16.22 | 4.64 |
| Subjects (S) | 194.77 | 7 | 127.82 | 8.18** |
| Replications | 80.65 | 9 | 8.96 | 2.40 |
| Pooled Error[1] | 2295.11 | 616 | 3.72 | |

** Significant at the .01 level.
[1]Pooling done according to Paull's Law (Hays, 1969, p. 434).

TABLE 10

MEAN ERROR FOR THE EIGHT EXPERIMENTAL CONDITIONS - VERBAL MODALITY

| | Reversal | Addition | 2 Classi-fications | 1 Classi-fications |
|---|---|---|---|---|
| Verbal Interpolated Task | 2.48 | 2.42 | 3.28 | 4.30 |
| K Interpolated Task | .98 | 1.60 | 3.05 | 3.90 |

TABLE 11

TEST OF LINEARITY AND DEVIATIONS FROM LINEARITY
V-V-V

| Source | df | Mean Square | F |
|---|---|---|---|
| Linear Regression | 1 | 14.27 | 31.02** |
| Deviations | 2 | 4.92 | 10.07** |
| S x D | 21 | .46 | |

** Significant at the .01 level

TABLE 12

TEST OF LINEARITY AND DEVIATIONS FROM LINEARITY
V-K-V

| Source | df | Mean Square | F |
|---|---|---|---|
| Linear Regression | 1 | 37.72 | 56.38** |
| Deviations from Linear | 2 | 1.97 | 2.94 |
| S x D | 21 | .699 | |

**Significant at the .01 level

# APPENDIX D

TABLE 13

FOUR WAY ANALYSIS OF VARIANCE
K MODALITY

| Source of Variance | Sum of Squares | d.f. | Mean Square | F |
|---|---|---|---|---|
| Interpolated Task Modality (TM) | 80.11 | 1 | 80.11 | .30 |
| Level of Difficulty (D) | 135.14 | 3 | 45.08 | 1.08 |
| TM x D | 203.06 | 3 | 67.69 | 10.10** |
| Subjects (S) | 1902.882 | 7 | 271.84 | 40.60** |
| TM x S | 1849.39 | 7 | 264.19 | 39.40** |
| Replications | 103.68 | 9 | 10.52 | 2.00 |
| D x R | 1133.43 | 27 | 41.97 | 6.3 ** |
| Pooled Error[1] | 22191.45 | 3311 | 6.7 | |

** Significant at the .01 level.
[1] Pooling done according to Paull's Law (Hays, 1963, p. 434).

TABLE 14

MEAN ERROR FOR THE EIGHT EXPERIMENTAL CONDITIONS - K MODALITY

| | Reversal | Addition | 2 Classi-fications | 1 Classi-fications |
|---|---|---|---|---|
| Verbal Interpolated Task | 2.62 | 3.12 | 3.20 | 3.69 |
| K Interpolated Task | 3.06 | 2.42 | 2.92 | 2.80 |

TABLE 15

TEST OF LINEARITY AND DEVIATIONS FROM LINEARITY
K-V-K

| Source | df | Mean Square | F |
|---|---|---|---|
| Linear Regression | 1 | 3.64 | 11.16** |
| Deviations from Linear | 2 | .019 | <1.00 |
| S x D | 21 | .31 | |

** Signficant at the .01 level

TABLE 16

TEST OF LINEARITY AND DEVIATIONS FROM LINEARITY
K-K-K

| Source | df | Mean Square | F |
|---|---|---|---|
| Linear Regression | 1 | .06 | <1.00 |
| Deviations from Linear | 2 | .90 | 3.10* |
| S x D | 21 | .29 | |

* Significant at the .05 level

APPENDIX E

TABLE 17

AMOUNT OF INFORMATION TRANSMITTED
VERBAL MODALITY

| Experimental Condition | No. of Bits |
|---|---|
| Verbal Interpolated Task | |
| Reverse | 2.44 |
| Add | 2.48 |
| 2 - Classifications | 2.34 |
| 1 - Classification | 1.93 |
| K Interpolated Task | |
| Reverse | 3.13 |
| Add | 2.78 |
| 2 - Classifications | 2.49 |
| 1 - Classification | 2.04 |

TABLE 18

AMOUNT OF INFORMATION TRANSMITTED
K MODALITY

| Experimental Condition | No. of Bits |
| --- | --- |
| Verbal Interpolated Task | |
| Reverse | 1.87 |
| Add | 1.48 |
| 2 - Classifications | 1.63 |
| 1 - Classification | 1.97 |
| K Interpolated Task | |
| Reverse | 1.68 |
| Add | 1.87 |
| 2 - Classifications | 1.70 |
| 1 - Classification | 1.94 |

TABLE 19

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES V-V-V

REVERSE CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .06 | | .009 | .0025 | .0014 | .0038 | .0031 | .0042 | .0025 | .0038 | .09 |
| 1 | .002 | .07 | .0016 | | .0042 | | .0031 | | .0025 | .005 | .088 |
| 2 | .002 | .0023 | .047 | .004 | | | .0047 | .0063 | .0025 | .005 | .075 |
| 3 | | .0023 | .0047 | .0625 | .0028 | | .0063 | .0042 | | .0013 | .085 |
| 4 | .002 | .0034 | .0063 | .0013 | .07 | | .0047 | | | .0013 | .089 |
| 5 | .002 | | .003 | .004 | .0028 | .07 | .0016 | | | .0025 | .086 |
| 6 | .0071 | .0034 | .003 | .0013 | .0014 | .0025 | .039 | | .0025 | | .06 |
| 7 | .009 | .0011 | .003 | .0025 | .0042 | .005 | .0063 | .054 | .0025 | .0025 | .09 |
| 8 | | | | .0025 | | .0025 | | | .075 | .0013 | .081 |
| 9 | .007 | .0034 | .0016 | | .0042 | .0013 | .0078 | | .005 | .01 | .031 |
| M.D. | .0125 | .014 | .021 | .02 | .0097 | .0178 | .025 | .028 | .0075 | .02 | .176 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 20

TABLE OF PROBABILITIES OF OCCURRENCE OF STIMULUS AND RESPONSE CATEGORIES V-V-V, ADD CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .05 | .0042 | .002 | .002 | .006 | .0016 | .0016 | .0038 | .0036 | .002 | .0768 |
| 1 | .0036 | .0625 | .0042 | .002 | .0013 | | | .0025 | .0036 | .004 | .079 |
| 2 | .0054 | .0042 | .0625 | | .0025 | .0016 | | .0013 | .0018 | | .079 |
| 3 | .0036 | .0042 | | .0625 | .0025 | .0031 | .0031 | .0025 | .0018 | | .083 |
| 4 | .0036 | | .062 | .001 | .0613 | .0063 | .0016 | .0038 | | .002 | .0816 |
| 5 | | | .002 | .003 | | .06 | .0031 | .0013 | | | .087 |
| 6 | .0018 | .002 | .002 | .003 | .0038 | .0047 | .07 | .0013 | | | .114 |
| 7 | | .0063 | .002 | .002 | .0025 | .0063 | .031 | .06 | .0018 | .002 | .087 |
| 8 | .0054 | | .0042 | .003 | | .0016 | | .0013 | .07 | .002 | .093 |
| 9 | .0054 | | .0042 | .003 | | .0016 | | .0013 | .07 | .002 | .093 |
| M.D. | .016 | .0167 | .0167 | .0167 | .02 | .014 | .016 | .02 | .014 | .0083 | .161 |
| Total | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 21

TABLE OF PROBABILITIES OF OCCURRENCE OF STIMULUS AND RESPONSE CATEGORIES V-V-V, 2-CLASSIFICATIONS CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .08 | .083 | .001 | .0031 | | .0013 | .0025 | | .0054 | .0025 | .104 |
| 1 | .0018 | .054 | .003 | .0042 | .002 | .0013 | | | .0036 | .0013 | .07 |
| 2 | | .002 | .06 | .0052 | .004 | | .0025 | | .0018 | .0025 | .077 |
| 3 | .0018 | .006 | .078 | .0427 | | .0038 | .005 | .0042 | .0018 | .0013 | .141 |
| 4 | | .0042 | .001 | .001 | .06 | | .0025 | | .0018 | .0013 | .072 |
| 5 | | .002 | .001 | .0031 | .002 | .0725 | .0025 | | .0036 | .0013 | .088 |
| 6 | | | .001 | .001 | .002 | .0013 | .05 | .0069 | .0036 | .0013 | .067 |
| 7 | .0018 | | .003 | .001 | .004 | .0013 | .005 | .071 | .0054 | .0038 | .096 |
| 8 | .0018 | .002 | .007 | .0042 | | .0025 | .0025 | .0028 | .04 | .0025 | .068 |
| 9 | .0018 | | .0047 | .0052 | .002 | | | .0014 | .009 | .06 | .084 |
| M.D. | .01 | .021 | .0156 | .03 | .025 | .01625 | .0275 | .014 | .023 | .026 | .208 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 22

TABLE OF PROBABILITIES OF OCCURRENCE OF THE STIMULUS AND RESPONSE CATEGORIES V-V-V, 1-CLASSIFICATION CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | . 04 | .0018 | .0063 | .0054 | . 003 | .0013 | .0025 | .0025 | .0063 | .0016 | . 074 |
| 1 | .0018 | . 05 | .0038 | | .0016 | | . 005 | .0063 | .0031 | .0032 | . 075 |
| 2 | .0018 | .0036 | . 049 | .0054 | .0016 | | | .0013 | .0016 | .0047 | . 069 |
| 3 | .0054 | .0018 | .0037 | . 049 | .0078 | .0025 | .0075 | .0013 | .0016 | .0032 | . 084 |
| 4 | .0036 | .0036 | .0037 | .0036 | . 04 | .0025 | | .0013 | | .0032 | . 062 |
| 5 | .0054 | .0036 | .0013 | .0018 | .0016 | . 057 | .0025 | .0037 | . 003 | .0032 | . 082 |
| 6 | .0018 | .0018 | .0013 | .0018 | .0047 | .0025 | .0037 | .0025 | . 003 | .0016 | . 059 |
| 7 | .0036 | .0036 | 0025 | | . 003 | .0013 | .0025 | . 056 | . 003 | .0016 | . 079 |
| 8 | .0036 | .0018 | .0037 | .0018 | | .0013 | .0025 | .0013 | . 053 | .0016 | . 074 |
| 9 | .0036 | | .0013 | .0018 | .0063 | . 005 | | .0025 | . 003 | . 041 | . 065 |
| M.D. | . 032 | . 027 | . 024 | . 03 | .0027 | . 026 | . 04 | . 021 | . 022 | . 036 | . 263 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 23

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES V-K-V, REVERSE CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .0964 | .0036 | | | .0013 | | | | | .002 | .103 |
| 1 | | .0929 | | | .0013 | | | | | | .094 |
| 2 | | | .0944 | | .0013 | .0014 | | | | | .097 |
| 3 | | | .0044 | .0953 | | | | .0016 | | .002 | .103 |
| 4 | .0018 | .0018 | | .0016 | .09 | | .0014 | | | | .097 |
| 5 | .0018 | .0018 | | | | .0903 | | | .0018 | .002 | .097 |
| 6 | | | | | | .0014 | .0944 | | .0018 | | .097 |
| 7 | | | | | | .0028 | | .095 | .0018 | | .099 |
| 8 | | | | | | | | | .089 | | .089 |
| 9 | | | | | | | | | | .0917 | .0917 |
| M.D. | | | .0012 | .0031 | .0625 | .0042 | .0042 | .0031 | .0054 | .002 | .029 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 24

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES V-K-V, ADD CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .0979 | | | | | | | | .0014 | | .099 |
| 1 | | .0875 | | | | .0011 | .0018 | .0014 | | | .093 |
| 2 | | | .0775 | | .0021 | | | | | | .079 |
| 3 | | | | .075 | .001 | .0011 | .0018 | | .0014 | | .081 |
| 4 | | | .0075 | .002 | .078 | .0022 | .0018 | .0013 | .0014 | | .094 |
| 5 | | .0031 | | | .0031 | .075 | .018 | .0038 | .0014 | .002 | .087 |
| 6 | | .0016 | | | .001 | .001 | .0786 | .0025 | .0028 | | .089 |
| 7 | | | | .002 | .001 | .0034 | | .07125 | .0028 | .0063 | .088 |
| 8 | | .0016 | | | .001 | .0034 | .0036 | .0013 | .075 | .002 | .088 |
| 9 | | | .0025 | .0042 | | .001 | | .0013 | | .083 | .093 |
| M.D. | .0018 | .0063 | .0125 | .0167 | .0125 | .011 | .0175 | .0125 | | .0063 | .11 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 25

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES V-K-V, 2-CLASSIFICATIONS CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .054 | .0014 | | .0016 | .001 | .008 | .006 | | .00125 | .005 | .0783 |
| 1 | .0014 | .072 | | .0032 | | | | | | .0016 | .078 |
| 2 | .0028 | .0014 | .07 | .0016 | | | .006 | | .00125 | .0031 | .083 |
| 3 | .0028 | .0028 | .0018 | .064 | .001 | | .0047 | .0025 | | | .083 |
| 4 | .0069 | .0014 | .0036 | | .0625 | | .0047 | .005 | .0025 | | .087 |
| 5 | .0028 | | .0018 | | .001 | .0625 | .0016 | .0025 | | | .072 |
| 6 | .0038 | | .0018 | .0016 | .0038 | | .052 | .0025 | | | .066 |
| 7 | | | | .0016 | | .00375 | .0031 | .0525 | .00125 | .0016 | .064 |
| 8 | .0028 | .0014 | .0018 | .0016 | | .00375 | .0016 | .005 | .079 | .0016 | .098 |
| 9 | .0014 | .0014 | .0036 | .0016 | | | | | .0025 | .0625 | .073 |
| M.D. | 02 | .018 | 016 | .0234 | .0298 | .0208 | .0203 | .03 | .0125 | .022 | .213 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 26

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES V-K-V, 1-CLASSIFICATION CONDITION

| S / R | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | . 05 | .0036 | . 007 | .0063 | | .0036 | . 005 | . 005 | . 005 | | . 085 |
| 1 | .0028 | . 066 | .0018 | .0013 | .0018 | .0018 | .0025 | . 005 | .0038 | . 003 | . 091 |
| 2 | .0014 | | .0607 | .0063 | .0018 | | .0013 | | .0013 | .0016 | . 074 |
| 3 | .0083 | . 054 | .0036 | .0412 | .0036 | .0018 | .0013 | | | .0063 | . 072 |
| 4 | .0028 | | | .0013 | . 066 | .0036 | .0013 | .0025 | .0013 | .0063 | . 085 |
| 5 | .0028 | .0036 | | .0036 | | . 064 | .0038 | | | .0016 | . 079 |
| 6 | .0028 | | | . 005 | .0018 | . 005 | . 056 | . 005 | .0026 | .0047 | . 083 |
| 7 | .0028 | | .0018 | .0013 | .0018 | .0018 | .0013 | . 05 | .0026 | . 003 | . 066 |
| 8 | .0038 | .0018 | | 0013 | .0018 | .0018 | .0036 | .0025 | . 064 | .0078 | . 087 |
| 9 | .0028 | . | .0036 | .005 | . 007 | . 007 | ..0013 | .0025 | .0038 | . 048 | . 074 |
| M.D. | . 017 | .0196 | . 02 | .028 | .0143 | .0089 | . 023 | . 025 | . 016 | . 017 | . 189 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 27

PERCENTAGE OF MISSING DATA FOR EACH DIFFICULTY CONDITION, VERBAL MODALITY

| Condition | Percentage Missing |
|---|---|
| V-V-V, Reverse | 18 |
| V-V-V, Add | 17 |
| V-V-V, 2-Classifications | 20 |
| V-V-V, 1-Classification | 28 |
| V-K-V, Reverse | 3 |
| V-K-V, Add | 10 |
| V-K-V, 2-Classifications | 20 |
| V-K-V, 1-Classification | 20 |

TABLE 28

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-V-K, REVERSE CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .07 | .0035 | .004 | | | | .003 | | .003 | | .085 |
| 1 | .01 | .05 | .007 | .02 | .003 | | .005 | | | | .095 |
| 2 | .004 | .02 | .05 | .003 | .006 | .008 | .01 | | .006 | .003 | .105 |
| 3 | .004 | .008 | .01 | .02 | .009 | .008 | .005 | .0025 | .009 | | .076 |
| 4 | | .005 | .007 | .02 | .03 | .0125 | .008 | .008 | .006 | | .097 |
| 5 | .004 | .008 | .0125 | .002 | .02 | .04 | .024 | .0125 | .009 | .003 | .147 |
| 6 | | .005 | .004 | .015 | .0125 | .02 | .017 | .0175 | .019 | .003 | .112 |
| 7 | .004 | | .005 | .003 | .006 | .01 | .014 | .035 | .009 | .006 | .092 |
| 8 | .004 | .003 | .004 | .003 | .009 | .002 | .009 | .015 | .02 | .009 | .078 |
| 9 | | | | | .003 | .002 | .005 | .01 | .02 | .075 | .115 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 29

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-V-K, ADD CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .05 | .008 | .008 | .003 | .002 | .002 | .0025 | | | | .075 |
| 1 | .018 | .05 | | .009 | .002 | .005 | | .002 | .002 | .004 | .092 |
| 2 | .01 | .0017 | .008 | .006 | .008 | .01 | .0075 | .006 | .008 | .004 | .085 |
| 3 | .01 | .0025 | .008 | .024 | .01 | .009 | | .004 | .002 | | .069 |
| 4 | | .005 | .0125 | .034 | .04 | .007 | .0125 | .004 | .008 | .017 | .14 |
| 5 | .0075 | ,005 | .025 | .025 | .01 | .032 | .025 | .017 | .008 | .008 | .164 |
| 6 | .0025 | .0025 | .008 | .009 | .01 | .014 | .03 | .004 | .006 | .004 | .09 |
| 7 | | .0025 | | .006 | .006 | .016 | .0125 | .033 | .006 | .004 | .086 |
| 8 | .0025 | | .021 | | .002 | .0012 | .008 | .02 | .033 | .0125 | .107 |
| 9 | .0025 | .0025 | .08 | .003 | .008 | .0012 | .0025 | .02 | .025 | .05 | .195 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 30

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-V-K, 2-CLASSIFICATIONS CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .03 | | .005 | | .0015 | | | .004 | | .003 | .044 |
| 1 | .015 | .05 | .0075 | .015 | .005 | .006 | .01 | .004 | .006 | | .118 |
| 2 | .015 | .01 | .028 | .0025 | .009 | .006 | .005 | .004 | .003 | .003 | .085 |
| 3 | .0025 | .0075 | .01 | .0375 | .0125 | .0125 | .0025 | .004 | .003 | | .092 |
| 4 | .018 | .0125 | .017 | .018 | .03 | .0125 | .022 | .008 | .008 | .006 | .15 |
| 5 | .0625 | .005 | .0025 | .0075 | .008 | .019 | .008 | .02 | .008 | .009 | .131 |
| 6 | .0025 | .0025 | .0125 | .0025 | .01 | | .03 | .004 | .009 | .0125 | .086 |
| 7 | | | .0025 | .005 | .003 | .019 | .005 | .029 | .01 | .009 | .083 |
| 8 | .01 | .0075 | .0025 | .0075 | .0075 | .019 | .018 | .0125 | .03 | .016 | .130 |
| 9 | .005 | .005 | .0075 | .0025 | .0125 | .006 | .0025 | .0167 | .02 | .04 | .116 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 31

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-V-K, 1-CLASSIFICATION CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .03 | .003 | .006 | | .006 | .021 | | | .0125 | .00175 | .069 |
| 1 | .015 | .034 | .006 | .007 | .009 | | .004 | .01 | .0036 | .0054 | .089 |
| 2 | ,0125 | ,92 | ,94 | ,014 | .0125 | .0125 | .002 | .008 | | .005 | .127 |
| 3 | .0075 | .0125 | | .018 | .009 | .004 | .0125 | | .007 | .005 | .08 |
| 4 | .005 | .003 | .028 | .0125 | .0125 | .008 | .008 | .004 | .0035 | .007 | .092 |
| 5 | .0125 | | | .0125 | .009 | .02 | .01 | .004 | .007 | .011 | .087 |
| 6 | .01 | .009 | .0125 | .016 | .015 | .0125 | .027 | .0125 | .028 | .007 | .164 |
| 7 | | .006 | | .036 | | .008 | .01 | .04 | .007 | .009 | .085 |
| 8 | .005 | .003 | | .055 | .003 | | .019 | .016 | .019 | .0125 | .085 |
| 9 | .0025 | .006 | .003 | .011 | .0175 | .008 | .006 | .008 | .023 | .036 | .121 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 32

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-K-K, REVERSE CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .0375 | | .0018 | | .003 | | | | | | .042 |
| 1 | .0125 | .045 | .01 | .006 | .006 | .004 | .003 | .005 | | .003 | .097 |
| 2 | .008 | .023 | .034 | .003 | .006 | .004 | .003 | .01 | .003 | .003 | .099 |
| 3 | .0125 | .015 | .016 | .0125 | .006 | .002 | .0078 | .005 | .0125 | .009 | .098 |
| 4 | | .002 | .007 | .009 | .0019 | .002 | .008 | | | .009 | .06 |
| 5 | .008 | .008 | .0125 | .025 | .034 | .027 | .0171 | .0125 | .009 | .009 | .163 |
| 6 | | .008 | .009 | .022 | .006 | .017 | .02 | .01 | .003 | .003 | .101 |
| 7 | | | | .003 | .006 | .017 | .013 | .01 | .006 | .003 | .058 |
| 8 | | | .005 | .066 | .003 | .017 | .09 | .018 | .037 | .009 | .104 |
| 9 | .02 | | .004 | .0125 | .009 | .006 | .014 | .03 | .028 | .05 | .174 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 33

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-K-K, ADD CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | . 03 | .0025 | | | | | | | . 002 | . 004 | . 038 |
| 1 | . 03 | . 05 | . 004 | . 004 | . 008 | . 007 | | | . 006 | | . 116 |
| 2 | . 017 | . 025 | . 025 | .0125 | . 006 | . 007 | . 006 | . 004 | . 004 | . 004 | . 116 |
| 3 | . 008 | . 01 | . 03 | .0125 | . 01 | . 006 | | . 002 | . 004 | . 004 | . 09 |
| 4 | . 008 | . 005 | . 008 | . 025 | . 022 | . 008 | | . 004 | . 002 | | . 077 |
| 5 | . 002 | | .0125 | . 021 | . 017 | . 03 | .0125 | . 01 | .0125 | . 008 | . 126 |
| 6 | . 002 | . 05 | | | . 027 | . 019 | . 034 | .0125 | . 008 | | . 108 |
| 7 | . 002 | | .0125 | . 006 | . 004 | . 017 | .0125 | . 02 | . 01 | | . 085 |
| 8 | | | | . 004 | . 002 | . 003 | . 019 | . 017 | . 025 | . 017 | . 086 |
| 9 | | .0025 | . 008 | . 008 | . 002 | . 006 | . 016 | . 029 | . 025 | . 6 | . 157 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 34

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-K-K, 2-CLASSIFICAITONS CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .04 | .008 | .1 | .0025 | | | .0025 | | .005 | .003 | .071 |
| 1 | .023 | .04 | .008 | .0025 | .005 | | .0025 | .004 | .006 | .006 | .097 |
| 2 | .018 | .0125 | .018 | .018 | .003 | | .005 | .008 | .005 | | .087 |
| 3 | .01 | .008 | .018 | .028 | .0125 | | .008 | .0125 | .005 | | .102 |
| 4 | .0025 | .005 | .01 | .02 | .028 | .0187 | .008 | .004 | .008 | .003 | .107 |
| 5 | | | .0125 | .008 | .02 | .0125 | | .0125 | .008 | .009 | .083 |
| 6 | | .005 | .005 | .008 | .016 | .0125 | .038 | .008 | .009 | .009 | .11 |
| 7 | | .0025 | .0025 | | .006 | .03 | .005 | .008 | .008 | .009 | .072 |
| 8 | .008 | .008 | .015 | .008 | .005 | .0125 | .015 | .0125 | .034 | .003 | .121 |
| 9 | | .0125 | .0025 | .008 | .005 | .0125 | .018 | .029 | .0125 | .056 | .156 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |

TABLE 35

TABLE OF PROBABILITIES OF OCCURRENCES OF STIMULUS AND RESPONSE CATEGORIES K-K-K, 1-CLASSIFICATION CONDITION

| R \ S | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .03 | .003 | | | .003 | .004 | | | .005 | .003 | .048 |
| 1 | .0125 | .034 | .016 | | .003 | | .002 | .004 | | .005 | .077 |
| 2 | .005 | .02 | .044 | .009 | .006 | .004 | | | .002 | .005 | .093 |
| 3 | .0125 | .02 | .02 | .04 | .0125 | .008 | .008 | .004 | .002 | .004 | .131 |
| 4 | .0125 | .009 | .009 | .018 | .038 | .008 | .008 | | .014 | .004 | .121 |
| 5 | .008 | . | .0125 | .009 | .019 | .07 | .023 | | .01 | .005 | .136 |
| 6 | .008 | .003 | | .008 | .0125 | .0125 | .027 | .0125 | .016 | .009 | .109 |
| 7 | | .003 | | .008 | | .004 | .008 | .05 | .009 | .01 | .092 |
| 8 | .0025 | .003 | | .008 | .003 | .008 | .008 | .008 | .025 | .025 | .090 |
| 9 | .01 | .003 | | .004 | .003 | | .015 | .021 | .016 | .029 | .100 |
| TOTAL | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | 1.00 |