EGGEMEIER, Frank Thomas, 1945-
MULTIDIMENSIONAL ENCODING IN SHORT-TERM MEMORY.
The Ohio State University, Ph.D., 1971
Psychology, experimental

University Microfilms, A XEROX Company, Ann Arbor, Michigan
MULTIDIMENSIONAL ENCODING IN SHORT-TERM MEMORY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Frank Thomas Eggemeier, B.A., M.A.

* * * * * *

The Ohio State University
1971

Approved by

[Signature]
Adviser
Department of Psychology
PLEASE NOTE:
Some Pages have indistinct print. Filmed as received.

UNIVERSITY MICROFILMS
ACKNOWLEDGEMENTS

The author expresses sincere appreciation to Dr. Delos D. Wickens for his advice during the planning and execution of this study and for the inexhaustible interest, guidance, and encouragement which he provided throughout the author's graduate training. The interest in, and enthusiasm for psychological research generated by Dr. Wickens has made the graduate experience an invaluable one. The assistance of the other members of the dissertation committee, Drs. Neal F. Johnson and George E. Briggs, is also acknowledged.

A special note of gratitude is extended to the author's wife, Judy, for the patience and understanding which she displayed throughout the preparation of the manuscript. It was she who deciphered the handwritten draft and ultimately produced the final typed copy. Without her understanding and assistance, completion of the study would have been infinitely more difficult.
VITA

January 13, 1945
Born - Covington, Kentucky

1967
B.A., University of Dayton, Dayton, Ohio

1967-1968
Teaching Assistant, The Ohio State University, Columbus, Ohio

1968-1970
Teaching Associate, The Ohio State University, Columbus, Ohio

1969
M.A., The Ohio State University, Columbus, Ohio

1970-1971
University Dissertation Year Fellow, The Ohio State University, Columbus, Ohio

FIELDS OF STUDY

Major Field: Experimental Psychology.

Studies in Human Learning and Memory. Professors Delos D. Wickens and Neal F. Johnson

Studies in Perception. Professor Dean H. Owen

Studies in Human Performance. Professor William A. Johnston
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>VITA</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vi</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>METHOD</td>
<td>41</td>
</tr>
<tr>
<td>Subjects</td>
<td>41</td>
</tr>
<tr>
<td>Materials and Design</td>
<td>41</td>
</tr>
<tr>
<td>Apparatus</td>
<td>44</td>
</tr>
<tr>
<td>Procedure</td>
<td>44</td>
</tr>
<tr>
<td>RESULTS</td>
<td>49</td>
</tr>
<tr>
<td>Overall Analysis</td>
<td>51</td>
</tr>
<tr>
<td>Evaluative (-) Activity (+) Analysis</td>
<td>56</td>
</tr>
<tr>
<td>Evaluative (+) Activity (-) Analysis</td>
<td>59</td>
</tr>
<tr>
<td>Evaluative (-) Activity (-) Analysis</td>
<td>62</td>
</tr>
<tr>
<td>Evaluative (+) Activity (+) Analysis</td>
<td>65</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>80</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>99</td>
</tr>
</tbody>
</table>
TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mean Standard Scores of Each of the Four Word Subsets</td>
<td>47</td>
</tr>
<tr>
<td>2.</td>
<td>Design of the Experiment</td>
<td>48</td>
</tr>
<tr>
<td>3.</td>
<td>Percentage of Correct Responses for All Experimental and Control Groups on Each Trial of the Experiment</td>
<td>69</td>
</tr>
</tbody>
</table>
FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Percent Correct Responses for the Double, High-Single, Low-Single, and Control Groups in the Overall Analysis Condition</td>
<td>70</td>
</tr>
<tr>
<td>2.</td>
<td>Trial 4 Response Distributions for the Double, High-Single, and Low-Single Groups in the Overall Analysis Condition</td>
<td>71</td>
</tr>
<tr>
<td>3.</td>
<td>Percent Correct Responses for the Double, High-Single, Low-Single, and Control Groups in the Evaluation Negative / Activity Positive Condition</td>
<td>72</td>
</tr>
<tr>
<td>5.</td>
<td>Percent Correct Responses for the Double, High-Single, Low-Single, and Control Groups in the Evaluation Positive / Activity Negative Condition</td>
<td>74</td>
</tr>
<tr>
<td>7.</td>
<td>Percent Correct Responses for the Double, High-Single, Low-Single, and Control Groups in the Evaluation Negative / Activity Negative Condition</td>
<td>76</td>
</tr>
<tr>
<td>8.</td>
<td>Trial 4 Response Distributions for the Double, High-Single, and Low-Single Groups in the Evaluation Negative / Activity Negative Condition</td>
<td>77</td>
</tr>
</tbody>
</table>
Figure Page


INTRODUCTION

Current models and theories concerning human memory have been characterized by an emphasis on description of the memory process as a complex of interacting components or stages which operate between initial stimulus presentation and any subsequent attempt to recognize or reproduce the information content of specific items. Models and theories differ somewhat with respect to the exact labels, complexity, and details of function associated with various components of the memory system, but in general, all have included a sequence of stages to deal with three basic processes considered necessary for successful recall of information. The three basic processes include: 1) the initial processing and encoding of stimulus information; 2) the storage or maintenance of coded representations of the information; and 3) the search for, retrieval, and decoding of the stored information.

The first, or stimulus encoding stage of processing, represents those operations considered necessary for identification and coding of stimulus materials.
Physical visual information is generally thought to be initially maintained in a rapidly decaying visual information store. The generally accepted function of the visual information or iconic store is to maintain physical information from a display long enough so that the information may be coded into forms more permanent than the purely physical representations available from the icon. Most recent models also include an auditory sensory store which performs a function similar to that of the visual information store for materials presented via the auditory modality. The more permanent forms of information coding which are thought to be employed include representation in terms of various physical, acoustic, and semantic characteristics of items.

When initial identification and encoding of stimulus information has been accomplished, the coded representations are assumed to be transferred to the second, or information storage, stage of processing. The majority of models distinguish at least two memory systems which operate within the second stage to provide the storage capability at different temporal intervals in the processing sequence. One is a temporary or short-term memory (STM) system, the other a more permanent or long-term memory (LTM) system. Coded informa-
tion initially enters the limited-capacity STM component of storage and if maintained in this temporary store through an active rehearsal process, may eventually be transferred to the more permanent LTM system. The LTM store is generally thought to be of unlimited capacity.

When utilization of stored information is required, the third basic process or search of the memory stores for information concerning a specific item is undertaken. The direction of the memory search in most instances is assumed to be governed by some type of retrieval cue or cues. Retrieval cues are encoded and passed through initial stages of processing. Successive comparisons of the coded cues and stored information are then accomplished until the best possible match between cue and information is obtained. The memory search is then terminated. Upon completion of the search, the information which has been retrieved is decoded and a response executed, completing the process of recall.

One central problem which has been incurred by the assumption that information is stored by means of a coded representation has been that of specifying the exact structure or format of the code which is produced,
stored, and eventually retrieved from memory. In attempting to deal with the coding issue, several models and theories (e.g. Bower, 1967; Shiffrin & Atkinson, 1969; Underwood, 1969; Norman & Rumelhart, 1970; Kintsch, 1970; Morton, 1970; Wickens, 1970) have proposed that representation of verbal materials in storage is accomplished through an encoding of individual items along a multiple number of attributes or dimensions related to selected physical, acoustic, or semantic characteristics of the coded item. The memory code for an individual item is thus assumed to be a multiply determined unit composed of a number of different types of information. The particular types of characteristics included as code dimensions vary from theory to theory and also within storage systems of particular models and theories. However, the basic proposal that the memory code takes the form of a multidimensional representation of an individual verbal item is common to all of the theories cited above.

Bower (1967) developed the first formal model of memory which applied the multidimensional encoding notion to the storage of verbal materials. The model is a multiprocess system composed of four major components which include a pattern recognition machine,
a STM store, a LTM store, and a response output machine.

According to the model, stimulus input is initially processed by the stimulus analyzers and encoders of the pattern recognition machine. The output of the machine is hypothesized to be multidimensional in nature, representing the stimulus in coded form as an ordered list of attributes with their corresponding values. The particular attributes examined as components of the code are dependent upon the program of the pattern recognition machine and the population from which the stimulus input has been selected. Once the coded representation has been produced by the stimulus encoders, information is made available for storage in either the STM or LTM components of the model. The format of the code in either store is described as the ordered list of encoded attributes, or alternately, as a vector of N ordered components. When retrieval of the stored information is required, a retrieval cue whose code overlaps somewhat with that of the stored information is encoded as new input by the stimulus analyzers and encoders. The coded cue is matched successively with various traces in storage until the best possible match between the cue and stored codes is obtained. The retrieved memory trace is then utilized
by the response output machine which decodes the list of attributes and produces the best possible response on the basis of the attributes present.

Forgetting of information is accounted for in the Bower (1967) model by assuming that for various reasons, certain attributes of the code for an item are lost or erased from storage. Search of the memory stores in some instances therefore results in retrieval of an incomplete or partial code for an item. When the remaining attributes of the code are analyzed by the response output machine, random values are assigned to the missing attributes. Confusions among similarly encoded items possessing a minimal number of discriminating attributes result when random values are assigned to the discriminative dimensions. Performance decrements in terms of incorrect responses are viewed as the consequences of such confusions.

Since the appearance of the Bower (1967) multicomponent theory of the memory trace, four other models of memory, those of Shiffrin and Atkinson (1969), Norman and Rumelhart (1970), Kintsch (1970), and Morton (1970), have also incorporated multidimensional coding and storage systems into functional accounts of the memory process.

The four major components of the Shiffrin and
Atkinson (1969) system closely parallel in function those already considered in the discussion of Bower's (1967) model. Included within processing sequence of the model are a sensory register, a short-term store (STS), a long-term store (LTS), and a response generator.

Information initially enters the system through the sensory register or iconic store which maintains sensory input during the coding and identification phase of processing. Transfer of processed material to the short-term or working memory proceeds permanent information storage in the LTM component. Organization of material in the LTS is assumed to be accomplished through a self-addressing storage system whereby specific storage location for materials are determined by the information content of the materials. A cohesive array of elements of information stored at any one of these memory locations constitutes the memory code or image. It is hypothesized that a single image might contain a wide range of information concerning an individual item to include its sound, meaning, and position as attributes or dimensions. The conceptual similarity of the Shiffrin and Atkinson (1969) code to the Bower (1967) notion of a vector of N ordered components is clear. Retrieval of information from LTM involves a search in which memory locations likely to
contain the required information are successively selected for examination by the response generator. An ultimate decision to either continue the search for more appropriate information or terminate the search is made by the generator which produces a response when the termination judgement has been reached.

Since information in LTS is assumed to be permanently stored, and not subject to autonomous decay, retrieval failures related to the size of the examination subset are proposed to account for forgetting within the system. Items which are of similar meaning, sound, etc. are assigned storage locations in the same local storage areas because of the self-addressing nature of the system. As the number of codes stored in a local set of memory locations increases, the probability that the search time allotted for recovery will be insufficient increases, as does the probability of selection of a similar, but incorrect, code from a local location. Retrieval failures are thus posited to be an increasing function of the number of similar codes stored in a specific area of locations. This position is consonant with the expectations concerning forgetting which were elaborated with respect to the Bower (1967) model.

Norman and Rumelhart (1970) have proposed a model
which is somewhat more complex than either of the two previously described systems. The model is functionally divided into two major systems— a perceptual system which deals with the processing of sensory input and a memory component which provides the storage, retrieval, and response production capabilities of the model.

The initial stage of the perceptual system is a sensory information store which maintains stimulus input while a feature extraction mechanism analyzes the input for critical physical characteristics necessary for identification of the item. The output of the feature extractor, which represents the physical information as a list or vector of critical features, is processed by a naming system which matches the perceptual vector with the relevant items of a sensory-memory dictionary. The ultimate product of the sensory-memory dictionary is an ordered list of attributes which, when formed into a memory vector, contains the name of the stimulus item.

Processed stimulus information is next assumed to enter the memory component of the model. Included within the memory component are a LTM processing unit, a decision process mechanism, and a response alternative dictionary. Storage of materials in the LTS is dependent upon the context in which each of the attri-
butes which constitute the memory vector of the item have appeared. It is assumed that each of the attributes of a vector has one specific representation already entered into the LTS. Any vector which contains a particular attribute must use the same representation in the store. When an item is entered into storage, a context marker unique to the item is placed on each of the permanently stored attribute representations which correspond to the attributes included in the memory vector of the item. At recall, given a retrieval cue in the form of information about the context in which the item appeared, the subject attempts to retrieve all the individual attributes which are marked with that particular context. The set of retrieved attributes are then entered into a dictionary of possible response alternatives by the decision process mechanism in an attempt to identify a unique item on the basis of the pattern of attribute values. In cases where such unique identification occurs, a response is generated. When positive identification is not possible because of loss of information about critical distinctive attributes, the subject may completely omit a response or may guess from among the set of responses which share the retrieved attributes and emit that response. Forgetting is thus
related to losses of context information about unique attributes which would serve to distinguish an item from a similarly encoded one. Increases in the number of similarly encoded items can therefore be expected to be related to increases in the number of errors at recall.

The Kintsch (1970) model of memory is markedly similar in structural components to the Shiffrin and Atkinson (1969) system outlined above and is functionally similar to the Norman and Rumelhart (1970) model in that storage of material is accomplished through a system of familiarity or time tags associated with the occurrence of certain markers or characteristics already entered in LTM. In the Kintsch (1970) system, it is not words themselves which are stored, but a tag on certain markers to indicate that a particular word has occurred.

Stimulus information selected for processing from a sensory store or buffer component initially enters the processing sequence as a sound pattern which is matched with a permanently stored reference phonetic matrix. Each word in S's vocabulary is assumed to be already encoded in memory as a list of markers which specify its meaning through indicating various relationships which it holds with other words. Three basic
classes of such markers are coded about each individual item. These include semantic-syntactic markers, sensory feature or image markers, and phonetic feature markers. The memory code for an item is thus assumed to consist of a multiply-determined set, with complexes of semantic, phonetic, and physical information stored about each individual word. Therefore, when the sound pattern is matched with the phonetic matrix in the initial stages of processing, access is automatically gained to the corresponding image and semantic markers, permitting the word to be understood or identified.

If the limited capacity STS is capable of accepting it, the phonetic matrix is next assumed to enter the STM component where further cognitive work is performed on it in order to facilitate later retrieval. This additional cognitive work consist of constructing better retrieval systems and is viewed as an integral part of the process by which information is transferred from STS to the LTS. When sufficient time is alloted for work with an item in STM, an elaborate cross reference system for retrieving the word from LTM is devised. Improvement or development of elaborate retrieval systems is accomplished in some instances through formation of new associations between two previously unrelated words, which results in the entry
of each word as a marker for the other word in LTM. Alternately, better retrieval systems are constructed through utilization of existing item associations, which consists of discovering a marker which is common to two or more words and tagging both words in the list of that marker. It is assumed that a system of effective cross references are built in this manner.

Each time a marker or set of markers is worked on within STM, the familiarity or temporal value of the marker is updated. When retrieval of information is attempted, items available is STM are produced. A word is then chosen from those available and its markers scanned. The marker with the highest familiarity value is selected and the system inspects the entry corresponding to that marker. The familiarity values of the entry are determined and if they exceed a certain criterion, the entry is produced as an overt response. The search process for additional items is then renewed with one of the already recalled words as its starting point.

Inability to recall materials from storage in the Kintsch (1970) system is accounted for by assuming that the familiarity or temporal tags used to identify markers as having occurred in some context decay exponentially over time. Although Kintsch does not ex-
plicitly consider the problem, it would appear that confusions among similar items could occur at recall in much the same manner as specified by Norman and Rumelhart (1970). Specifically, since the similarity between two words is determined by the number of shared semantic markers, increases in similarity should be accompanied by decreases in the number of markers which serve to distinguish one word from another. As the number of distinctive markers decreases, it can be assumed that there would be concomitant increases in the probability that the tags on the distinctive markers would be lost through the decay process, leaving little or no ability to distinguish among similar items at recall. Therefore, it is reasonable to assume that the Kintsch (1970) model, like the systems considered previously, would predict that as the number of similarly encoded items in the memory stores increases, so does the probability of failure at recall.

The final model to be considered, that of Morton (1970), actually represents an adaption of a word recognition system into a general functional model of the memory process. As such, the primary emphasis and contribution of the model rests with the stimulus encoding stage of processing, because retrieval and information loss problems are not considered in detail.
Stimulus input in the Morton (1970) model undergoes initial feature analysis in either a visual or acoustic analysis system, depending upon the presentation modality. The analyzed input is next transferred to a logogen system of the model which is composed of an unspecified number of individual logogens. A logogen is a counting device which is incremented whenever an attribute or feature which is a member of one of its defining sets enters the logogen system from either the visual or acoustic analysis components of the model. The defining sets of any given logogen are composed of the unique phonological, acoustic, visual, and semantic attributes associated with the particular word which the logogen represents. Word recognition is presumed to be a process whereby the various attributes or features of an input item are tallied by each logogen sensitive to that particular attribute until the loadings on one logogen surpass a threshold value. When the threshold value of a logogen has been exceeded, the appropriate response in the form of the word represented by the triggered logogen is made available and other response words are inhibited. The sufficient conditions for the subjective phenomenon of perception of the word are assumed to have been met at this particular point in the processing sequence.
Each logogen is assumed to have two outputs capable of being stored within the system once item recognition has been accomplished. One of the two outputs is assumed to be transferred to a temporary storage or response buffer component of the system. The response buffer temporarily maintains the response until it can be overtly produced and so parallels in function the STS of previously discussed models. The second logogen output enters the cognitive or LTS component of the model. Information in the cognitive store is assumed to be primarily coded in semantic format as a list of attributes obtained as output from the logogen system.

Thus, as in the previously described models, multidimensional encoding is proposed as a key process in both initial item recognition and subsequent storage of materials.

Although multidimensional encoding has been developed as a central concept in a number of multi-process memory models, several theorists working independently of such a framework have also been led to incorporate the multidimensional position into descriptions of the memory process. Included among these theoretical positions are the Underwood (1969) multiple-attribute analysis of the memory trace and the multidimen-

A memory or memory code in the Underwood (1969) schema is conceptualized as a collection of a multiple number of individual attributes. The process of encoding an item involves the establishment of the attributes of a memory, which is in turn stored and is eventually the subject of a retrieval search. Underwood's (1969) basic approach has been to review the human memory literature in an attempt to identify certain attributes which might serve to discriminate one trace from another and in so doing serve as effective retrieval cues.

Critical attributes identified through the review of the literature are numerous and include temporal, spatial, frequency, modality, orthographic, associative nonverbal, and associative verbal dimensions of individual items. Temporal attributes are posited on the basis of the notion that perception of an event occurs at a unique specific point in time, thus providing a unique attribute or tag for every encoded item. The spatial attribute reflects much the same sort of reasoning, except that the reference is to the unique physical rather than temporal position which an item occupies. Differences in the frequency of occurrence of items is viewed as an attribute capable
of mediating distinctions between traces, as are differences in the sense modality used in presentation of items. Information concerning orthographic characteristics, such as the number of syllables in and initial letter of words, are also cited as possible components of a memory representation. Associative attributes, nonverbal in the form of acoustic and visual distinctions which exist between items, and verbal in the form of class distinctions, form the last broad category of attributes described as potential contributors to the composition of the memory traces.

Forgetting in the multi-attribute theory is attributed to an interference or competition effect among stored memory traces at the time of recall. Interference is therefore posited to be basically a retrieval phenomenon, a position consistent with that of the other models discussed above. Competition among traces is viewed as a consequence of overlap in attribute values within the memory codes of two or more target memories. Overlap in attribute values causes a reduction in the distinctiveness among various memory traces, resulting in confusions or competition among similarly coded traces during the search and retrieval process of recall. According to the theory, to the
extent that differences exist among attribute values in the memory codes of target memories, distinctiveness will be enhanced, interference minimized, and recall effectiveness increased.

Wickens (1970) has proposed a similar theory in which the process of perceiving an individual word involves encoding the word within a multiple number of distinct attributes or dimensions, primarily related to the semantic content of the item.

The procedure employed to yield evidence concerning the encoding of individual items is a modification of the Brown-Peterson (Brown, 1958; Peterson & Peterson, 1959) STM distractor technique. The modified procedure involves presentation of triads of verbal material which are homogeneous with respect to some psychological class or suspected encoding dimension for approximately three trials, the observation of the build-up of proactive inhibition (PI) for these materials, and a shift on a fourth trial to a triad of material drawn from a potentially different class. On this fourth or critical shift trial, an experimental group receiving a triad of material from a different psychological class demonstrates a marked increment in performance or release from PI, while a control group which continues with the same class of materials from previous
trials continues to exhibit the effects of PI. This release from PI was interpreted by Wickens, Born, and Allen (1963), who first demonstrated the effect, as an indication that items composing trigrams are encoded not only as individual items, but also as members of some psychological class. The inhibitory effect of PI was hypothesized to be restricted to the homogeneous class of material for which PI had been accumulated. The Wickens et al. (1963) research can be taken as an indication that items which are members of the same class and are therefore similarly encoded eventually tend to interfere with one another at recall, causing decrements in performance or build-up of PI, while items which are members of a different class and encoded somewhat differently are not subject to the accumulated interference, resulting in the PI release phenomenon. The results of the Wickens et al. (1963) study and subsequent experiments which have been successful in demonstrating the release from PI can therefore be interpreted as support for the position proposed in the models discussed above which relates the number of unique or discriminative attributes of a coded item to success in retrieving it at recall.

The PI release procedure has been used as a type of projective technique for investigations of dimensions
along which verbal items are actually encoded. A num-
ber of the encoding categories identified with the
technique to date include: taxonomic category (Loess,
1967); different dimensions of the Osgood semantic
differential (Simpson, 1967); opposite ends of the same
dimension of the semantic differential (Wickens & Clark,
1968); frequency of word usage (Swanson & Wickens,
1970); phonological characteristics of items (Colt-
heart & Geffen, 1970); sense impression dimensions
(Wickens, Reutener, & Eggemeier, 1971), and language
of presentation (Goggin & Wickens, 1971).

The data of encoding obtained with the PI release
technique have led Wickens (1970) to advance the posi-
tion that the perception of a word involves a successive
and automatic assignment of values specific to the word
on each of a multiple number of encoding dimensions of
the type identified. The resulting unique combina-
tion or pattern of values on the utilized encoding
dimensions provides the basis of the perceived meaning
of the word. Words of similar meaning or words belong-
ing to similar semantic categories would have some
overlap in locus on a number of encoding dimensions,
but the multiple number of dimensions coded provides
the opportunity for a unique coding pattern for every
word. Thus, it is only after successive entries are
made in all pertinent dimensions that the complete and unique word meaning is achieved. Determination of ultimate word meaning is therefore dependent upon completion of a multidimensional encoding of each individual item.

This review of a number of current models and theories of human memory has served to indicate that the concept of a multidimensional encoding process has been utilized to a considerable extent in recent descriptions of the memory process. An assumption basic to all the models and theories presented is that the process of initial analysis of verbal materials involves an encoding of each item along a multiple number of attributes or dimensions. The resulting multicomponent code is assumed to be the basis for storage and eventual retrieval of information from the memory stores. Retrieval in these models and theories is viewed as a process which is at least in part dependent upon the number of unique positions or values which an item holds in the multicomponent code. Items with considerable overlap in dimensional positions tend to be confusible at recall, causing either complete omissions or incorrect responses. Items with less overlap are more easily distinguished from one another at recall and retrieval performance can be expected to
be facilitated to a point as the number of unique
dimensional positions of a word increases.

Although the multidimensional encoding theory
has been extensively employed in current conceptions
of the memory process, relatively few direct empirical
assessments of the position have appeared in the litera-
ture. Those studies which provide some basis for evalua-
tion of the theory have, for the most part, produced
results which are suggestive of, or consistent with,
the multidimensional coding and storage of items.

Research relevant to the multidimensional issue
can be organized into four major categories according
to the type of experimental technique used to examine
some aspect of the issue. The four primary types of
techniques employed to date include: the examination
of systematic trends in recall or recognition errors,
evaluation of effectiveness of different types of mem-
ory cues or probes, the release from PI in STM, and the
demonstration of availability of component features of
words prior to word recognition itself. Research rep-
resentative of each type of technique will be consider-
ed in turn.

Systematic confusion errors in recognition tasks
among items judged to share similar coding dimensions
have been interpreted by a number of theorists aś
indicative of a multifeature memory code from which critical distinctive features may be lost on an independent basis.

Anisfeld and Knapp (1968) analyzed false recognition errors in a continuous recognition task. Included among the distractor items were common associates and synonyms of words which had appeared previously. False recognition responses occurred more frequently to the common associates and synonyms than to a set of control words which were unrelated to preceding items. Anisfeld and Knapp (1968) maintained that their false recognition data indicated that words in memory are encoded and stored not as words, but as complexes of features. The multidimensional feature coding notion was employed to account for the false recognition data by assuming that words share a significant number of features with their synonyms and high associates. It was hypothesized that in a recognition task, such overlap might cause S to mistakenly disregard the distinguishing features of two words and consider them identical, causing the high rate of false recognition errors.

Fillenbaum (1969), however, pointed out that the Anisfeld and Knapp (1968) data, while consistent with a multidimensional coding view, do not require it since
it might be argued that false recognition of synonyms requires only that the general concept or gist of a word be stored. According to the general concept view of storage, when synonyms or high associates of a previously presented item are tested later in a continuous recognition task, the general concept is recognized as having occurred before and a false positive response is emitted. In an attempt to circumvent this potential difficulty, Fillenbaum (1969) tested false recognition rates of synonym, anyonym, and control pairs which were matched for degree of associative relatedness. Fillenbaum (1969) contended that in the feature complex view, all semantic attributes of an antonym pair except one would be identical. The two words would contrast in their value on that critical feature or attribute. In situations in which the critical contrasting feature is lost, antonyms would be expected to be falsely recognized as having occurred previously. Fillenbaum (1969) reasoned that in the general concept storage theory, concepts represented by antonym pairs would be markedly different and few confusions among these types of pairs would be expected. False recognition rates for synonym and antonym pairs were reliably greater than those for control pairs, but did not differ significantly from one another. Fill-
enbaum (1969) interpreted the results as consistent with the feature complex but not the general concept view of coding and storage.

Even though the Fillenbaum (1969) results are consistent with the multidimensional coding and storage of items, they, like the Anisfeld and Knapp (1968) data, do not appear to require such an explanation. It can be contended that antonym pairs in many instances share common superordinates or salient characteristics and that it is only the superordinate label or salient characteristic which is coded in the recognition task. Thus, a modified version of the general concept storage theory as espoused by Fillenbaum (1969) could also be posited to account for the false recognition of antonym pairs.

Generally, then, results of experiments which have examined systematic error tendencies in word recognition tasks have been suggestive of the multidimensional coding and storage of individual items. It would appear, however, that the results can best be termed only suggestive, for alternative explanations, not based on a multicomponent code, can be considered tenable.

Evaluation of the effectiveness of different types of recall cues or probes represents the second major technique which has yielded some basis for evaluation
of the multidimensional coding theory.

Evidence which implies that the coding of information within the memory stores can be multidimensional is provided in a report by Bregman (1968) who tested the effectiveness of four different types of cues in retrieval of nouns which had been previously presented in sequences. Probe recall tests were interspersed at varying intervals within the presentations sequence and were cued by use of contiguous nouns, graphic attributes of the target noun, phonetic attributes of the target noun, or semantic attributes of the target noun. Results indicated that the graphic, phonetic, and semantic attributes were equally effective in cuing noun recall within a mixed cuing condition which involved random presentation of cue types as retrieval signals. The equality of effectiveness of the phonetic, graphic, and semantic cues under conditions in which S had no basis for prediction of which would be the next relevant cue can be interpreted as an indication that S coded and stored multiple types of information about each item as it was presented.

A somewhat similar experiment by Shulman (1970) provided evidence which strongly suggests that the format of the code within STM is multidimensional in nature. The purpose of the Shulman (1970) research
was a test of the hypothesis that semantic as well as phonemic encoding was possible within STM when task demands required it. Previous literature indicated that phonemic encoding was the predominant form of representation used within STM and that semantic encoding was limited to the LTM system. Each trial of the experiment consisted of sequential presentation of ten items followed by a probe recognition test in which the probe was a homonym, a synonym, or was identical to one of the previously presented words. Ss were never informed of which probe type would appear on any particular trial until the probe was about to be presented. Of interest to the present discussion is the fact that Ss were able to maintain high levels of performance across conditions with all three types of probe information. The lowest overall rate of correct responding was 72%, which was obtained with synonym probes, while the other two probe types provided even greater proportions of correct responses. The fact that such levels of performance were obtained with all three cue types coupled with the similarity of the shape of the three retention curves for all cue types strongly implies that the STM code is both semantic and phonemic in character, thus supporting the notion of a multicomponent memory code.
Both the Bregman (1968) and Shulman (1970) experiments appear to demonstrate that when task demands require it, the memory code for an individual item can be multidimensional in content. The question of particular interest left unanswered by the data of both experiments is whether or not the memory code can be characterized as multidimensional in situations wherein task requirements do not demand it.

The release from PI in STM, discussed previously as a technique which has been used to identify individual encoding categories of words, has also been recently employed in evaluations of the multiple encoding position.

Goggin and Wickens (1971), in an experiment with bilinguals referred to earlier, demonstrated that trial-four shifts in the language of presentation in a standard STM distractor-technique experiment were effective in production of the release from PI. In addition to the language variable, taxonomic category shifts were included within the design so that single shifts on language and category alone were possible, as was a shift in both language and category. If Ss were simultaneously coding information about the language of presentation and taxonomic category of an item, it would be expected that a trial-four change
in both dimensions would produce greater performance increments than those produced by a single-dimension shift. All shift trials were significantly superior to a control and although the dual shift was superior to the language alone, it was not reliably greater than the category-alone shift. Therefore, although the ordering of shift trials was in the direction predicted by the multidimensional encoding theory, the difference between the category alone and category-language shift was not statistically significant. The result is suggestive of a multicomponent code but not conclusive in its support of it.

In a slightly different approach to the multiple-encoding problem, Wickens and Morisano (1971) conducted a PI release experiment in which trial-four shift categories were systematically varied in their relatedness to the preceding materials. A multiple encoding theory, which assumes that increases in the percentage of relatedness of categories would be accompanied by concomitant increases in dimensions of code overlap, would predict increasingly greater PI release as the relatedness of shift categories decreased. Results indicated that shifts between categories related 100% of the time produced the smallest trial-four performance increments relative to a control, that
shifts between 50% related categories produced intermediate amounts of release, and that shifts between categories which were never rated as similar produced the greatest trial-four increase compared to the control. Although the differences between the 100% and 50% groups were reliable, the difference between the 50% and 0% groups failed to reach statistical significance. Despite the failure to obtain significant differences, the ordering of groups is consistent with the prediction of a multiple encoding theory.

The general pattern of results obtained with the PI release technique is therefore supportive of the multidimensional theory in that differences between groups have consistently been in directions predicted by the theory. However, the degree of support must be considered somewhat limited by the fact that all predicted differences have not been statistically reliable. This lack of significance appears attributable to a possible ceiling effect on release in the Goggin and Wickens (1971) research, but no such effect seems to have been operative in the Wickens and Morisano (1971) data.

Two final experiments, those of Brown and McNeill (1966) and Wickens, Shearer, and Eggemeier (1971), represent the fourth major technique used to investi-
gate the multidimensional coding issue. Both indicate that partial or component information about a word is available during instances in which the word is unable to be identified and are thus compatible with the notion of a multicomponent code for individual words.

Brown and McNeill (1966), in an investigation of the "tip of the tongue" (TOT) phenomenon, reported data on the availability of such partial information which is readily interpretable within the multidimensional coding framework. Definitions of low frequency English words were presented to Ss who were asked to recall the words specified by the definitions. In some instances in which they were unable to recall the entire word, Ss were nevertheless able to demonstrate knowledge of some letters in the word, the sound of the word, words of similar meaning, or the number of syllables in the word. Brown and McNeill (1966) interpreted their results as indicative that words in LTM are coded as a set of semantic and physical features. It was hypothesized that on the basis of the semantic retrieval cues provided by the definition, Ss were able to conduct a search of LTM and recover a unit which might contain only partial feature
information about the complete word. Such partial information was hypothesized to include the first letter in the word, number of syllables in the word, etc., thus accounting for S's ability to produce some information about the target word but not the complete word itself.

In an experiment designed to test the Wickens (1970) successive encoding hypothesis, Wickens, Shearer, and Eggemeier (1971) also obtained component information data which are consistent with the expectations of a multidimensional encoding theory. In order to determine if some dimensions of word meaning are present prior to actual word recognition as implied by the successive encoding theory, Wickens et al. (1971) tachistoscopically presented words at several pre-recognition thresholds followed by a visual pattern mask. A different word which shared a common position on an encoding dimension with the first or which shared no common encoding position with the first was then presented at a supra-threshold duration. Ss were asked to judge if the two words or semantic experiences were similar. Several coding dimensions produced correct responding at a rate reliably greater than chance, while other dimensions remained at essentially the 50% level throughout. The results were
interpreted as evidence for the pre-recognition processing of certain semantic characteristics of words, a finding which is consistent with the multidimensional processing and storage of items.

The results of both the Brown and McNeill (1966) and Wickens et al. (1971) experiments demonstrate that prior to word recognition, Ss have access to one or more semantic or physical characteristics of an item. Such demonstrations are wholly in agreement with the expectations of a multicomponent coding theory which would imply that aspects or dimensions of information about a word might be available in some instances in which the total item itself was not accessible. As such, both experiments are supportive of the multidimensional theory.

On the basis of the evidence reviewed above, it can be generally concluded that results of experiments which have dealt with aspects of the issue have been consistent with the predictions of the multidimensional encoding theory. It must also be noted however, that although consistent with the theory, the majority of results can only be termed suggestive. In some instances, other interpretations of the data appear tenable, in others some question exists with regard to the necessity of task demands in producing support
of the theory, and in still other situations, group differences, although in the direction predicted by multidimensional encoding, are not statistically reliable. A number of the experiments reviewed produced results which are only suggestive because they were not designed as direct investigations of the theory and therefore tested only an aspect of it. In order to provide substantial support for the multiple encoding theory, it would appear necessary that a direct test be conducted in which S demonstrates in some manner that multiple types of information about a single item have been coded and stored in memory.

The purpose of the present research was to provide such a direct test of the multidimensional theory with respect to the semantic contents of the memory code using the PI release technique as the means of assessment. It was hypothesized that if initial encoding of an item is multidimensional, and if increases in the number of unique dimensional positions or values of a code are related to increases in performance at recall, then changes within two encoding dimensions would produce significantly greater PI release on a fourth-trial shift than would a change within a single dimension. It was also predicted that the change within a single dimension should result in
significantly more release than that demonstrated by a control group which would undergo no such changes.

Substantiation of the pattern of results outlined above, would, however, constitute only necessary but not sufficient conditions for support of the multidimensional coding of individual items. The pattern of results could conceivably be produced by the coding of only a single attribute about each item. Such a single-attribute coding position could maintain that over the first three trials of the experiment, individual Ss consistently choose and code only one attribute about each item. On the trial-four shift, all Ss within the double-shift groups would be expected to demonstrate the release effect since regardless of which single attribute had been coded, the value of that attribute would be changed on trial four. Only a certain proportion of single-shift group Ss would be expected to undergo the release effect, however, since some Ss might be expected to have coded the changed attribute, while the remainder would have coded the unchanged attribute. The control condition, in which no attribute values undergo a change, would be expected to produce the characteristic low levels of performance. Hence, the predicted ordering of trial-four performance is the same for this single-attribute
coding approach as it is for the multiple encoding hypothesis. The two positions, do, however, differ in their explanation of how the ordering occurs and thus differ in their predictions with respect to the actual pattern of responses within groups on trial four.

Since information within the single-attribute view is available about only one aspect or dimension of an individual item, PI release according to this approach represents an all-or-none phenomenon for any given S. The S has either chosen the code aspect which will be changed or has not. Therefore, any recall differences which might exist between the double and single-shift groups cannot be a matter of all Ss within their respective groups experiencing different degrees of release effectiveness, but are solely attributable to the fact that within the double group, the majority of Ss are experiencing a complete release effect, while in the single groups, a certain proportion of Ss are experiencing the complete effect, while others are experiencing no effect at all. Differences in recall performance would therefore not result from differences in degree of release demonstrated by all Ss between groups, but by differences in the number of individual Ss within groups undergoing an all-or-none release effect.
According to the multidimensional encoding position on the other hand, all Ss within each group are performing on the basis of multiple types of information about each individual item. The release effect on trial four in this view is not all-or-none but is incremental in nature. Accordingly, any recall differences which occur between groups are attributed to differential release effectiveness produced by an increasing number of distinct code dimensions for all Ss within their respective groups. All single-shift group Ss would therefore be expected to demonstrate some release, while all Ss within a double-shift group would undergo release of a greater degree of effectiveness. Differences in recall performance between groups in this view are not a function of differing numbers of individual Ss experiencing an all-or-none release effect, but are produced by all of the Ss in each of their respective groups displaying release effects which are incremental in effectiveness.

An examination of the distribution of trial-four responses in the single-shift and in the double-shift groups should permit some distinction to be drawn between the two encoding positions. If the single-aspect coding position is correct, significant recall
differences on trial four should be accompanied by significant differences between the variance of responses in the single and double-shift groups. Specifically, since superior performance of a double-shift group is attributed to the fact that the majority of Ss in the double groups demonstrate complete release while a proportion of the single groups Ss produce complete release and some produce none, the variance of the single group score distribution should be reliably greater than that of the double group. Alternatively, if the multidimensional encoding hypothesis is correct, no significant variance differences would be expected to accompany double-shift superiority. Since the multidimensional position holds that all Ss are performing on the basis of multiple information about each item, some degree of a release effect would be expected from the majority of Ss in both shift groups. The dichotomy in performance of single-shift Ss predicted by the single-attribute coding theory would therefore not be expected to occur. If the actual effect of a change in two code dimensions is to add an increment of effectiveness to the performance of all double-shift Ss relative to all single-shift Ss, then the distribution of double-shift scores would simply be displaced toward the high end of the
scale, leaving the variance of scores in the two groups unaltered with respect to one another.

A comparison of trial-four score variances would therefore provide the information necessary to decide which of the two encoding hypothesis outlined above most appropriately accounts for trial-four recall performance.

To briefly reiterate the hypothesis stated above, it was maintained that if initial item encoding is multidimensional and if increases in the number of distinctive code dimensions are related to increases in recall performance, then changes within two encoding dimensions would produce a significantly greater increment in performance on a trial-four shift in a PI release paradigm than that produced by a change within one encoding dimension. It was further hypothesized that if individual item encoding is in fact multidimensional, then the recall performance differences specified above should be accompanied by no significant differences between the variance of trial-four scores when the distributions of the single and double-dimension shift groups are compared.
METHOD

Subjects. The Ss were 768 male and female introductory psychology students at the Ohio State University. There were 48 Ss in each of the 16 groups included in the experiment. All groups were run concurrently, with assignment rotating across groups in the order in which Ss appeared for participation in the experiment.

Materials and Design. Four twelve-item sets of words were chosen from the Heise (1965) semantic differential atlas. The semantic differential (Osgood, Suci, Tannenbaum, 1957; Osgood, 1962) represents a system by which the connotative meaning of word is specified by its rating or position on three major factors or dimensions which account for the major portion of the variance among a series of bipolar adjective scales used to assess the connotation associated with individual words. The three major factors repeatedly extracted from such rating include the evaluation, activity, and potency dimensions.

The semantic differential materials were chosen for the present experiment for a number of reasons.
First, since a semantic differential profile consists of a word's position on the scales of evaluation, activity, and potency, multiple dimension ratings on the same word are provided in such a profile. Second, the magnitude of the PI release effect from previous experiments utilizing the semantic differential materials had not been of sufficient strength to preclude the possibility of superior performance of a double-shift group relative to a single group due to a ceiling effect on release potential. Third, as noted above, it had been previously demonstrated that both polarity shifts within a dimension (Wickens & Clark, 1968) and shifts between dimensions (Simpson, 1967) produce significant release effects. It therefore was plausible to assume that polarity shifts within dimensions would be effective in production of PI release and that the different dimensions of the semantic differential are actually encoded as independent categories.

The materials drawn from the semantic differential atlas were characterized as either positive (+) or negative (-) with respect to the evaluation and activity scales and neutral with respect to the potency dimension. The atlas consists of a standardized factor score on each of the three semantic differential dimensions for each of the 1000 words which were included.
within the atlas. The polarity designation of either positive or negative therefore refers to the fact that the factor score of a particular word was either above or below the mean rating of the other words within the dimension under consideration. In the notation employed, the evaluation polarity rating always appears first and the activity polarity rating second, such that a (+-) represents a word which is rated as positive on the evaluation scale and negative on the activity scale. The four subsets of words chosen from the atlas consist of twelve words which were positive on both the evaluation and activity scales (++), twelve which were negative with respect to both dimensions (---), twelve which were positive in evaluation and negative in activity (+-), and twelve which were negative in evaluation and positive in activity (-+). The mean standard score on each dimension for words included within each of the four major subsets appears in Table 1.

A series of four word trigrams were constructed from each subset of twelve words. Each word within a particular subset appeared in only one trigram. The word trigrams were rotated across the four trials involved in each experimental session such that each trigram appeared in each of the four trial positions.
an equal number of times when the entire experiment is considered.

The design of the experiment included a total of twelve experimental and four control groups. Of the twelve experimental groups, four consisted of a "double shift" in which both the evaluation and activity dimensions underwent polarity changes on trial four, and eight consisted of a "single shift" in which either the evaluation or activity dimension underwent a polarity change but not both. The four control groups were not subjected to any polarity reversals on trial four. The sixteen groups of the design are outlined in Table 2.

Apparatus. All materials were presented to Ss by means of a Kodak Carousel projector which was programmed by a Gerbands tape timer. Slides were projected onto a white screen which was positioned approximately four feet in front of S. A metronome, set to produce one beat per second, was used to pace Ss' activity during the rehearsal-preventative task.

Procedure. Each S was tested individually and after being seated in the experiment room, was read standard distractor-technique instructions which described the entire procedure:
This is an experiment in which we are studying your ability to perform a mathematics task and to repeat words which you have seen previously without your having rehearsed them. During the experiment you should keep your eyes on the screen in front of you at all times because all materials will be presented there.

The first thing you will see on the screen in front of you will be an asterisk. This serves as a ready signal for the beginning of each trial. Following the ready signal, you will see three words. You are to read the words out loud once as quickly as you can. It is important that you read the words out loud as rapidly as possible because they will only be projected on the screen for 1.5 seconds — which is just enough time to read them aloud if you read them very rapidly. As soon as you have pronounced the words they will be replaced by a slide with a three-digit number. Your task at this time is to start counting backwards by threes from the number to the beat of a metronome which sounds like this. (At this point the metronome was turned on for a brief period.) For example, if 999 appeared, you would say: 999, 996, 993, 990, 987, and so forth — as accurately as you can and in beat with metronome until a slide with a question mark appears on the screen in front of you. When you see the question mark, try to repeat out loud the three words that were given on the slide immediately preceding the numbered one. Give the words in order if you can, but this is not necessary.

After a short interval, an asterisk will again appear as the ready signal for the next trial and will go through the same sequence of events again: asterisk, three words, number, and question mark.

Now there are two things I'm interested in this experiment. One is what happens to material or words which have not been practiced or rehearsed. So when you see the slide with the three words on it, just read it out loud once as quickly as you can, but don't sit there and practice it to yourself or run through it in your head. Second, I'm interested in your score on the mathematics task, so when the number appears begin immediately to count backwards as accurately as you can.
Finally, you should know that this is a difficult task which will require your complete concentration and attention. Don't become discouraged and give up if you make a few mistakes. Do you have any questions?

Any question which S had regarding the procedure were answered at this time. After questions were answered each S was then told:

Now before we begin, I would like to remind you of two things. First, remember to say the words out loud as rapidly as possible when they appear on the screen. Second, I really meant what I said when I asked you not to rehearse or practice the words to yourself. Regardless of how well or how poorly you might feel you are doing, don't begin to rehearse the words at any point in the sequence.

Each experimental session included four trials. A single trial included presentation of an asterisk as a ready signal for 1.5 sec., which was followed by the 1.5 sec. presentation of a triad of words which S read aloud. The triad of words was replaced on the screen by a three-digit number which was projected for 20 sec. During the 20 sec. retention interval, Ss subtracted threes from the number to the beat of the metronome. At the end of the retention interval, a question mark as the signal to recall the three words was projected for a period of 10 sec. Upon completion of the 10 sec. recall interval, an asterisk appeared as the ready signal for the next trial and the entire sequence was begun again.
A three-point scoring system was used to assess recall. One point was awarded for each word which was correctly recalled during the 10 sec. recall interval.

**TABLE 1**

MEAN STANDARD SCORE OF EACH OF THE FOUR WORD SUBSETS

<table>
<thead>
<tr>
<th>Word Subset</th>
<th>Evaluation</th>
<th>Activity</th>
<th>Potency</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>-1.65</td>
<td>-1.39</td>
<td>-0.16</td>
</tr>
<tr>
<td>++</td>
<td>+1.29</td>
<td>+1.36</td>
<td>+0.26</td>
</tr>
<tr>
<td>+-</td>
<td>+1.45</td>
<td>-1.90</td>
<td>-0.30</td>
</tr>
<tr>
<td>-+</td>
<td>-2.25</td>
<td>+1.67</td>
<td>+0.21</td>
</tr>
</tbody>
</table>
### TABLE 2

**DESIGN OF THE EXPERIMENT**

<table>
<thead>
<tr>
<th>Trials 1-3</th>
<th>Trial 4</th>
<th>Condition</th>
<th>Trials 1-3</th>
<th>Trial 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>++</td>
<td>(Control)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>(Single)</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>(Single)</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>(Double)</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>++</td>
<td>+-</td>
<td>(Control)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>(Single)</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>++</td>
<td>+-</td>
<td>(Single)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+-</td>
<td>+</td>
<td>(Double)</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>(Control)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>(Single)</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>(Single)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>++</td>
<td>(Double)</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>(Control)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>(Single)</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>(Single)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>(Double)</td>
<td>++</td>
<td>-</td>
</tr>
</tbody>
</table>


RESULTS

The results of the memory task for all experimental and control groups are presented in Table 3 which indicates the percentage of correct responses in each of the sixteen groups as a function of trials.

As part of a preliminary analysis of the results in Table 3, a $4 \times 4 \times 3$ Analysis of Variance (ANOVA) with repeated measures on the last factor (Winer, 1962) was performed on the four levels of word type ($++$, $--$, $+-$, $-+$) and the four group conditions within each level of word type (control, single, single, double) over the first three trials of the experiment for all sixteen individual groups. The ANOVA indicated that:

- the main effect of word type was significant, $F(3, 752) = 3.50, p < .05$;
- the main effect of group conditions was not significant, $F(3, 752) = 0.47, p > .25$;
- and that there was a reliable trials effect, $F(2, 1536) = 1390.16, p < .001$. The ANOVA further indicated that:
- the word type x group conditions interaction was not significant, $F(6, 1536) = 0.32, p > .25$;
- the interaction of word type x trials was not significant,
F (6, 1536) = 1.87, \( p < .10 \); the group conditions x trials interaction was not reliable, F (6, 1536) = 0.37, \( p > .25 \); and that the word type x groups condition x trials interaction was not significant, F (18, 1536) = 0.51, \( p > .25 \). In order to determine which differences had contributed to the significant word type effect, the Tukey A test for simultaneous comparisons (Winer, 1962) was performed on the word type data. The Tukey A indicated that the (+-) word type was recalled at a significantly higher level over the first three trials than was the (++) word type, \( p < .05 \). All other comparisons were nonsignificant.

The Tukey A was also performed on the trials data and indicated that all three trials differed from one another, \( p < .01 \). The results of the preliminary analysis therefore indicated that although there were significant differences between levels of performance on various word types, the performance of all conditions within a particular word type were equivalent over the first three trials. The results further serve to indicate that performance declined in a similar manner within all groups across the first three trials of the experiment.

The data were the analyzed in terms of five
primary groupings—an overall analysis of the entire design and four individual analyses of each of four major subconditions as defined by type of trial-four words. The critical trial-four comparisons within individual conditions were therefore always performed on the same words, eliminating the effects of different materials as a source of variance.

**Overall Analysis.** The overall analysis included each of the sixteen groups within the design. The four individual control conditions were combined to yield the overall control group. Likewise, the four individual double-shift groups were collapsed into an overall double-shift group. Two overall single-shift groups were derived by combining the high single-shift groups from each of the four subconditions to form an overall high single condition and by similarly combining the four low single-shift groups to obtain an overall low single condition. The high and low single-shift designations refer to the level of performance on trial four without regard to the level of performance on the three preceding trials. The decision to combine all high single-shift groups into an overall condition was made in an effort to provide the most stringent possible test of the multidimensional encoding hypothesis.

Figure 1 shows the percentage of correct responses
for each group on each of the four trials of the experiment. It is apparent from Fig. 1 that performance in all four groups declines over the first three trials of the task. An ANOVA for a two-factor experiment with repeated measures (Winer, 1962) over the first three trials indicated that: there was no significant groups effect, $F(3, 764) = 0.36, p > .25$; the trials effect was highly significant, $F(2, 1528) = 1363.0, p < .001$; and that there was no significant groups x trials interaction, $F(6, 1528) = 0.37, p > .25$. Thus, all groups demonstrate a similar decline in performance or buildup of PI which is typically noted in this type of experiment. It can be also noted from Fig. 1 that both the double and single-dimension shifts were effective in producing increments in trial-four performance relative to the control group. In order to determine if a PI release effect were present, an ANOVA for a two-factor repeated measures design was performed on the data of trials three and four. The results indicated that: there was a significant groups effect, $F(3, 764) = 22.65, p < .001$; there was a significant trials effect, $F(3, 764) = 111.36, p < .001$; and most importantly, a significant groups x trials interaction, $F(3, 764) = 21.24, p < .001$. The significant interaction indicating that the experi-
mental treatment differentially affected performance on trials three and four substantiates the conclusion which can be drawn from Fig. 1 that there was in fact a significant PI release effect present. Since the groups x trials interaction was significant, individual tests on the simple main effects on trial three and on trial four were conducted as suggested by Winer (1962). The ANOVA for simple main effects on trial three indicated that the groups did not differ from one another on this trial: $F(3,764) = 0.48$, $p > .25$. However, the ANOVA on the trial-four data did demonstrate that significant differences existed among the groups: $F(3,764) = 43.50$, $p < .001$. Of particular interest to the present experiment is not the fact that PI release was obtained, but is whether or not the double-dimension shift produced a significant increment in performance over that produced by the highest single-dimension shift. In order to determine which trial-four differences contributed to the significant $F$, the Tukey A test for simultaneous comparisons was conducted on the trial-four data. The Tukey A indicated that all experimental shift groups differed significantly from the control, $p < .01$, and that the double-shift group was reliably different from both the high and low single-shift groups, $p < .01$. 
The differences between the high and low single-shift group were not significant.

Since it was demonstrated that the double-dimension shift produced performance which was superior to both single-dimension shifts, an analysis of the trial-four response distributions was undertaken in order to determine if the results were consistent with the multidimensional encoding theory or with the single-aspect coding hypothesis. Fig. 2 represents the distribution of trial-four scores for Ss within each of the three shift groups. As is evidenced by Fig. 2, there is little tendency in either of the single-shift distributions toward the bimodality which would have resulted from the dichotomous performance predicated by a single-aspect coding theory. Both single-shift groups clearly demonstrate a mode of one item correct while the double group clearly demonstrates a mode of two items correct. The marked similarity in the shape of the two distributions is also consistent with the expectations of the multidimensional theory. An ANOVA to test the equality of variance between two distributions (Hays, 1963) was conducted on all possible comparisons of the double, high-single, and low-single distributions. The ANOVA indicated that the double-shift distribution did not
differ significantly from the high-single distribution, 
F(191,191) = 1.02, p > .25; the double-shift and low 
single distributions were not reliably different, F 
(191,191) = 1.13, p > .10; and that the two single-shift 
distributions did not differ significantly from one an­
other, F(191,191) = 1.09, p > .25.

Further inspection of Fig. 2 provides some addition­
al information concerning the exact nature of the double­
dimension shift effect relative to that of the single­
dimension shift on trial four. It is notable that the 
double-dimension shift does not simply increase the 
probability of recall of all numbers of items relative 
to the single-dimension shift, for the absolute number 
of instances in which recall of a single item occurs is 
actually less in the double than in the single-dimension 
shift groups. The primary effect of the double shift 
relative to the single-dimension shift is to produce 
fewer instances of either complete recall failure or 
recall of only one item, and to increase the proportion 
of instances in which two or three items are recalled. 
A 3x4 Chi Square test for independent samples (Siegel, 
1956) conducted across the three groups on the frequency 
of occurrence of all four scores confirmed this conclu­
sion by indicating that the noted interaction was signi­
significant, \( x^2 (6) = 15.63, p < .02 \).

**Evaluative (-) Activity (+) Analysis.** Fig. 3 shows the percentage of correct responses as a function of trials for each of the four groups which were tested with (-+) words on the fourth trial. Inspection of Fig. 3 indicates that progressive decrements in performance in all groups over the first three trials are again obvious. An ANOVA for a two-factor experiment with repeated measures conducted on the data of the first three trials confirmed this observation by indicating that: there were no significant differences between groups, \( F (3,188) = 1.09, p > .25 \); the effect of trials was significant, \( F (2,376) = 345.12, p < .001 \); and that the groups x trials interaction was not significant \( F (6,376) = 0.24, p > .25 \).

Fig. 3 makes it evident that the effects of both single dimension trial-four shifts are comparable and that both produce increments in performance relative to the control group. Fig. 3 further indicates that the trial-four performance of the double-dimension shift group is superior to that of all other groups, but that the difference between the double and high single groups is not as large as the difference which exists between the low single and the control conditions. An ANOVA
for a two-factor repeated measures design over trials three and four indicated that: there was a significant groups effect, $F(3,188) = 13.77, p < .001$; that the effect of trials was significant $F(1,188) = 33.56, p < .001$; and that the trials x groups interaction was reliable $F(3,188) = 5.10, p < .005$. Again, the significant interaction confirms the fact that a significant PI release effect was obtained. Because the trials x groups interaction was significant, tests of simple main effects were performed on the data of trial three and of trial four. The ANOVA showed that the groups did not reliably differ on trial three, $F(3,188) = 0.84, p > .25$; but indicated that there were significant differences between groups on trial four, $F(3,188) = 17.26, p < .001$. The Tukey A test for simultaneous comparisons of the trial-four groups indicated that both of the single-shift groups and the double-shift group differed from the control, $p < .01$. Performance of the double-dimension shift group was reliably greater than that of both of the single-dimension groups, $p < .05$.

Fig. 4 represents the distribution of fourth-trial scores for the double-shift, high single, and low single-dimension shift groups. Since both single-dimension
shift groups attained equal levels of performance on trial four, the high single and low single designations are arbitrary and were adopted for labeling purposes only. Examination of Fig. 4 indicates that the mode of the double-shift distribution is again two items correctly recalled, while the mode of both single-dimension distributions is one item correctly recalled. However, it should be noted that the low single distribution also includes a large number of instances of two items correctly recalled. An F test for equality of the variances indicated that: the double and high single-shift groups did not differ significantly, F (47,47) = 1.21, p > .25; and that the double and low single-shift groups, were not reliably different, F (47,47) = 1.16, p > .25. The differences between the high and low single-dimension shift conditions also failed to reach significance, F (47,47) = 1.04, p > .25. Since the significant differences in recall performance cited above were not accompanied by concomitant differences in the variance of the response distributions, the results can be considered most consonant with the multidimensional theory.

Further inspection of Fig. 4 reveals much the same pattern of tendencies as were noted in the overall anal-
ysis section with respect to the effect of the double-dimension shift. Again, the distribution of scores tends to indicate that the primary effect of the double-dimension shift was to increase the number of larger recall units relative to the single-dimension shift. Once more, there are also fewer instances of correct recall of one item in the double-shift group than in either of the single-shift groups. However, a 3x4 chi square analysis for independent groups conducted over the score distributions of all three experimental groups failed to demonstrate that there were significant differences between groups, $x^2(6) = 8.33, p < .30$. The tendencies noted must therefore be considered only nonsignificant trends in the data.

**Evaluation (+) Activity (-) Analysis.** The percentage of correct responses on each of the four trials for groups which received (+-) words on the last trial are presented in Fig. 5. Fig. 5 clearly demonstrates that the decrement in performance or build-up of PI noted in previous analyses was once again obtained in all groups. An ANOVA for the repeated measures two-factor design over the first three trials showed that there were no significant differences between groups, $F(3,188) = 1.73, p > .10$; the trials effect was highly signifi-
cant, $F(2,376) = 374.32, p < .001$; and that there was no reliable groups x trials interaction, $F(6,376) = 0.56, p > .25$. Thus, all groups within the (+-) analysis demonstrate an equivalent accumulation of PI over the initial trials of the task.

In addition to the rapid build-up of PI, Fig. 5 also indicates that all three experimental groups are superior in trial-four performance to the control. As has been the case previously, both single-dimension shift groups demonstrate comparable trial-four performance in that they differ only marginally. However, in this instance, the double-dimension shift group reached a level only slightly above that of the high single-shift condition. An ANOVA for the two-factor repeated measures design on trials three and four showed that there was no significant effect of groups, $F(3,188) = 2.52, p < .10$; that the effect of trials was significant, $F(1,88) = 48.66, p < .001$; and that the groups x trials interaction was significant, $F(3,188) = 6.37, p < .001$. The significant interaction indicates that a PI release effect was also obtained within this condition. The lack of a reliable groups effect is apparently due to the relatively high level of performance of the control group on both trials three and four, as
evidenced by Fig. 5.

Because the interaction between groups and trials was significant, additional tests of the simple main effects were conducted separately for each trial. Results of the ANOVA on the trial three results indicated that no reliable differences existed between groups, $F(3,188) = 0.44$, $p > .25$. However, the trial-four ANOVA did show that there were significant differences between groups, $F(3,188) = 8.25$, $p < .001$. The Tukey A test was applied to the trial-four data to determine which of the differences had contributed to the significant $F$. The Tukey A indicated that the low single, high single, and double-dimension shift groups differed from the control at $p < .01$. No other differences were significant, confirming the conclusion which was drawn from Fig. 5 which indicated that all three shift treatments were approximately equal in effectiveness.

Fig. 6 shows the score distributions for each of the experimental groups. All groups produced curves which are similar in shape, demonstrating a tendency for an equal distribution of the majority of scores in two middle positions of the scale. The consistent tendencies noted with respect to the overall and (-+) analyses are not apparent in this instance. A chi square
test for independent groups which was carried out over the score distributions of all experimental groups confirmed that there were no significant differences between group distributions, \( x^2 (6) = 7.57, p < .30 \).

An ANOVA comparing the variance in the distributions indicated that: the variance in the double-dimension shift group was significantly greater than the variance of the low single-shift group, \( F (47,47) = 1.85, p < .05 \); the variance in the double group did not differ significantly from that of the high single group, \( F (47,47) = 1.38, p > .10 \); and that the two single-shift conditions did not differ reliably, \( F (47,47) = 1.34, p > .10 \).

**Evaluative (-) Activity (-) Analysis.** Fig. 7 shows the percentage of correct responses on each trial for groups of the (--) condition. As has been the case in previous analyses, Fig. 7 clearly demonstrates the progressive decrements in performance over the first three trials of the memory task. An ANOVA for a two-factor experiment with repeated measures over the first three trials demonstrated that: there were no reliable differences between groups \( F (3,188) = 0.24, p > .25 \); the effect of trials was significant \( F (2,376) = 355.56, p < .001 \); and that the groups x trials interaction was
not significant, $F(6,376) = 0.74, p > .25$.

Fig. 7 further indicates that performance in each of the three experimental groups is superior to that demonstrated by the control group on trial four. It is also apparent that the double-dimension shift produces a greater increment in performance than do either of the two single-dimension shifts, which are again approximately equal in effectiveness. In this particular case, the double-dimension shift actually produces a greater increment in performance relative to the high-single shift than do either of the single shifts when they are compared with the control. The ANOVA for the two-factor repeated measures design conducted on the data of trials three and four showed that: there were significant differences between groups, $F(3,188) = 5.78, p < .001$; the trials effect was reliable, $F(1,188) = 17.25, p < .001$; and that the interaction between groups and trials was significant, $F(3,188) = 5.94, p < .001$. The significant interaction is again critical, indicating that the PI release effect had been obtained. Tests of simple main effects were carried out separately on the trial-three data and on the trial-four data. The trial-three ANOVA indicated that there were no reliable differences between groups,
$F(3,188) = 0.41, p > .25$. However, the ANOVA for trial four demonstrated that the groups were significantly different in their performance on the shift trial, $F(3,188) = 11.29, p < .001$. The Tukey A test was conducted on the trial-four data and showed that both single-dimension shift groups were superior to the control, $p < .05$. The Tukey test further indicated that the double-dimension shift group differed from the control, $p < .01$; and that it also differed from both single-dimension shift conditions, $p < .05$.

The score distributions of experimental groups in the $(--)$ condition are shown in Fig. 8. The distributions of the single-shift groups are noticeably skewed to the right, a reflection of the comparatively low levels of performance produced by the single-dimension shifts in this condition. The double-dimension shift distribution exhibits the pattern identified in the overall and $(+-)$ analyses in that there are fewer Ss failing to recall an item or recalling only one item than in either of the single-dimension shift groups. The double-dimension shift again produces more instances in which two items were recalled than produced in the single-shift groups. The chi square test for independent groups which was performed on the trial-four score
distributions of the experimental groups confirmed that the differences which existed between group distributions were significant, \( x^2 (6) = 13.22, p < .05 \). The effect of the double-dimension shift therefore is again one of producing a tendency for recall of larger units than is the case in the single-shift analysis.

In order to determine which of the two encoding hypotheses was the most appropriate explanation of the double-dimension superiority, comparisons of distribution variances was undertaken. The F test for equality of variances showed that: the high single and double groups did not differ significantly, \( F (47,47) = 1.02, p > .25 \); there were no reliable differences between the low single and double-dimension shifts, \( F (47,47) = 1.18, p > .25 \); and that the two single-shift groups were not different, \( F (47,47) = 1.20, p > .25 \). Therefore it is again the case that significant differences in recall data between the double-dimension and single-dimension shift groups were not accompanied by significant differences in the distribution variances of the groups.

**Evaluation (+) Activity (+) Analysis.** The percentage of correct responses as a function of trials for groups which recalled (++) words on trial four is presented in
Fig. 9. It is once again clear that the expected drop in performance across the initial three trials occurs in each group. The ANOVA for a two-factor repeated measures design which was conducted on the data over the first three trials indicated that: the groups did not differ significantly from one another, F (3,188) = 1.10, p > .25; the effect of trials was significant, F (2,376) = 292.05, p < .001; and that there was no reliable groups x trials interaction, F (6,376) = 0.98, p > .25. Therefore, the results of the ANOVA substantiate the conclusion drawn from Fig. 9 that all groups within the (++) analysis demonstrated an equivalent decrement in performance over the initial trials of the task.

It is clear from Fig. 9 that the performance of each of the experimental groups was superior to that of the control on trial four. Fig. 9 further serves to indicate that the increments produced by the double-dimension and both single-dimension shifts were approximately equal within this condition. Performance of the double-dimension shift group is superior to that of both single-dimension shift conditions, but by an extremely narrow margin. An ANOVA for the two-factor repeated measures design which was carried out on the
data of trials three and four indicated that; the differences between groups was reliable, $F(3, 188) = 5.70$, $p < .001$; the effect of trials was significant, $F(1, 188) = 17.67$, $p < .001$; and that the interaction of groups and trials was significant, $F(3, 188) = 4.69$, $p < .005$. The significant interaction is again indicative of the fact that a reliable PI release effect had been produced by the experimental treatments. Tests of simple main effects indicated that there were no reliable differences between groups on trial three, $F(3, 188) = 0.45$, $p > .25$, while the ANOVA conducted with the data from trial four indicated that there were significant group differences, $F(3, 188) = 10.06$, $p < .001$. The Tukey A test for simultaneous comparisons performed on the trial-four results demonstrated that the low single, high single, and double-dimension shifts groups all differed significantly from the control, $p < .01$. None of the other group comparisons produced statistically reliable differences. Thus, the conclusions drawn about the equal effectiveness of the shift treatments is verified by the results of the Tukey test.

The trial four score distributions of all three experimental groups are presented in Fig. 10. Fig. 10 reflects the fact that there were no differences in
in recall results among groups in that all three curves are similar in shape, each having a mode of one correctly recalled item. The chi square test for independent groups which was performed on the score distribution of all experimental groups confirmed that fact that the distributions did not differ significantly, $x^2 (6), = 4.01, p > .50$.

The test for equality of variances between distributions demonstrated that: the high single and double-dimension distributions did not differ significantly, $F (47,47) = 1.05, p > .25$; the low single and double-shift groups did not differ significantly, $F (47,47) = 1.43, p > .10$; and that the high single and low single conditions were not reliably different, $F (47,47) = 1.50, p < .10$. 
TABLE 3
PERCENTAGE OF CORRECT RESPONSES FOR ALL EXPERIMENTAL AND CONTROL GROUPS ON EACH TRIAL OF THE EXPERIMENT

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Trials</th>
<th>Trials</th>
<th>Trials</th>
<th>Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>++/++</td>
<td>Control</td>
<td>89.58</td>
<td>40.27</td>
<td>24.30</td>
<td>18.75</td>
</tr>
<tr>
<td>+/-++</td>
<td>Single</td>
<td>88.19</td>
<td>50.00</td>
<td>29.16</td>
<td>43.05</td>
</tr>
<tr>
<td>-/+++</td>
<td>Single</td>
<td>90.27</td>
<td>53.47</td>
<td>23.61</td>
<td>39.58</td>
</tr>
<tr>
<td>--/++</td>
<td>Double</td>
<td>86.11</td>
<td>45.83</td>
<td>26.38</td>
<td>43.75</td>
</tr>
<tr>
<td>--/--</td>
<td>Control</td>
<td>86.80</td>
<td>40.87</td>
<td>25.69</td>
<td>19.44</td>
</tr>
<tr>
<td>+/-</td>
<td>Single</td>
<td>89.58</td>
<td>50.00</td>
<td>22.22</td>
<td>35.41</td>
</tr>
<tr>
<td>-/+</td>
<td>Single</td>
<td>91.66</td>
<td>46.52</td>
<td>22.91</td>
<td>34.02</td>
</tr>
<tr>
<td>++/-</td>
<td>Double</td>
<td>88.19</td>
<td>42.36</td>
<td>27.77</td>
<td>52.08</td>
</tr>
<tr>
<td>+/--</td>
<td>Control</td>
<td>88.88</td>
<td>49.30</td>
<td>29.16</td>
<td>27.77</td>
</tr>
<tr>
<td>++/-</td>
<td>Single</td>
<td>85.41</td>
<td>39.58</td>
<td>24.30</td>
<td>48.61</td>
</tr>
<tr>
<td>--/+</td>
<td>Single</td>
<td>90.27</td>
<td>41.66</td>
<td>22.22</td>
<td>46.52</td>
</tr>
<tr>
<td>-/+</td>
<td>Double</td>
<td>93.05</td>
<td>44.44</td>
<td>25.00</td>
<td>52.08</td>
</tr>
<tr>
<td>--/+</td>
<td>Control</td>
<td>88.88</td>
<td>41.66</td>
<td>21.52</td>
<td>20.13</td>
</tr>
<tr>
<td>++/-</td>
<td>Single</td>
<td>86.80</td>
<td>38.19</td>
<td>26.38</td>
<td>44.44</td>
</tr>
<tr>
<td>--/+</td>
<td>Single</td>
<td>87.50</td>
<td>40.97</td>
<td>23.61</td>
<td>44.44</td>
</tr>
<tr>
<td>+/-</td>
<td>Double</td>
<td>90.97</td>
<td>45.13</td>
<td>29.86</td>
<td>59.72</td>
</tr>
</tbody>
</table>
Figure 1. Percent correct responses for the double, high-single, low-single, and control groups in the overall analysis condition.
Figure 2. Trial 4 response distributions for the double, high-single, and low-single groups in the overall analysis condition.
Figure 3. Percent correct responses for the double, high-single, low-single, and control groups in the evaluation negative / activity positive condition.
Figure 4. Trial 4 response distributions for the double, high-single, and low-single groups in the evaluation negative/activity positive condition.
Figure 5. Percent correct responses for the double, high-single, low-single, and control groups in the evaluation positive / activity negative condition.
Figure 6. Trial 4 response distributions for the double, high-single, and low-single groups in the evaluation positive/activity negative condition.
Figure 7. Percent correct responses for the double, high-single, low-single, and control groups in the evaluation negative / activity negative condition.
Figure 8. Trial 4 response distributions for the double, high-single, and low-single groups in the evaluation negative / activity negative condition.
Figure 9. Percent correct responses for the double, high-single, low-single, and control groups in the evaluation positive / activity positive condition.
Figure 10. Trial 4 response distributions for the double, high-single, and low-single groups in the evaluation positive/activity positive condition.
DISCUSSION

All of the experimental and control groups within the experiment demonstrated the marked decrement in performance across the first three trials of the distractor task, a finding which is consistent with that of previous research and which is attributed to the build-up of PI across trials. One interesting aspect of the decrement in the present experiment is the rapidity with which PI built-up or was accumulated across trials. In this experiment, all groups fell from approximately a 90% recall level on the first trial to a level of approximately 40-50% on the second trial, and eventually to a level of 20-30% on trial three. When these performance figures are compared with those of Wickens and Clark (1968) and Simpson (1967) who also used semantic differential materials in distractor-technique experiments, it is apparent that differences of considerable magnitude are present. Wickens and Clark (1968) reported performance levels of approximately 95-100% for trial one, 70-80% on trial two, and 60-70% for trial three of their experiment. Simpson
(1967) obtained levels of 90-100%, 70-80%, and 50-60% on trials one through three respectively. Comparison of the three sets of data make it evident that performance on trials two and three of the present experiment was considerably below that of comparable trials in the Wickens and Clark (1968) and Simpson (1967) experiments. Since the build-up of interference is used to account for progressive decrements in performance, it would appear that PI was accumulated more rapidly or that items interfered with one another more in the present experiment than in the previous two studies with these materials.

Direct comparisons of the results of the experiments are impossible because of differences in the specific items, retention intervals, and triad exposure durations which were employed in the three studies. Any one or a combination of these factors could conceivably mediate the apparent discrepancy in trial two and three results. However, a theoretical consideration, based on the concept of a multidimensional memory code is also plausible. In the Wickens and Clark (1968) and Simpson (1967) experiments, items which were presented over the initial trials of the distractor task were similar in or matched for their departure from neutrality on one semantic differential or po-
tential encoding dimension. On the other hand, words presented on the first three trials of the present experiment were similar in their departures from neutrality on two semantic differential dimensions. If items are actually encoded and stored as multidimensional units, then a potential exists for greater code overlap in the present experiment than in the Wickens & Clark (1968) or Simpson (1967) studies. Since greater code overlap has been theoretically linked to increases in amounts of forgetting or interference by the memory models and theories discussed above, it would be reasonable to assume on the basis of the multidimensional theory that greater amounts of interference would be generated over comparable trials in the present experiment than in those of Wickens and Clark (1968) and Simpson (1967). That such is the case is consistent with the predictions of the multidimensional theory. Additional research which eliminates the methodological inconsistencies noted above would be necessary to directly confirm the hypothesis, however.

Because the results of the various subconditions were not identical with respect to the effects of the double-dimension shift on trial four, each will be considered separately.

The results of the overall analysis indicated
that when polarity changes within two semantic differential dimensions were introduced in a trial-four shift, the increment in performance or release from PI produced by the change was significantly greater than the release produced by a polarity change within only one such dimension. Additionally, the overall data demonstrated that the change in one dimension resulted in a significant PI release effect with respect to the control condition which underwent no such change, confirming the expectation based on the Wickens and Clark (1968) research which had indicated that such a single shift would produce the effect. The results further indicated that the differences in recall performance between the double and high and low single-shift groups were not accompanied by significant differences in the variances of the trial-four score distributions of the three groups. The data of the overall analysis therefore support the position espoused by the models and theories outlined above which contends that information about both the evaluation and activity scales of the semantic differential were encoded, stored, and eventually utilized in performance of the memory task.

Such a conclusion is based on two aspects of the data noted above, the superiority of the double-dimen-
sion shift to both single shifts, and the equality of variances in all three trial-four score distributions. The superiority of the double-dimension shift to both single-dimension shift groups is consistent with the multidimensional encoding theory which assumes that multiple types of information are coded, stored, and retrieved about each item but is also interpretable within the framework of the single-aspect coding theory discussed previously which holds that only one aspect or dimension about an individual item need be coded and stored. However, the fact that significant differences in the variances of the distributions did not accompany significant differences in recall performance is inconsistent with predictions based on the single-aspect coding theory which maintained that greater variability in the single-shift scores relative to the more consistent high performance of the double-dimension shift group would constitute the sole reason for differences in the recall scores of the three groups. On the other hand, the similarity in shape of the three distributions and the fact that no significant differences existed among the variances are entirely consistent with the prediction generated from the multidimensional coding theory which maintained that since all Ss were working on the basis of
multiple information about all items, there was no reason to predict such differences in variability. As such, the data of the overall analysis are most consistent with the prediction of the multidimensional encoding theory.

The lack of significant differences between the two overall single-shift groups indicated that both types of single-dimension shifts were equal in their effectiveness. Both groups produced an approximate 20% increase in retention relative to the control condition on trial four. This increment in effectiveness is comparable to the results reported by Wickens and Clark (1968) who noted about the same increase in performance on shift trials involving polarity shifts on evaluation and on activity dimensions considered separately. The additional increment in performance produced by the double-dimension shift over that of the high-single condition was 9%, about one-half the increase obtained with the single-shifts relative to the control. The effect of the additional change in dimensions in the overall group was therefore not to double the effect of a single-dimension shift but was to add only approximately 50% of the original increment.

The pattern or ordering of groups in the overall
analysis was similar to that obtained in the Goggin and Wickens (1971) study outlined earlier. Shifts in both the language of presentation and taxonomic category in that experiment produced a greater PI release effect than either the language-alone or category-alone shifts, but the double-shift effect was not significantly above the category-alone shift. The lack of significance was attributed to the operation of a ceiling effect on release due to the high level attained by the category-alone shift. Since no such ceiling effect was operative in the overall condition of present research, the variable would apparently account for the difference between the studies.

Generally, then, the results of the overall analysis support those predictions based on the multidimensional encoding and storage theory proposed in the current models and theories of memory reviewed above. Specifically, the pattern of results obtained with the PI release technique are consistent with the position that information concerning both the evaluation and activity dimensions was initially encoded, that information about both dimensions was included as part of the memory code used to maintain the materials during the retention interval, and that at recall on a trial-four shift, the number of changed coding
positions or values on the evaluative and activity dimensions were positively related to success in producing the items.

The results of the overall analysis, must, however, be interpreted with considerable caution, because only two of the four subconditions which were included within the design actually contributed a significant increment to the double dimension shift effect. Although the results of the overall analysis are supportive of the theory, they include instances in which there was clearly no advantage gained relative to a single-dimension change on a trial-four shift by introduction of an additional change in a potential code characteristic.

Results of shifting to both evaluation (-) activity (+) words and to evaluation (-) activity (-) words were similar to those of the overall analysis. The double-dimension shift in both instances produced a significant increase in the performance on trial four relative to the performance of both respective single-dimension shift conditions. Additionally, the significant differences in recall data were not accompanied by concomitant reliable differences in the variance of trial-four score distributions of the single and double-shift conditions. Both results are again consistent
with the expectations of the multidimensional encoding theory and thus provide support for the hypothesis that the (+-) and (--) items were encoded and stored along both the evaluation and activity dimensions and that the number of unique coding values on evaluation and activity were related to success in recall of the materials on the trial-four shift.

Both analyses further indicated that while both high and low single-dimension shifts produced significant increments with respect to their control groups, the single shifts in both instances were comparable to one another. Both single shifts resulted in performance levels which were 15-20% above that of their respective controls. However, trial four performance with the (--) words was somewhat lower than that obtained with the (+-) words. While the additional increment provided by the double-dimension shift relative to the high single shift was approximately equal to that provided by both single shifts relative to the control in the (--) condition, the corresponding double vs. high single increment obtained in the (+-) condition was only about two-thirds that of the low single vs. control increment.

The results of the (+-) and (--) analyses lead essentially to the same general conclusions which were
drawn in evaluating the overall analysis. The pattern of results from both subanalyses support the position that when (-+) and (- -) words are considered, information concerning both the evaluation and activity dimensions are encoded and stored, and that the number of unique or changed positions which an item holds within these two dimensions is directly related to success in recalling the item on a trial-four shift.

The results of shifting to evaluation (+) activity (-) and evaluation (+) activity (+) words provide a marked contrast to the results of those analyses already discussed. The double-dimension shifts in both of these analyses, although significantly superior in performance to their respective controls, failed to produce a significant increment in trial-four performance relative to either the high or low single-dimension shift groups. Although the performance of the double-shift group exceeded that of all others on trial four in both instances, the increment provided by the additional potential code change in the (+-) analyses is little larger than the difference between the two conceptually identical single-shift groups, while the same difference in the (++) analyses was actually smaller than the difference between the conceptually identical single-dimension change conditions.
It would therefore appear that the differences cannot be considered reliable tendencies in the data.

The results of the single-dimension shifts in both instances are comparable to one another and in each instance produce a 20% increment relative to the control, suggesting that the single-dimension shifts were equal to those in the (+-) and (++) analyses in their ability to produce the PI release effect. The failure of the double-dimension shift to produce additional performance increments in the (+-) and (++) groups does not therefore seem attributable to inordinately high levels of performance of the single-dimension shift groups within these conditions. Rather, the lack of effectiveness of the double shifts seems most appropriately attributable to the failure of that condition to function differently than the average level of performance displayed in the single-dimension shifts throughout the design.

This apparent inability to perform above the level of the average single-dimension shift cannot, however, be a function of a ceiling effect on release effects in either group. Evidence that a ceiling effect on release potential was not operative comes from a comparison of trial one performance with the (+-) and (++) words and the percentage correct attained on trial
four by the double-dimension groups. Trial one performance on (+-) materials estimated by averaging percentage of correct responses from all groups which recalled these words on the initial trial is approximately 90%, while the double-dimension shift reaches a level of only 52%, leaving ample potential opportunity for additional trial-four improvements. Likewise, trial one performance for (++) words is approximately 88%, while the double-dimension shift group reached a 44% correct response level. The concept of a ceiling effect on release potential does not therefore appear to be applicable to the (+-) and (++) analyses.

Idiosyncrasies associated with choice of specific words from the semantic differential or possible confounding of some other extraneous variable associated with word choice do not appear to offer a viable solution to the problem. As was previously indicated, shifts from (+-) to (-+) words and shifts from (++) to (--) words produced significant performance increments over those provided by their respective single-dimension controls, while double-dimension shifts in the opposite direction with the same word sets do not result in such increments. If idiosyncrasies associated with specific items employed within the design were
responsible for the discrepant results, it would appear that the effectiveness of both double-dimension shifts which employed the same words would be depressed or enhanced to an equal degree. Since this was not the case, this approach to the problem also fails to provide a plausible explanation of the results.

The only consistent variable which appears capable of having mediated the subcondition discrepancy with respect to the double-dimension shift effectiveness is the directionality of the evaluative dimension change on double-shift trials. Comparison of the characteristics of trial-four items in the two subgroups which provided support for the multidimensional theory with those which did not indicates that double-dimension shifts to words rated as negative in evaluation provided evidence of multidimensional encoding regardless of the activity dimension rating, while double-dimension shifts to items rated as positive in evaluation produced no evidence of multidimensional encoding, regardless of the rating on the activity dimension. This suggests that the characteristic of a word on the evaluation dimension may be a factor which somehow mediated double-shift performance on trial four. Specifically, it appears that a shift on the evaluation dimension to a positive value had a somewhat
different effect than a shift to a negative value. When the shift was from an evaluation (-) to (+), results indicated that a change or lack of it on an additional dimension was irrelevant to performance on the fourth trial, for the level of performance was statistically equivalent to that of a single change. When the change was from evaluation (+) to (-), however, an additional dimension change contributed a significant additional increment to that provided by a single change.

Determination of exactly what mechanism might mediate this apparent interaction of word type and double-shift effectiveness is not possible on the basis of the data which are available. Any attempt to specify the locus of the effect within the framework of this experiment will be indirect because the design does not permit distinctions to be drawn between stages of processing. As has been indicated previously, this experiment constituted an examination of three assumptions: 1) that words are initially coded in a multidimensional manner, 2) that the storage code of the word is multidimensional, and 3) that success at retrieval is related to the number of unique positions in the code held by an item. In order for a double-dimensional shift group to demonstrate superiority on
trial four, it was necessary that each of the assumptions be met. The present experiment does not therefore permit specification of the exact location of the failure. It is possible that evaluation positive words were not encoded in a multidimensional manner, that the words were coded multidimensionally but stored as a single salient characteristic, or that the words were encoded multidimensionally, stored as a multidimensional unit but that for some reason, the evaluation positive or the activity characteristic was the only functional distinguishing characteristic at retrieval.

Although the results of the present experiment cannot be directly addressed to the issue, some suggestion concerning the locus of the effect can be derived from the data.

As indicated above, it might be argued that when evaluation (+) is a part of a word's makeup, that only that aspect of the word is encoded and that the initial code is therefore not multidimensional. It might also be argued that although the initial code for a word with the evaluation (+) characteristic is multidimensional, the memory code may only consist of that dimension. A number of points in the present data would suggest that neither of these two alternatives can be
the complete explanation of the effect. The superiority of the (++) to (--) shift over that of the (+-) to (--) shift and the superiority of the (+-) to (--) shift over that of the (++) to (-+) shift implies that this is not the case. If words with the evaluation (+) characteristic were coded or stored within the connotative dimension simply with respect to the evaluation (+) aspect of the word, then the (++) to (--) and (+-) to (--) shifts would reduce to basically the same shift, that of (+) to (--). Likewise, the (+-) to (--) and (++) to (--) shifts would both be reduced to the same (+) to (--) shift. These results imply that at least in some instances in which evaluation (+) is a characteristic of an item, information must be encoded and stored about both dimensions, otherwise there would be no basis for the noted double-shift superiority. If both types of information are encoded and stored on trial four as they appear to be on trials one through three, it suggests that some limitation in the recall system or retrieval strategy would be the locus of the apparent word type by double-dimension shift interaction.

A possible retrieval mechanism which would produce limitation in the effectiveness of the double-dimension shift would consist of a restriction in the
number of retrieval cues from within the connotative dimension used in a search of the memory stores. Shiffrin (1970) has postulated that the memory search for an item is undertaken on the basis of individual coded dimensions or aspects about the item which, taken together, define the so-called search-set. Individual search units are sampled from the search-set and are employed in the search for an item. Shiffrin (1970) further proposed that not all search units are necessarily sampled with equal probability from the search-set. Search-sets themselves are hypothesized to be selected according to task demands, clues provided by the stimuli, and strategies of the S. If the effect of presentation of an evaluation (+) as a changed dimension on a shift trial in the present task were to heavily bias the selection of evaluation (+) as the sole search unit from the search-set related to the connotative meaning of the word, the result would be a reduction of the effectiveness of a double-dimension shift to that of a single-dimension shift, since the additional unique coded dimension would only infrequently be used as the basis of a memory search in addition to the evaluation (+) cue. The potential causes of such an evaluation (+) bias are unclear. Boucher and Osgood (1969) have proposed
a theory which maintains that evaluative (+) words are used more diversely and facilely than evaluative (-) words. If this is actually the case, $S$ may be biased to conduct the memory search solely in terms of the characteristic about which he perceives the most facility.

However, this restricted retrieval hypothesis represents only one possible explanation of the failure of the (+-) and (++) subconditions to demonstrate a multidimensional encoding effect. Since the data provide no direct evidence that both the evaluation (+) and activity dimensions were actually encoded on trial four, similar restriction hypotheses related to failures to multiply encode or store a multicomponent unit must also be considered tenable.

In summary, the results of the present experiment indicate that evidence which supported the multidimensional encoding, storage, and retrieval of items was obtained in the overall condition and in two of the four subconditions included within the design. As such, these results support the theoretical position of the models and theories of memory discussed previously. The success or failure to provide support for the multidimensional theory was systematically related to the position which a word held on individual
dimensions of connotative meaning. The results suggest that individual dimensions related to connotative meaning do not combine in all instances in a purely additive manner to determine recall success, but suggest that at some point in the memory processing sequence, interactions among potential code dimensions may occur which determine ultimate success at recall.
BIBLIOGRAPHY


