AFOSR TR-71-2600

08773-83-T

HUMAN PERFORMANCE CENTER

DEPARTMENT OF PSYCHOLOGY

The University of Michigan, Ann Arbor

Organization in Free Recall Learning: Output Contiguity and Interresponse Times as a Function of Presentation Structure

HAROLD GELFAND

Technical Report No. 29

June 1971

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Michigan, Human Performance Center Department of Psychology, Ann Arbor, Michigan	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
ORGANIZATION IN FREE RECALL LEARNING: OUTPUT CONTIGUITY AND INTERRESPONSE TIMES AS A FUNCTION OF PRESENTATION STRUCTURE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Scientific Interim

5. AUTHOR(S) (First name, middle initial, last name)
, Harold Gelfand

6. REPORT DATE June, 1971	7a. TOTAL NO. OF PAGES 127 plus vii	7b. NO. OF REFS 91

8a. CONTRACT OR GRANT NO. AF 49(638)-1736 b. PROJECT NO A.O. 461-11 c. 61101D d. 681313	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 29 08773-83-T 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR - TR - 71 - 2600

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES TECH, OTHER	12. SPONSORING MILITARY ACTIVITY AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (NL) 1400 WILSON BLVD ARLINGTON, VIRGINIA 22209

13. ABSTRACT

The experiment was designed to (a) validate the use of interresponse times (IRTs) as an index of organization in learning, and (b) to determine whether the effects of input contiguity on organization and recall are due to direct representations of contiguity relationships in S's functional organization, or to the indirect potentiating effect of contiguity on item-dependent organization.

Presentation orders and semantic relatedness among words were varied factorially in a multitrial free recall task. Words were either members of a superordinate category, or unrelated. Members of groups were either blocked or randomly dispersed on individual trials, and presentation orders were either constant or varied across trials.

The results indicated that IRTs provide similar and supplementary information about organization when compared with indices of clustering and subjective organization. Differences in IRTs between members of different categories as compared to members of the same category were related to the degree of clustering according to those categories. The IRT between two words was related to the number of previous recall trials on which the pair occurred together as well as to the probability of adjacent occurrence of the pair on subsequent trials.

On Trial 1, an interaction of contiguity and semantic relationships was obtained with clustering scores, but not with recall scores. In the multitrial situation, intra-trial contiguity was effective for related words, and intertrial contiguity consistency was effective for unrelated words. There was no evidence for direct contiguity effects. Other effects of multiple potential bases for interitem relationships were considered.

DD FORM 1473 1 NOV 65

Unclassified

THE HUMAN PERFORMANCE CENTER

DEPARTMENT OF PSYCHOLOGY

The Human Performance Center is a federation of research programs whose emphasis is on man as a processor of information. Topics under study include perception, attention, verbal learning and behavior, short- and long-term memory, choice and decision processes, and learning and performance in simple and complex skills. The integrating concept is the quantitative description, and theory, of man's performance capabilities and limitations and the ways in which these may be modified by learning, by instruction, and by task design.

The Center issues two series of reports. A Technical Report series includes original reports of experimental or theoretical studies, and integrative reviews of the scientific literature. A Memorandum Report series includes printed versions of papers presented orally at scientific or professional meetings or symposia, methodological notes and documentary materials, apparatus notes, and exploratory studies.

TECHNICAL REPORTS NOT OTHERWISE PUBLISHED

1. Phillips, L. D. Some components of probabilistic inference. January 1966.

3. Biederman, I. Human performance in contingent information processing tasks. October 1966.

4. Peterson, C. R. & Beach, L. R. Man as an intuitive statistician. November 1966.

8. Ligon, E. The effects of similarity on very-short-term memory under conditions of maximal information processing demands. May 1968.

9. Triggs, T. J. Capacity sharing and speeded reactions to successive signals. August 1968.

11. Lively, B. L. The Von Restorff effect in very-short-term memory. December 1968.

13. Swensson, R. G. The elusive tradeoff: Speed versus accuracy in choice reaction tasks with continuous cost for time. December 1968.

15. Kaulet, A. S. Processing of sequentially presented signals in information-combining tasks. June 1969.

16. Pollatsek, A. W. Rehearsal, interference, and spacing of practice in short-term memory. July 1969.

17. Garskof, M. H. The effect of spacing and variation of repetition in short-term memory. August 1969.

19. Du Charme, W. M. A responsive bias explanation of conservative human inference. December 1969.

20. McCormack, P. D. Monitoring eye movements during the leaning of paired-associate lists. March 1970.

21. Goodman, B. C. Risky decisions by individuals and groups. June 1970.

22. Wattenbarger, B. L. The representation of the stimulus in character classification. August 1970.

23. Gardner, G. T. Spatial processing characteristics in the perception of brief visual arrays. August 1970.

24. Adams, R.A.S. Interference in short-term retention of discrete movements. September 1970.

25. Armstrong, T. R. Feedback and perceptual-motor skill learning: A review of information feedback and manual guidance training techniques. August 1970.

26. Armstrong, T. R. Training for the production of memorized movement patterns. August 1970.

27. Collins, A. M. The effect of visual stimulus traces on memory. August 1970.

28. Cohen, V.V.R. Short-term memory for quantitative information from three kinds of visual displays. June 1971.

MEMORANDUM REPORTS AFTER 1968

6. Greeno, J. G. Theory of graphs on sets with applications to problem solving and understanding. October 1968.

7. Edwards, W. A bibliography of research on behavioral decision processes to 1968. January 1969.

9. Greeno, J. G. A cognitive interpretation of negative transfer and forgetting of paired associates. November 1969.

10. Martin, E. Associative interference theory and spontaneous recovery. November 1969.

12. Greeno, J. G. Theoretical entities in statistical explanation. October 1970.

THE UNIVERSITY OF MICHIGAN
COLLEGE OF LITERATURE, SCIENCE AND THE ARTS
DEPARTMENT OF PSYCHOLOGY

ORGANIZATION IN FREE RECALL LEARNING: OUTPUT CONTIGUITY AND INTERRESPONSE TIMES AS A FUNCTION OF PRESENTATION STRUCTURE

Harold Gelfand

HUMAN PERFORMANCE CENTER--TECHNICAL REPORT NO. 29

June, 1971

This research was supported by the Advanced Research Projects Agency, Department of Defense, and monitored by the Air Force Office of Scientific Research, under Contract No. AF 49(638)-1736 with the Human Performance Center, Department of Psychology, University of Michigan.

PREFACE

This report is an independent contribution to the program of research of the Human Performance Center, Department of Psychology, on human processing and retrieval, supported by the Advanced Research Projects Agency, Behavioral Sciences, Command and Control Research, under Order No. 461, Amendments 3 and 5, and monitored by the Behavioral Sciences Division, Air Force Office of Scientific Research, under Contract No. AF 49(638)-1736.

This report was also a dissertation submitted by the author in partial fulfillment of the degree of Doctor of Philosophy (Psychology) in the University of Michigan, 1971. The doctoral dissertation committee was: Drs. A. W. Melton, Chairman, R. A. Bjork, K. F. Riegel, and R. S. Tikofsky.

BLANK PAGE

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

ABSTRACT

Investigation of the role of organization in learning requires a behavioral index of organization, both to determine the dependence of organization on experimental manipulations, and to specify the relationship between organization and other independently defined behaviors. This dissertation reports an experiment designed with the dual purpose of validating the use of interresponse time (IRT) as an index of organization, and of determining the nature of presentation contiguity effects of organization and recall.

Although the effects of presentation contiguity on organization and recall are well established, it is not clear whether these effects are due to direct representations of contiguity relationships in S's functional organization, or whether contiguity only has the indirect effect of potentiating the item-dependent organization of the contiguous items. The direct hypothesis suggests an independent, additive combination of the effects of item-independent contiguity and item-dependent semantic characteristics, while the indirect hypothesis suggests an interactive, multiplicative combination.

Ninety-six Ss were tested in a multitrial free recall task in which presentation orders and semantic relatedness among the items were manipulated factorially. The list consisted of groups of items which were members of a superordinate category, or were unrelated. Intratrial and intertrial contiguity characteristics were manipulated, the former by presenting the members of a group either blocked or randomly dispersed, and the latter by maintaining a constant order of presentation on all trials, or varying the order.

On the basis of the following results it was concluded that IRTs provide a valid and useful index of organization, in that they provide similar, and in some cases additional, information about organization when compared with the behavioral indices of clustering and subjective organization: (a) the magnitude of the difference in IRTs between members of different E-defined categories and members of the same E-defined category was related to the degree of clustering according to those categories; (b) the IRT between two words was a decreasing function of the number of previous recall trials on which the pair occurred together; (c) the probability of adjacent occurrence of a pair of words on subsequent trials was a decreasing function of the IRT between the two words on earlier trials.

The data concerning the effects of contiguity were more equivocal. On Trial 1, the interaction of contiguity and semantic relationships was obtained with clustering scores, but not with recall scores. In the multitrial situation, intratrial contiguity was effective for related words, and intertrial contiguity consistency was effective for unrelated words. There was no evidence for direct contiguity effects. Either there are indirect effects determining how contiguity is effective, or the presence of multiple potential bases for interitem relationships determines when contiguity is effective, and obscures how it is effective within the context of the present experimental design.

CHAPTER I

ORGANIZATION: MEASUREMENT AND CONTIGUITY EFFECTS

All verbal learning and memory experiments require the choice of a unit of analysis, and the unit selected may have important theoretical implications (Tulving, 1968). For any unit selected there are potential relationships among the elements comprising a single unit, between one unit in the task and another, and between units in the task and other units not directly represented in the stimulus situation presented to the subject. Furthermore, it is possible for the subject to utilize any and all of these relationships, for the degree of utilization and specific relationships utilized to be affected by the subject's prior experience with verbal information, and for the subject's learning and memory performance to be affected by the relationships utilized.

The investigation of these relationships and of the critical role of prior experience has been an increasingly dominant theme in research on human learning and memory, as evidenced by the changes in stimulus materials as well as empirical and theoretical analyses of learning and memory behavior. Although some studies dealt directly with the role of prior experience, the focus of early memory research was to minimize, if not eliminate, the role of prior experience. This is not to deny an awareness on the part of those investigators of the potential importance of experiential factors. Certainly Ebbinghaus was cognizant of the potential effects of relationships among items due to prior experience, or he would have had no need to invent the nonsense syllable in order to study raw association formation. By employing nonsense syllables in his research he assumed he was dealing with a homogeneous set of stimulus materials, equally and almost completely devoid of relationships amongst themselves or with any other aspects of prior experience. While Ebbinghaus and those following in his tradition who have employed nonsense material made extensive contributions to our knowledge of the empirical relationships between a variety of task variables and performance in learning and memory tasks, the adequacy of their solution to the problem of the role of prior experience was called into question by later research.

The shift in orientation towards direct investigations of the nature and consequences of transfer from prior experience can be attributed to a great extent to the scaling of association values of nonsense syllables by Glaze (1928). The findings that nonsense syllables vary in association value and that even under the conditions existing when the normative data were collected (with syllables being presented individually, relatively little context present, and limited times for responding) few syllables had zero association values, are incompatible with the view that nonsense syllables are homogeneous and unaffected by prior experience.

The availability of normative data on some stimulus characteristic provides two research advantages. For investigations concerned with other variables, the stimulus property can be controlled by selecting items with equal normative values or by balancing experimental conditions with respect to this stimulus characteristic. More importantly, it is possible to manipulate this stimulus characteristic and determine its effect upon learning and memory. Following Glaze, there were a number of other attempts to scale association values of nonsense syllables and other stimulus materials. Additionally, normative data on other stimulus characteristics were collected. Discussions of the variety of stimulus characteristics for which normative data are available, the scaling methods employed, and the effects of the various stimulus characteristics on learning are to be found in Noble (1963), Paivio (1969), and Underwood and Schulz (1960). The results of such research programs contributed to Underwood's (1964) assertion that, "The image of a subject in a verbal-learning experiment as being a _tabula rasa_ upon which the investigator simply chisels associations, and quite against the _S_'s wishes, is archaic. The _S_ is far from passive and the tablet has already impressed upon it an immense network of verbal habits" (p. 52). For Underwood, the implications of such a viewpoint were that "in verbal-learning experiments we may not be dealing with 'raw' learning, some might say that we never study the formation of associations uninfluenced by associations which the _S_ already possesses" (p. 52). Therefore, "our theories of verbal learning must inevitably explain phenomena which are, in a manner of speaking, built on top of this network" (p. 53).

Items in verbal learning studies are not presented in isolation, but in the context of a list containing other items, with the potential for direct and indirect interitem relationships to affect the course of learning. Yet, investigations of stimulus characteristics in the period following Glaze (1928) were primarily restricted to manipulations of properties of individual items. During that period, and even prior to it, there were studies concerned with interitem relationships, including investigations of grouping based upon rhythmic patterns (reviewed in Woodworth, 1938), studies comparing recall of unrelated items to prose and poetry (reviewed in McGeoch & Irion, 1952), and Katona's (1940) many experiments suggesting the central role of grouping operations in memory. The absence of more extensive research on organizational processes, as well as the lack of acceptance of proposed interpretations of the effects of interitem relationships reported in the earlier studies, can be attributed in large measure to the lack of available procedures for measuring the organization of information by the subject (see Melton, 1941). An appropriate research strategy for an understanding of organization and its effects on learning and memory would parallel the course of research dealing with characteristics of individual items. The development of measures of organization would be required, followed by a determination of the variables affecting organization as well as the relationship between organization and performance in learning and memory tasks.

The adaptation of procedures for measuring characteristics of individual items to the measurement of organization does not seem feasible. A procedure similar to the rating of meaningfulness of individual items would involve the rating of degree of organization of groups (lists) of items, and the enormity of such a procedure dictates against it. Even for a relatively small vocabulary of 100 words, the number of subsets of a given size, say 20 words, is greater than 5×10^{20}, and there are over 2×10^{18} possible orders of the words within each of those subsets. In addition, to the extent that the bases of organization are idiosyncratic, there would be little inter-subject consistency in ratings of specific sets of items, and normative ratings would be homogeneous across sets. Yet, the organization of a specific set by an individual subject in a learning task might have large effects on his learning. Considerations such as these suggest the need for the development of alternative procedures for measuring organization.

The employment of different measurement techniques does not necessarily imply that the processes underlying the effects of characteristics of individual items are different than those underlying the effects of interitem relationships. Current terminology often involves the use of different terms, meaningfulness and organization, for individual and multiple item characteristics. However, in both cases the processes operating are related to integration and coding of physically separable events--in one case the elements comprising the item, and in the other case the different items on the list (cf. Miller, 1956a; Tulving, 1968). Since the "item" is defined somewhat arbitrarily, by the E, the coding and integrating processes and their degree of determination by prior experience may be identical in the two cases. On the other hand, there may be some psychological significance of E-defined items such that there are processual differences between intraitem and interitem integrations. A choice between the alternatives must await further research on both types of stimulus characteristics.

In the past eighteen years a number of procedures for the measurement of organization have been developed, leading to the accumulation of an extensive body of research dealing with the nature of organization and its relationship to learning and memory. The experiment reported here is designed to extend our capabilities for measuring organization by validating the use of interresponse time (IRT) patterns in the sequence of responses on a recall trial as an index of the amount and specific nature of organization. It also involves an attempt to determine the effects of within- and between-trial contiguity relationships among items on both organization and recall performance. The need for such research will be indicated by a review of the literature dealing with the measurement of organization and the variables affecting organization and recall, which will follow a brief discussion of the nature and theoretical status of the concept of organization.

The Nature and Theoretical Status of Organization

Organization is one term which is applied to the establishment of functional relationships among items or events; other terms include categorizing, chunking, grouping, recoding, and structuring, all of which have similar connotations. The implication of the psychological reality of relationships among events was evident in Katona's (1940) extension of the Gestalt theory to human memory. Katona asserted that the nature of the elements of a group are determined by the structure of the group as a whole, and that grouping operations were fundamental to memory. Similarly, Garner (1962) argued that meaningfulness is not determined by the individual elements, but by the structure itself. Mandler (1967) proposed that a set of objects "are said to be organized when a consistent relation among the members of the set can be specified and specifically when membership of the objects or events in subsets (groups, concepts, categories, chunks) is stable and identifiable" (p. 330).

The significance of organizational processes for the understanding of learning and memory was indicated in two important theoretical papers, by Underwood (1963) and Miller (1956a). Underwood indicated the necessity for distinguishing between the nominal, _E_-defined stimulus, and the functional, _S_-defined stimulus in verbal-learning studies. There is opportunity for a variety of transformations of the nominal stimulus, usually defined in terms of individual letters, nonsense syllables, or words, into the functional or psychological stimulus. The functional stimulus is the S's representation of the stimulus event. Although Underwood discussed the need for the distinction in the context of serial and paired-associate learning tasks, it is evident that the problem applies to all learning and memory situations. The organization of separate items into groups or units is one type of transformation from nominal to functional stimulus. While Stevens (1951) may have been correct that the problem of psychology is to define the stimulus, Underwood has suggested, in effect, that an understanding of behavior requires a specification of the functional stimulus.

Miller's (1956a) paper was more directly concerned with the organization process, and his theoretical treatment provided a basis for much of the subsequent research dealing with organization. On the basis of studies by Hayes (1952) and Pollack (1953), Miller observed that there was a limited capacity of immediate memory which was relatively invariant over a variety of types of stimuli at a value of seven plus or minus two items. However, the invariance of the capacity could not be attributed to a limit on the amount of information in the stimulus which the subject was capable of retaining. Lists containing equal numbers of letters, digits, and words vary in their amount of information, since the amount of information per item is different for digits, letters, and words. Therefore, Miller suggested that immediate memory was limited in terms of units which he labeled "chunks." He postulated a unitization process, that the subject recodes some number of the stimulus elements into a single memory unit, the chunk. The number of chunks capable of being stored is fixed at seven plus or minus two. The amount of information which can be stored is dependent on how informationally rich the chunks which the subject forms are. The mechanism by which the number of elements recalled after a single presentation is increased, as well, no doubt as the mechanism by which recall is increased as a function of repetition, is the coding and recoding process.

Organization is thus conceived as a process which has as its product a functional stimulus, or stimulus representation, in the form of categories, chunks, or S-units (Tulving, 1968). The organizational process allows the S to maximize his performance within the constraints of a system with limited storage capacity. Most theoretical discussions of the role of organization have been variations on Miller's (1956a) theme. Mandler (1967) proposed that memory storage is organized hierarchically, with groups of items belonging to categories, groups of categories belonging to higher level categories, and so on. Furthermore, he proposed a limited storage capacity at each level of the hierarchy. Tulving (1967, 1968), also accepted the notion of a storage system in which information is organized into chunks or S-units. However, he argued that the limited capacity is not a property of the storage system, but of the retrieval system.

Measurement of Organization

If organizational processes are to be investigated, they must be made observable, which requires the development of appropriate measures of organization. In discussing the various measures of organization available, a number of characteristics of each will be evaluated. First, an attempt will be made to specify the explicit or implicit assumptions which must be made about the nature of organization in order to apply the measure. A related concern is the sensitivity of the measure, which will be discussed in terms of what aspect(s) of organization are assessed by the particular measure, how much discriminability of organization is possible, and whether in addition to measuring amount, the procedure provides information as to the specific nature of the organization. Finally, the generality of the measure will be considered. Organization is usually discussed as a ubiquitous process in human learning and memory behavior. Ideally, a measure of organization should be applicable to the variety of situations in which organization might occur. Therefore, the task constraints imposed by the various measures are important in any discussion of their utility.

Manipulations of Nominal Organization

One approach to the study of organization is to manipulate some independent variable which is presumed to involve a manipulation of organization because the experimental operations are tied to some characteristic of grouping or interitem relationships among the elements comprising the list. Most studies of organizational processes obviously involve such manipulations. In many of these studies the dependent variable is one of the other measures of organization to be discussed below. Such studies are not presently at issue, since they are apparently designed to test the hypothesis that the experimental operations do, in fact, affect organization, where organization is measured by the dependent variable. However, there are also a number of studies, both early studies involving rhythmic patterns (see Woodworth, 1938) and grouping operations (Katona, 1940), as well as more recent studies involving structure and categorization (e.g., Garner & Degerman, 1967; Miller & Selfridge, 1950; Tulving, 1965), where the only dependent variable is degree of learning or amount retained. Such studies are often offered as tests of the hypothesis that organization affects learning and memory. The problem with relying upon experimental manipulations as a measure of organization derives from the recognition that there may be a discrepancy between the nominal stimulus and the functional stimulus (Tulving, 1968; Underwood, 1963), and that it is the functional stimulus, or the organization by the subject, that plays the critical role in affecting behavior. Experiments which obtain a positive relationship between nominal organization and amount recalled do not pose too great a problem, since they can be accepted as support for the joint hypothesis that the nominal organization affected the functional organization and the functional organization affected amount recalled. However, studies which fail to find positive relationships between nominal organization and amount recalled do present interpretive difficulties since it is not apparent whether to attribute the failure to a lack of functional relationship between organization and recall or to an ineffective manipulation of the functional stimulus by the experimental operations. Therefore, it would seem desirable to measure the functional organization directly, which will generally require an assessment of the S's behavior from which the nature of his functional organization of the information may be inferred. With sufficient investigation experimental manipulations may be identified which have a consistent effect on organization, and can therefore be expected to affect the functional organization in another task, with no need to measure it directly. Still, the basis of organization measurement would reside in the measurement of functional organization as indicated by subjects' behaviors in previous tasks.

<u>Measurement of Functional Organization</u>

<u>Amount recalled</u>. The remaining measures of organization to be discussed are similar in that they all attempt to evaluate functional organization by analyzing some aspect of the subject's behavior. They differ in what behaviors they assume best reflect the organizational processes and are therefore to be favored in the study of those processes. Of the behaviors employed, the one that seems least directly tied to descriptions of the organizational process is amount recalled. If a biconditional relationship between degree of organization and amount recalled is assumed, then the degree of organization can be measured by observing the amount recalled. This measurement approach is a reversal of the direction of analysis of Miller (1956a, 1956b), in his discussion of the unitization process. Miller argued that the greater the amount of organization, which he discussed in terms of the recoding of greater numbers of elements and amounts of information into single chunks, the greater would be the number of items recalled. Melton (1963) extended Miller's analysis and presented the argument for the reverse approach to measurement. Miller's presentation of the chunking concept was primarily in the context of immediate memory research. Citing research of his own dealing with the retention of consonant strings of varying length, and Murdock's (1960) experiment showing that, in terms of retention curves, consonant trigrams were nearly identical to word-triads and very different from individual words, Melton argued that "the critical determinant of the slope of the short-term retention function was the number of Millerian (1956) 'chunks' in the to-be-remembered unit" (p. 9). Melton suggested determining the slopes of short-term retention curves for 1, 2, 3, ..., *n*

chunks in order to "use these slopes to calibrate our verbal learning materials in terms of a chunk scale" (p. 12).

The procedure proposed by Melton suggests some of the problems inherent in the use of amount recalled as a measure of organization. The first problem is to decide on the materials which will be considered to have 1, 2, 3, ..., n chunks to serve as the reference point for calibration of other materials. One solution would be to make arbitrary selections, combined with a recognition that we may be dealing with a relative, rather than an absolute chunk scale. An alternative solution would be to employ some independent measure of organization t calibrate reference material and proceed from there. The major difficulty with any procedure that measures organization by amount recalled is that it relies upon the existence of a biconditional relationship between organization and recall. The relationship must either be accepted as an axiom of the theory of organization and recall, or be subjected to empirical test. An empirical determination of the relationship, which would no doubt be preferred for so critical an assumption about the basis for learning and memory, requires a measure of organization which is independent of amount recalled. The ultimate use of recall as a measure of organization need not be restricted to immediate recall, or short-term retention; the measure has the potential for being extended to any situation in which recall can be measured. As such, it has a great deal of potential generality, as well as sensitivity to the extent that differences in recall can be observed. The measure is lacking in a different kind of sensitivity in that it provides information only about the overall degree of organization of the list tested for recall, without providing information as to the specific nature of the organization, in terms of the partitioning of the list into subsets of functional units, or the basis for such partitioning.

Ordering properties in free recall. Clustering and subjective organization, the two measures of organization which are utilized most frequently in the study of organizational processes, have a number of characteristics in common. Both measures are directed at an evaluation of the functional organization of the subject in the learning situation. Clustering and subjective organization are both measures which are applied in a free recall task, where there are no E-imposed constraints on the order of recall. Implicit in both measures is the assumption that the organization of the S's recall, as manifest in the order of recall, reflects the functional organization of the material. More specifically, it is assumed that items which are functionally organized will be recalled contiguously in free recall. Any organization of items which does not result in contiguous recall of those items is not reflected in the measure of organization. When a subject recalls a set of items, he cannot recall them all simultaneously. He must recall the items in some order, and therefore items are always recalled contiguously with other items. The problem for any measure which relies upon recall order is to distinguish those contiguous occurrences of items due to organization from those contiguous occurrences which are forced by the need to recall a set of items in a nonsimultaneous fashion. The two techniques, clustering and subjective organization, are different solutions to the problem which make different further assumptions concerning the nature of organization and how it is reflected in a S's recall.

Clustering analyses measure the degree to which the S's organization is consistent with some experimenter-defined grouping of the words in the list. The analyses require a pre-experimental partitioning of the list of items into mutually exclusive groups. The basic observational unit for clustering analyses is the category repetition, which is defined as the contiguous occurrence of two words from the same E-defined category in the subject's recall. Clustering measures originated with Bousfield's (1953) experiment involving free recall of a list of 60 nouns, including 15 instances from each of four superordinate categories. The index of clustering employed by Bousfield was the ratio of repetition (RR), which was defined as the ratio of category repetitions to the number of words in the list. Chance values for the RR index have been calculated (Cohen, Sakoda, and Bousfield, 1954) based upon assumptions of random recall order. In addition, other indices based upon category repetitions have been developed which take into consideration intercategory transitions in recall (Robinson, 1966), and unequal availability of items during recall (Bousfield & Bousfield, 1966; Bousfield & Puff, 1964). A detailed discussion of differences among the various indices is contained in Shuell (1969).

For the present discussion it is the commonalities among the measures, rather than the differences, that are critical. All clustering analyses have limited generality in that they are restricted to free recall tasks in which there are E-defined groupings of the set of items. Furthermore, the measures have limited sensitivity. They are not measures of overall organization, but only of the degree to which the S's organization conforms to the E's. Thus, the observation of a lack of clustering according to some E-defined categorization of the list does not imply that there is no organization. There may be alternative modes of grouping by Ss which are uncorrelated or negatively correlated with the E-defined groupings, and which therefore go undetected by the clustering analysis. The limitation on the interpretation of clustering scores is also important in studies designed to determine the relationship between organization and recall. The dangers in using clustering measures for such a determination should now be apparent. If clustering increases as a function of an experimental manipulation and recall does not, there may be an alternative, equally efficient but undetected mode of organization which is being used by the nonclustering group. Similarly, if clustering is constant but recall changes, there may be some undetected change in degree of organization which is related to the change in amount recalled.

A flexibility allowed by clustering measures is that clustering can be measured for any partition of the list into groups, based upon any relationships of interest to the E. For some relationships investigators have performed analyses which rest upon similar assumptions as clustering, but have not employed the specific clustering indices described above. Jenkins and his associates (Jenkins, Mink, & Russell, 1958; Jenkins & Russell, 1952) have developed measures for clustering of associatively related word pairs. The measurement of adopted chunks developed by Tulving and Patkau (1962) is a form of clustering analysis for contiguity groupings, since an adopted chunk is an ordered, contiguous sequence of words in a recall protocol which corresponds to a similar sequence in the input list.

Finally, it should be noted that clustering measures have been applied in three types of investigations. The first type is an attempt to determine whether a S does functionally organize according to a particular categorization, which requires a comparison to chance clustering. The second is a comparison of clustering as a function of some experimental manipulation. Relative, as opposed to absolute clustering is of interest and chance clustering scores are not as vital. The third type of study is one with powerful potential, but limited application to this date. It is possible to compare clustering for two or more different partitions of the same list of words to determine which organizational scheme dominates the behavior of Ss. This approach has been utilized by Bousfield, Esterson and Whitmarsh (1958), and by Bourne and Parker (1964).

In those situations where the E is unable to make a reasonable partitioning of the list into groups, or where he does not wish to restrict his evaluation of organization to that which is consistent with a specific categorization, measures of subjective organization may be appropriate. Since we have no a priori expectations as to which words will be organized together, we must establish an alternative criterion for distinguishing contiguous occurrences of words in free recall due to organization from contiguous occurrences due to the need to recall the items in some order. The criterion exployed in subjective organization measures is stability of output order over a number of recall trials. All indices of subjective organization require a multitrial free recall task, where each trial consists of the presentation and free recall of the same list of items. The basic behavioral unit for measures of subjective organization is the intertrial repetition (ITR), which is defined as the occurrence of an ordered pair of words in the

S's recall protocol on two successive trials. The assumption made by subjective organization measures is that organization is a relatively stable phenomenon, and therefore an ordered pair of items which occurs in a S's recall protocol on a particular trial due to the organization of the members of the pair will be more likely to recur as an ordered pair of subsequent trials. A less restrictive view of organization would not require the assumption that all organization is stable, but that subjective organization only measures that organization which is stable.

As with clustering, a number of different indices of subjective organization have been developed and are reviewed in detail by Shuell (1969). The measure of subjective organization originated by Tulving (1962a) requires the construction of a matrix in which the rows and columns represent the words in the list, and the entry in each cell is the number of times the word in row i was followed by the word in column j in the various output trials being considered. The index can be calculated for blocks of two or more trials. For a block of b trials, if there are no repetitions of words within a recall trial, the entries in each cell of the matrix can range from 0, indicating that word j never followed word i in that block, to b, indicating that word j followed word i on every trial in that block. The index employed by Tulving is derived from information theory and represents the amount of redundancy in the matrix. Tulving has suggested that subjective organization can be determined for backward orders, and can be estimated for higher orders of organization by calculating the redundancy index for lag L, where the entries in the matrix are the number of times the word in row i is separated from the word in column j by L

words.

The measures of subjective organization which were developed subsequent to Tulving (1962a) are easier to calculate. They all involve deviation scores representing the difference between observed ITRs and expected ITRs. The formula for expected ITRs proposed by Bousfield, Puff, and Cowan (1964) assumes equal availability of all items in the list and random ordering of the number of items recalled on the two trials for which subjective organization is being determined. Bousfield and Bousfield (1966) modified the formula for expected ITRs to take into account unequal availability of items by calculating chance ITRs for random orders of the specific words recalled on the trials for which subjective organization is being determined. Fagan (1968) has suggested converting the deviation measure to a ratio score in order to take into account the maximum possible deviation.

Subjective organization measures, like clustering measures, require free recall tasks. Measures of subjective organization require a multitrial situation, but do not require nor only assess a specific organization of the list. However, subjective organization does measure only stable organization. It is sensitive to pairwise organization and relatively insensitive to organization into clusters containing little intracluster organization.

It has been suggested that the application of measures of clustering and subjective organization is limited to tasks where there is no structure in the presentation order of the list. It will be argued that this restriction is unduly limiting, and one that should not be placed on the application of the measures, but on the interpretation of scores obtained from such applications. Cofer and Bruce (1965) suggested that, "it perhaps makes no sense to compare clustering under block presentation to a figure representative of chance under random presentation conditions" (p. 338). Similarly, Tulving (1962a) presented items in a different order on each trial so that sequential redundancy during presentation, over the set of trials for each S, would be eliminated. He defined subjective organization as sequential redundancy across trials in the absence of input redundancy, and therefore organization which is imposed on the material by the subject.

Chance values for category repetitions and intertrial repetitions are obtained from random output orders. Since input order never enters into the calculation of clustering and subjective organization scores, it would seem appropriate to consider such scores as valid indices of functional organization, whatever the nature of input conditions. What must be recognized, however, is that the functional organization which results in a particular clustering or subjective organization score may derive from a number of relationships. Cofer and Bruce (1965) wanted to restrict their interpretation to clustering which was due to categorical relationships among the words, and Tulving (1962a) wanted to restrict his interpretation to subjective organization due to the nature of the words themselves. Obviously, when one wishes to restrict the source of functional organization to which to attribute high clustering or subjective organization scores, one must eliminate other sources, such as input order relationships. At the same time, it is appropriate to recognize that input order relationships may affect functional organization, and can be assessed by clustering or subjective organization measures.

Temporal patterns in recall. As already noted, the use of indices of clustering and subjective organization to assess functional organization rests upon the assumption that the ordering properties of a set of items in the recall phase of a free recall task reflects the functional organization of that set of items. One of the first statements of this assumption was made by Bousfield (1953), in his original study of category clustering. Bousfield indicated that the study of clustering was suggested by observations of Ss' response protocols in a restricted association task performed by himself and Sedgewick (Bousfield & Sedgewick, 1944). When Ss were asked to list items from specific categories, e.g., birds, they often emitted sequences of related items within the category, such as birds of prey (hawk, eagle, vulture) and domestic fowl (chicken, turkey, duck, goose). Bousfield assumed that this clustering was a consequence of organization in thinking and recall, and that the quantification and further study of such behaviors would provide additional information about organizational processes. In discussing the clustering which occurred in the Bousfield and Sedgewick (1944) study, Bousfield reported that the members of a cluster were emitted in relatively rapid succession; that is, there would be a burst of related responses, followed by a pause, another burst, and so on. This would suggest that the temporal pattern of responses in a recall task could also be used as a measure of organization; the shorter the interresponse time (IRT) between two successive words the greater the probability that the two words are members of the same functional unit.

IRT measures share a number of characteristics with clustering and subjective organization measures. They are all methods of assessing functional organization, and they would appear to be more intimately tied to the organizational process than are gross behavioral measures such as amount recalled. At the same time, some of the properties of IRT measures suggest their potential value as an alternative or supplementary means of studying the organizational process. Considerations of generality and sensitivity favor the use of such measures. The utility of clustering and subjective organization measures is limited to free recall situations. Since the measures are related to ordering properties in recall, they provide little information about organization in an ordered recall task, where the recall order is prescribed by the experimenter. That does not imply that there is no organization in an ordered recall task. Most theoretical treatments of the organizational process suggest that it is a ubiquitous and perhaps necessary process in all learning and memory behavior. In an ordered recall task, the nature of the functional organization may be restricted by task requirements, but it is still present in some fashion. IRT patterns may reflect the size and nature of functional groupings of items in ordered recall tasks. Moreover, the measure can be applied to free recall tasks, without further restrictions of predefined categories or multitrial consistency of output order. The availability of a single measure of organization for a variety of situations allows for the demonstration of the centrality of organizational processes in all learning, as well as the indication that the various measures of organization which are dependent upon different aspects of behavior, in fact reflect the identical process or mechanism. The IRT between two words is a continuous variable, which may indicate differences in organization which are not detected by clustering and subjective organization. An ordered pair of words either is or is not a category repetition, and either is or is not an intertrial repetition. All category repetitions are treated as equal manifestations of organization, since each repetition contributes the same amount to the clustering score. The same holds true for intertrial repetitions in the case of measures of subjective organization. There may be differences in the degrees of organization which result in different instances of category or intertrial repetitions that would be manifest in differences in IRTs. Indices of clustering and subjective organization yield a single score which represents the degree of organization on a particular trial or block of trials. One could also obtain a single score for a trial or block of trials by determining the average IRT between every pair of words in the recall protocol. However, the main advantage to the use of IRT measures would appear to derive from the opportunity to examine the pattern of IRTs in order to draw inferences concerning the size and nature of specific groupings of items by the subject. Such an approach generates some problems, since there are no easily specifiable criteria for absolute or relative IRTs that would allow a distinction between intraunit and interunit pauses. When using IRT measures care must be taken that the response requirement of the task does not mask the manifestation of organization. If the response required is of long duration, and the processes that are affected by organization can be carried out simultaneously with the emission of a response, then a ceiling effect will be produced. All of the IRTs would be equal, not because there are no differences in organization, but because the response requirement is masking the organizational processes. The analysis of IRTs in oral recall, as opposed to written recall, therefore recommends itself. The oral emission of words is a relatively rapid and highly skilled response which should permit the study of organization through the analysis of IRT patterns.

While ordering properties in free recall received attention and elaboration as measures of organization in memory tasks in the period following Bousfield (1953), it was not until recently that IRT analyses were employed. IRT analyses do have a longer history of use in studies of coding processes in language behavior. In a symposium of psycholinguists, Lounsbury (1954) distinguished between two types of pauses in speech. Hesitation pauses are of long duration and were hypothesized to occur at points of high statistical uncertainty, corresponding to points of encoding; facultative pauses are of short duration and occur at syntactic boundaries, corresponding to points of decoding. The encoding-decoding distinction was expressed in terms of the speaker, who originates the sequence of items, and the listener, who comprehends the sequence. It is not clear which type of pause should reflect organization in the typical memory task, or whether the distinction is important in such tasks. Although the listener in Lounsbury's analysis has a memory task, the decoding aspect seems to result from a perceptual problem, the need for the listener to understand and reproduce the speaker's organization. Most analyses of organization in memory (cf. Miller, 1956a, 1956b; Tulving, 1968) place emphasis on an encoding or recoding process by the subject, which is necessary to bring a large amount of information within the capacity constraints of the individual. A decoding process at the time of recall would also be necessary, but it would seem that the decoding units must correspond to the encoding units.

Goldman-Eisler has conducted extensive investigations of pausal behavior in speech. In her earlier studies she demonstrated that individual differences in pausal phenomena were reliable and stable (Goldman-Eisler, 1951), and that variations in the rate of speech production could be accounted for mostly by pausing behavior, as opposed to duration of vocal emissions (Goldman-Eisler, 1956). Later experiments by Goldman-Eisler (1958) confirmed Lounsbury's (1954) hypothesis concerning the relationship between hesitation pauses and points of uncertainty in spontaneous speech. The stimulus materials were tape recordings of sentences of spontaneous speech derived from a number of sources. Hesitation pauses were treated as a dichotomous variable, with a pause duration of at least 250 msec. required for classification as a "pause." Ss other than those who had produced the sentence were utilized to obtain uncertainty measures. Ss were required to guess the word of a sentence, given all of the preceding or following words of the sentence. Transition probabilities were estimated by the ratio of correct guesses to total guesses made. In the first experiment, using only forward guesses, pauses were usually followed by words of low transition, but many low transition probability words were not preceded by pauses. That is, words following pauses had a low probability of being guessed, given all of the words preceding the pause. But, many words that had a low probability of being guessed, given all of the words preceding them, were not preceded by a pause. However, in a second experiment, using uncertainty estimates from both forward and backward guesses, a reciprocal relationship was obtained between pauses and low transition probability words. Pauses were generally followed by low transition probability words, and low transition probability words were preceded by pauses. In both experiments pauses were preceded by high transition probability words; there was a high probability of guessing a word which preceded a pause, given all of the words which preceded that word.

Martin (1967) provided further support for Lounsbury's hypotheses and distinguished between encoders and decoders. Encoders were required to describe pictures in short utterances; decoders, yoked to the encoders, listened to the encoders' descriptions and attempted to reproduce them. Although decoders produced fewer words, indicating that forgetting occurred, the ratio of content to function words was approximately equal for encoders' descriptions and decoders' reproductions. However, encoders's pauses tended to precede content words, which are generally high uncertainty words, while decoders' pauses tended to occur at syntactic boundaries.

The experiments described indicate that pauses are intimately tied to coding processes in speech behavior and therefore suggest that IRTs may provide informative measures of organization in recall tasks. However, the tasks often employed spontaneous, self-generated sequences. Those that did require recall (Martin, 1967) were not designed to tax the subjects' memory capacities. In addition, all of the studies involved natural language sequences and indicated that pausal behavior was related to syntactic structure. Before adopting IRT patterns as a general measure of organization in standard recall tasks, it would be necessary to demonstrate the relationship between pausal phenomena and organization in tasks requiring recall of sets of verbal items which are lacking in syntactic structure.

Pollio (1964) used IRT measures in a free association task, where syntactic organization was not a factor. Ss gave continuous free associations to each of four stimulus words for a period of 4 min. The cumulative curve of free associations as a function of time was negatively accelerated. As in Bousfield and Sedgewick (1944), Pollio found that the rate of responding was irregular, with periods of rapid response bursts interspersed with periods of slower response bursts. For each S, a fast, medium, and slow sequence of responses was selected from each of the four free association protocols on the basis of IRT data. In a later session the Ss gave associations to all of the members of the selected sequences and rated all of the words on the semantic differential. Pollio found that words which were members of rapid response sequences were more closely related than were words which were members of slow response clusters, both in terms of a measure of associative overlap as well as in terms of connotative meaning as indicated by semantic differential ratings.

The sensitivity of IRTs to organizational factors in memory tasks was demonstrated by Suci (1967) and McLean and Gregg (1967). Suci's experiment was designed to test the validity of pause as an index of psychological units in language. He argued that the elements comprising a psychological unit are more highly related to one another on some basis, and as such are more resistant to fracturing, than are elements from different psychological units. Learning a list for ordered recall consists of the coding of subsets of sequential elements, or the formation of psychological units. Relearning a list in which the psychological units are reordered simply requires the learning of a new order of the coded units, and therefore should be easier than relearning in which the old units are fractured and recoding is required. Given the above assumptions, a test of the validity of pause as an index of psychological units was possible. Suci employed pause behavior as the criterion to define units. If a list maintaining the integrity of units as defined by pauses was easier to learn than a list in which the integrity of units was destroyed, the hypothesis that units selected on the basis of pause behavior are psychological units would be supported.

Ss in Suci's first experiment learned a story, consisting of 48 words divided into two sentences, to a criterion of two consecutive correct ordered recalls. For each S the average pause length between every pair of successive words was determined. The nine longest average pauses were utilized to determine nine points in the story at which to make breaks in order to divide the story into ten parts. For Ss in the pause condition, the ten parts were placed in a new random order. For Ss in the nonpause condition, the ten parts of the story were determined by breaking the story at points where average IRTs were short. These ten parts were also reordered creating a new word list for the nonpause condition. Ss in both groups returned a week later, first relearned the original list to the criterion of one correct recall, and then learned their mutilated version, pause or nonpause, of the original story. The results supported the validity of pause as an index of organization, in that Ss took a significantly greater number of trials to learn the mutilated nonpause version of the original story than to learn the mutilated pause version.

Due to the nature of the stimulus materials and the fact, observed elsewhere (Goldman-Eisler, 1961; Martin, 1967) as well as by Suci in his study, that pauses are more likely to occur at phrase boundaries than anywhere else, it was necessary for Suci to consider the role of syntactic factors in his study. One argument which could be made is that pauses occur at syntactic boundaries, but these are not psychological units. The procedure for constructing pause and nonpause mutilated versions of the original story would have resulted in strings of phrases and nonphrases, respectively. The difference between the pause and nonpause condition may therefore be due to differences in learning the two types of materials, independent of organizational factors. Suci provided data to the contrary. From the same stories as were used in the main experiment, he constructed phrase and nonphrase mutilations, based on syntactic factors and independent of subjects' pausing behaviors. Although there were differences in ease of original learning of these phrase and nonphrase mutilations, the differences were not as large as the differences between the learning of the pause and nonpause mutilations. These results suggest that even if the pause vs. nonpause difference is related to syntactic factors, it is at least partially a transfer effect from original learning, and therefore readily interpretable as syntactic units which become psychological units, with psychological units maintained or fractured in the transfer task.

Given that pauses reflect aspects of organization, it is still possible that the only organizational factors reflected by IRTs are syntactic factors and that pause analysis contributes nothing beyond what could be obtained by syntactic analyses. Suci argued against both of these possibilities, although the data he presented seem more relevant to the latter argument. He indicated that the relationship between pause and grammatical structure was not perfect and that there were individual differences in the placement of pauses. Furthermore, in Suci's second experiment using materials of second order of approximation to English, Ss received their own pause mutilation as the pause condition, and another S's pause mutilation as the nonpause condition. Again, differences were obtained between pause and nonpause conditions, which indicated that pauses were sensitive to individual differences in organization. Although Suci appropriately interpreted these data as indicating that pause analyses provide information about organization beyond what is available in syntactic analyses, it is possible that the organization that is tapped by interresponse time analyses is syntactic organization. If pauses occur at nongrammatical boundaries for reasons unrelated to organization, such as respiratory factors, and if only some grammatical units become psychological units, then we would not obtain a perfect biconditional relationship between pausing and syntax and we would obtain individual differences in the location of pauses, for both organizational and nonorganizational reasons. The individual differences in which grammatical structures become psychological units would make it possible for the pause mutilation of one subject to involve the fracturing of another S's psychological units and therefore explain the difference between pause and nonpause conditions in the second study.

Thus, Suci's data support the validity of pause, at least as a measure of that psychological organization which has a syntactic basis. One could argue that in language behavior all organization has a syntactic basis and therefore pause is the only required measure of organization. However, there are situations in which grammatical organization is impossible, as in the recall of a list of nouns, and the validity of pause as an index of organization in such tasks remains to be demonstrated directly.

McLean and Gregg (1967) began with the assumption that groups of items emitted in a rapid burst form a coherent memory unit, or chunk. They used IRT patterns as a measure of chunking to determine whether spatial-temporal grouping in the presentation of a set of items would affect the nature of the chunking of the set. The task involved alternating presentations and ordered recalls of a list containing 24 different letters in a random order. The items were presented visually, on cards, and external grouping was manipulated by presenting either 1, 3, 4, 6, or 8 letters simultaneously on a card. _S_s were run to a criterion of one perfect recall, and were then asked to recall the list in backward order. To test whether a list was being chunked by the _S_ into groups of size _n_, the _S_'s recall was divided into groups of size _n_, and the ratio of average between-group to average within-group IRTs was calculated. The higher the ratio, or chunking index, the stronger was the indication that the subject was chunking according to the pattern tested. A chunking index for groupings of size 2, 3, 4, 6, and 8 was calculated for each of the input conditions. For each input grouping condition, the highest chunking index was for an output pattern that corresponded to the input pattern. The effect of input pattern was quite strong on forward recall, and even more pronounced for backward recall. While not specifically noted by McLean and Gregg, their data showed evidence of hierarchical organization whose nature was also affected by input conditions. Thus, for stimulus groupings of size 8, the chunking index was greatest for a pattern of 8, but also high for patterns of 4 and 2, and low for patterns of 3 and 6; for groupings of size 6, the index was highest for patterns of

6, but second highest for patterns of 3.

A comparison of the experiments by Suci (1967) and McLean and Gregg (1967) reveals one commonality and one difference, both of which are relevant to the consideration of IRT measures as an index of organization. Both studies indicated a relationship between organization and IRTs in ordered recall tasks, thereby supporting the earlier proposal that IRTs offer the potential of an organization measure with generality, since there are fewer task restrictions on their applicability. The difference between the two studies is in the role played by IRT measures and the basic assumptions made in each experiment about the nature of organization. Suci assumed a relationship between organization, however it is to be measured, and recall, and used this relationship to test the validity of a particular measure, IRTs. McLean and Gregg, on the other hand assumed the validity of IRTs as a measure of organization, and used the measure to test the effect of a manipulation of input structure on functional organization.

An alternative to the validation procedure employed by Suci (1967) would be to demonstrate a relationship between IRTs and the behaviors generally accepted as indices of organization by clustering and subjective organization measures. If Ss are organizing a set of items according to some E-defined categorization of the list, then the IRT between two words from the same category should be shorter than the IRT between two words from different categories. This prediction has been confirmed by Pollio, Richards, and Lucas (1969). Ss were presented a categorized list consisting of five instances of each of five categories three times, followed by a single free recall trial. Between-category IRTs were significantly longer than within-category

IRTs. Similar analyses comparing IRTs and subjective organization have not been reported, although they would be valuable for confirming the generality and sensitivity of IRTs as indices of organization, as well as determining the potentiality of IRTs for providing otherwise unavilable information concerning organization.

Effects of Contiguity on Organization and Recall

The development and acceptance of a method of measuring organization does not complete our understanding of the organizational process. A measurement procedure, be it clustering, subjective organization or IRT analyses, is simply a tool. Its availability makes organization observable and therefore allows for an investigation of the independent variables that affect functional organization as well as an explication of the relationship between the quantity and quality of organization on the one hand and other aspects of behavior such as amount recalled on the other. The specification of these relationships will constitute at least a partial explanation of the organizational process.

It is possible to distinguish between two classes of independent variables, item-independent and item-dependent characteristics of the stimulus, that have potential effects on functional organization and recall. Item-independent characteristics, as their name implies, are stimulus characteristics which are defined independently of the specific items constituting the list. They are usually studied in terms of the spatial and temporal properties of presentation imposed by the experimenter which would remain constant despite changes in the specific list items. Item-dependent characteristics on the other hand are properties of the items themselves, defined in terms of interitem relationships which are known or assumed to have a basis in the subject's prior experience with, and responses to, the items qua items.

A distinction between these two classes of independent variables has been proposed by a number of authors. Katona (1940) distinguished between grouping according to arbitrary, or artificial, principles in which the nature of the parts do not determine the form of grouping, and grouping according to an arrangement which is dependent on the material itself. Two of the factors which McLean and Gregg (1967) suggested may contribute to the development of chunks--external punctuation of the stimuli, and stimuli which form a unit with which the subject is familiar--correspond to item-independent and item-dependent characteristics respectively. Finally, Tulving (1968) distinguished between primary organization and secondary organization in terms of whether consistent discrepancies between input order and output order in free recall result from factors which are independent of, or dependent on, the subject's prior familiarity with a set of items.

Studies of organization have been primarily concerned with item-dependent characteristics. The relationship between number of categories in the list and amount recalled has been investigated using item-dependent categories such as superordinate systems (Dallett, 1964; Matthews, 1954; Tulving & Pearlstone, 1966) and S-defined groupings (Mandler, 1967). The effect of strength of relationship among items has been evaluated for members of superordinate categories (Bousfield, Cohen, & Whitmarsh, 1958; Cofer, Bruce, & Reicher, 1966), for associations between pairs of words (Jenkins, Mink, & Russell, 1958), and for associations among the set of words comprising the list (Deese, 1959; Marshall & Cofer, 1963; Rothkopf & Coke, 1961); Cohen (1963) compared exhaustive and nonexhaustive categories. In addition to the general superordinate and associative relationships, the effectiveness of a variety of item-dependent characteristics as bases for organization has been evaluated, including alphabetical (Tulving, 1962b), grammatical form class (Cofer & Bruce, 1965), synonymic (Cofer, 1959), semantic differential (Cowan, 1964), response dominance (Bousfield & Puff, 1964), syntactic (Bourne & Parker, 1964) and structural characteristics of geometric designs (Bousfield, Berkowitz, & Whitmarsh, 1959).

Item-independent characteristics have not been investigated as extensively nor as systematically as item-dependent characteristics. Yet, any time a list of items is presented the individual items have temporal and spatial properties which may allow for the functional organization of items due to relationships based upon these properties. Characterizations of the memory trace as a multidimensional representation of the stimulus (cf. Underwood, 1969; Wickens, 1970) have recognized that spatial and temporal characteristics of the stimulus may be effective, that is, coded and utilized, dimensions in some situations. Most studies which have utilized clustering and subjective organization measures have been concerned with the assessment of organization that derives from item-dependent relationships. They have therefore generally employed random presentation orders and different orders on each trial to eliminate the effects of spatial and temporal factors. Such randomization procedures may not eliminate item-independent organization, but rather fail to assess it, since the organization is incompatible with the E's grouping in clustering experiments; it also changes over trials and therefore may not be detected by subjective organization measures.

If we define organization in terms of groupings of items, the most fundamental item-independent basis for organization would be contiguity relationships. Items which are presented in contiguous positions might be organized together due to their contiguity in presentation. Rozov's (1964) report of "original clusters" in the recall of categorized word lists supports the existence of contiguity organization. Ss were presented a categorized list of words in random order for free recall. In addition to finding groups of words from the same category recalled contiguously, which he termed "topic clusters," he also found evidence of "original clusters," or groups of words that were presented together recalled contiguously. Furthermore, some of these "original clusters" were maintained in a second recall which followed the first one with no intervening presentation. Rozov reported no analyses to indicate that the "original clusters" occurred with a greater frequency than would be expected by chance. Wallace (1969) provided stronger evidence for the existence of contiguity organization. A set of 16 unrelated words was randomly divided into pairs. The study trial consisted of the presentation of the 16 words three times, with members of a pair presented either in adjacent or nonadjacent positions. Clustering according to the predetermined random pairing was significantly greater for the adjacent condition than for the nonadjacent position, indicating that contiguity relations provide a sufficient basis for clustering in recall. Although not directly demonstrated, the existence of contiguity organization provides the basis for the explanation of lag effects in free recall (Melton & Shulman, 1967; Melton, 1970).

Direct versus Indirect Effects of Contiguity

Although the evidence presented supports the existence of contiguity organization, in that items that were presented contiguously were recalled contiguously, it is not yet clear what the basis for this organization is. The use of the term "contiguity organization" suggests that contiguity itself is a possible functional relationship between events. This type of relationship would be possible if items were coded with position cues, allowing for the organization of items with similar position cues, or if items were coded as having been presented next to other items. An alternative to this direct representation of contiguity relationships is an indirect representation. Contiguity relationships during presentation may simply prime item-dependent relationships. If there exist a multiplicity of item-dependent characteristics which have the potential for being coded and utilized, contiguity could affect the specific dimensions coded in such a way that items that are presented contiguously are stored with coded properties that allow for the item-dependent organization of those items. Given Wallace's (1969) finding of contiguity organization of unrelated words, indirect contiguity interpretations would lead us to question whether there is such a thing as "unrelated" words. We would have to leave open the possibility that all items are potentially relatable, which is not unlikely given the adult S's vast amount of experience with acoustic, alphabetic, orthographic, semantic, and affective characteristics of words.

Contiguity organization need not require the immediate adjacency of the items that are organized together. As Robinson (1932) recognized, contiguity is a continuous variable, with increasing effects the more nearly simultaneous the occurrence of two events. One mechanism that presupposes contiguity effects is the postulation of a short-term memory buffer, with the further assumptions that organization of items requires their simultaneous presence in the buffer, and that the probability of simultaneous presence in the buffer is a decreasing function of the lag in presentation between the items (Atkinson & Shiffrin, 1968; Glanzer, 1969). Both direct and indirect contiguity effects are possible within such a system. Direct effects would occur if simultaneous presence in the buffer is itself a basis for organization, and indirect effects if simultaneous presence provides the occasion for the relating of items according to item-dependent characteristics. Although Wallace (1969, 1970) apparently favors the direct effect hypothesis, researchers who have been concerned primarily with item-dependent characteristics seem to favor the indirect hypothesis. Puff (1966) hypothesized that contiguity of presentation primes common associative responses, making them more available as effective mediators at recall. Tulving (1968) called for a determination of the intraexperimental conditions that affect the ease with which item-dependent subjective units are formed, suggesting an indirect effect of contiguity characteristics. If we change the focus of Tulving's suggested research strategy and inquire into the factors that affect contiguity organization we may discover means for distinguishing between the direct and indirect effects of contiguity relationships on organization.

The variables which have been shown to affect contiguity organization on the input side are analogous to the three response characteristics which are employed to identify which contiguously recalled words are instances of organization on the output side by measures of interresponse times, clustering, and subjective organization. Interresponse time analyses rely upon the temporal spacing of output, which is analogous to what McLean and Gregg (1967) termed the external punctuation of stimuli. A number of studies have shown that external temporal or spatial punctuation enhances the grouping of contiguous items within the punctuation, and decreases the likelihood of grouping across punctuation marks. In an ordered recall task the only effective organization is the organization of contiguous items. Yet there is freedom as to which contiguously presented items to organize together. Early studies on rhythmic presentation patterns, reviewed in Woodworth (1938) and Katona (1940) indicate that pauses in presentation promote grouping and facilitate recall. The more recent study by McLean and Gregg (1967) indicated that the temporal pattern of input grouping of letters affects the temporal pattern of output in ordered recall. The importance of spatial grouping was demonstrated by Musgrave and Allen (1968). They presented Ss a list of 64 words, containing 32 unrelated words and 32 words which were related in that they represented four instances of each of eight categories. In presentation, one related word was paired with one unrelated word, and the members of a pair were presented either successively, or simultaneously in a row. In addition to finding clustering of the words related according to the categories, they obtained clustering of the random pairs when presented simultaneously, but not when presented successively. In the tasks described, contiguity organization was affected by an item-independent characteristic, external punctuation, whose effects are consistent with a direct or indirect basis of contiguity relationships.

Intratrial contiguity. On any particular presentation of a list, some items are presented contiguously with other items. Clustering analyses examine the item-dependent characteristics of items which are recalled contiguously. Similarly, we can manipulate the item-dependent characteristics of items which are presented contiguously. This type of manipulation is essentially accomplished by varying the order of approximation to English, where item-dependent sequential structure increases with order of approximation. In both free recall (Miller & Selfridge, 1950) and ordered recall (Marks & Jack, 1952), recall increased as a function of order of approximation. Tulving and Patkau (1962) using word sequences, and McNulty (1966) using letter sequences, measured adopted chunks in the free recall of varying orders of approximation; an adopted chunk is a successive set of items in presentation which are also recalled successively. With both types of stimuli, recall increased but number of adopted chunks was constant with increasing orders of approximation, implying that the number of words (or letters) per chunk increased with order of approximation, and therefore that degree of contiguity organization also increased.

Further evidence of the interaction of contiguity and item-dependent characteristics is provided by comparisons of blocked and random presentation, defined by contiguous versus noncontiguous presentation of category members. In free recall, blocked presentation facilitated recall for categories defined on the basis of sentence structure (Bourne & Parker, 1964), recall data (Tulving, 1965), and restricted word-association norms (Cofer, Bruce, & Reicher, 1966; Dallett, 1964), and in the latter case also augmented clustering. Puff (1966) manipulated the correlation between contiguity and category membership over intermediate values of blocking. With a list containing ten words from each of three categories, he used presentation orders which involved 0, 9, 18, or 27 category repetitions, and found that both recall and clustering increased regularly with increases in number of category repetitions during presentation.

The effect of blocked presentation on clustering has generally been attributed to indirect effects of contiguity (Cofer, Bruce, & Reicher, 1966; Puff, 1966). The contiguity of category members is presumed to influence the storage of the semantic based relationship between the category members. However, superior clustering in blocked conditions would also be expected if there were direct effects of contiguity on organization. Suppose two contiguous items are organized together and therefore recalled together on the basis of their contiguity relationship. If these two items also happen to be members of the same experimenter defined category, then the contiguity organization will augment the clustering score. If they are members of different categories, the clustering score will be unaffected. In blocked presentation, more contiguous items are members of the same category than is the case in random presentation, and therefore direct contiguity organization would augment clustering scores for blocked presentation more than for random presentation.

One way to distinguish between direct and indirect contiguity effects would be to examine recall data, under the assumption that recall is dependent on organization. Direct contiguity effects should lead to no effect of blocking on amount recalled. The blocked and random groups have equal amounts of contiguity organization. The only difference is that the clustering measure does not detect the contiguity organization in the random group. Since organization is equal, recall should be equal in the two conditions. However, indirect contiguity effects attribute the higher clustering to increased categorical organization in the blocked condition, mediated by the contiguity relationships, and therefore would predict higher recall in the blocked condition.

Additional evidence for distinguishing direct and indirect contiguity effects can be obtained by manipulating independently contiguity relationships and categorical relationships in the list presented. Indirect contiguity can only be effective if there is some potential for item-dependent organization to occur. The greater the potential for item-dependent organization, up to some limit, the more effective should contiguity be. Blocking would be expected to increase clustering scores to a greater extent when the items that are blocked are categorically related then when they are unrelated. There may be a blocking effect for unrelated words, since truly unrelatable words may be impossible to attain, but the blocking effect for related words would be greater. In addition, blocking should increase recall for the related items, but not for the unrelated items. If contiguity is an independent basis for organization, then blocking would be expected to augment clustering equally for related and unrelated items. Whatever gains in clustering scores for blocked presentation of related words are due to contiguity effects would also result in increased clustering scores for blocked presentation of unrelated words. However, blocking should have no effect on amount recalled for either type of item. If the evidence suggests indirect effects of contiguity, there may also be direct effects. If blocking facilitates clustering of related items, but has no effect on unrelated items, it would suggest indirect effects and no direct effects. However, if blocking facilitates clustering of both types of items, but has a greater effect on related items, indirect effects would still be implicated, but there would be uncertainty concerning direct effects. We would not know whether to attribute the blocking effect on unrelated items to additional direct effects or to indirect effects operating on item-dependent characteristics of the supposedly unrelated items.

The data available concerning blocking effects are inconsistent with respect to the source of contiguity effects. That there are contiguity effects has been amply demonstrated. The research dealing with orders of approximation involve item-dependent characteristics whose definition resides in contiguity relationships. Although they do suggest indirect effects their generality to other kinds of item-dependent characteristics may be limited. Most blocking studies involving categorical relationships have employed only one degree of relationship, and therefore the clustering data are not diagnostic for distinguishing direct and indirect contiguity effects. The facilitating effect of blocking on recall in those studies again suggests an indirect effect.

The one study in which degree of item-dependent relationship and blocking were manipulated factorially was reported by Cofer, Bruce, and Reicher (1966). Although they interpreted their data with respect to indirect effects only, their data are relevant to the question of whether contiguity has a direct or indirect organizational basis. They used random and blocked presentation of words which were high- and low-frequency associates of categories. They found that blocking augmented clustering equally for high- and low-frequency associates, which is consistent with a direct contiguity interpretation. They also found that blocking facilitated recall, which is inconsistent with direct contiguity effects. In their third experiment, blocking was more effective on recall with high frequency than with low frequency words, which would support the indirect interpretation. However, in their first experiment, the facilitative effect of blocking on recall was of the same magnitude for both types of items. This result is consistent with neither direct nor indirect contiguity effects. The reasons for the internal inconsistency of their data are not altogether obvious. One possibility which the authors suggested is that there were ceiling effects operating so that the data underestimate the effects of blocking on high frequency words. Although there may be more opportunities for indirect contiguity effects with high frequency words, some of the opportunities might already have been taken advantage of without contiguity in the random order. The ceiling effects might also have been operating on the recall data.

Intertrial contiguity consistency. Measures of subjective organization index organization by the stability of output orders over trials. Similarly, in a multitrial free recall task contiguity organization and its effect upon learning may be affected by the stability of input orders over trials. The only studies investigating the effects of intertrial presentation order relationships have compared constant and randomly varying presentation orders over trials of unrelated word lists. In the first such study, Waugh (1961) found no varied orders of presentation of monosyllabic words. Stimmel and Stimmel (1967) reported a similar result with consonant trigrams as stimuli. However, the majority of studies involving comparisons of constant and varied presentation orders have reported a superiority of the constant order condition. Lachman and Laughery (1968) and Mandler and Dean (1969) included constant and varied presentation order conditions in their experiments and reported a superiority in the constant conditions. Jung and Skeebo (1967) obtained the same advantage for constant order conditions. They also found that under constant conditions there was a shift from recalling the last-presented items first, to recalling in the order of presentation. Similarly, Wallace and Nappe (1970) found that constant presentation order resulted in significantly better recall than varied order, and that there was a strong correspondence between presentation order and recall order for constant conditions. Sohn (1967) employed simultaneous tachistoscopic presentation of a list of words in a circular array and found that free recall learning was more rapid when items maintained a constant spatial position across trials than when spatial location varied. In all of the studies cited, contiguity organization was not required, though the effectiveness of presentation order manipulations in most of the studies suggests that it did occur. Bower, Lesgold, and Tieman (1969) forced contiguity organization. Ss were presented quartets of unrelated words with instructions to form a mental image incorporating the words in the quartet (a procedure which they reported produced large clustering effects of the quartet members). Learning was faster when the assignment of items to quartets, and the order of quartets, was constant over trials than when the composition of quartets changed randomly over trials.

The evidence reviewed indicates that consistency of contiguity relationships across trials facilitates recall, and presumably the organization of those contiguous items. Again, though, these intertrial presentation order effects can result from both direct and indirect effects. In the multiple trial case, even the direct contiguity hypothesis would predict differences in recall, since groups receiving changing orders would have no constancy of contiguity, while those receiving constant orders would have the opportunity for organization based upon consistent contiguity. Distinguishing between the direct and indirect bases would again seem to require a manipulation of the item-dependent relationships between the items which undergo the various intertrial presentation order relationships. All of the studies testing the effects of presentation order constancy have used unrelated words only. Indirect contiguity effects would predict a greater facilitation of constancy of presentation for related words than for unrelated. This would only be true if the items that are contiguous are the related items, as would be the case for blocked presentation. With blocked presentation, different degrees of intertrial variation can be achieved by varying the order of categories, instances within categories, or both, while maintaining blocked presentation. These manipulations would be expected to be more effective with a greater degree of relationship of members of a category. However, if contiguity is an independent basis for organization, manipulations of contiguity consistency should be equally effective for all degrees of item-dependent relationships among items. If the related items are presented in random order, then maintaining a constant order should not be any more advantageous than a constant order of unrelated items. From a direct contiguity viewpoint, constant orders should facilitate recall of randomly ordered related and unrelated items. Whether there should be any effect of constancy of random orders according to the indirect view would depend on whether there are sufficient opportunities for item-dependent relationships between contiguous unrelated words to be actuated by the consistency of their contiguity.

Summary and Foci of Present Research

The literature review has focused on two aspects of the study of organizational processes, the measurement of organization and the determination of the nature of item-independent contiguity effects on organization and recall. With respect to the latter problem, it is clear that there are effects of contiguity on organization, and that theoretical explanations of a variety of learning and memory phenomena rely upon their existence. It was suggested however, that whether the effects of contiguity derive from the direct representations of contiguity relationships or from the indirect effects of contiguity on item-dependent representation has not yet been demonstrated. Comparisons of clustering after blocked and randomized presentation orders of categorized words cannot answer the question, because direct contiguity effects would augment clustering also. And, the demonstration of contiguity organization of normatively unrelated words is not incompatible with an indirect effect interpretation, unless the rather tenuous assumption is accepted that the contiguously occurring, normatively unrelated words are indeed not potentially relatable semantically by the individual S in the experimental context. The approach proposed here to disentangle the two sources of contiguity effects is to manipulate simultaneously item-independent contiguity and item-dependent semantic relationships. Cofer et al. (1966) followed such a procedure, with ambiguous results. They presented high- and low-frequency associates of categories in random and blocked orders. In the present experiment, differences in degree of semantic relationship are maximized, by comparing category associates to normatively unrelated words. In addition to measuring clustering and recall, IRTs are examined in an attempt to obtain further information concerning the operation of contiguity effects.

The comparison of blocked and random presentation orders is a manipulation of contiguity within a trial. This manipulation serves as a starting point for the examination of the effects of the constancy of contiguity across trials. In random conditions, a constant presentation order is compared to a varying order. In blocked conditions, the constancy of category order and instance order are manipulated simultaneously. As with the intratrial contiguity comparison, the presentation orders are compared for semantically related and unrelated words in order to ascertain whether the constancy of contiguity effects are due to direct or indirect contiguity effects.

The second major purpose of the present study is to extend the basis for regarding IRT analyses as valid and useful indices of organization. The need for such a measure was suggested by the desire to have a common index of organization for a variety of experimental situations, and by the unavailability of alternative indices in some experimental tasks. Three varieties of IRT analyses are attempted in the present experiment. The first is partially a replication of Pollio et al. (1969), in that it compares IRTs for within- and between-category pairs. It goes beyond their study in that the comparison is made for semantically related and unrelated categories, yielding varying degrees of adoption by S of the E-defined categories. In addition to determining the relationship between IRT patterns and indices of category clustering, the relationship between IRT patterns and indices of subjective organization is also examined. In the multitrial situation, the IRT between two words is expected to be a function of the number of previous trials on which that pair was recalled.

Demonstrating a relationship between IRT patterns on the one hand, and clustering and subjective organization on the other hand, would support the validity of IRTs as a measure of organization. An attempt is made to go further and demonstrate that IRT analyses are useful, in that they provide information concerning organization that is otherwise unavailable. Two types of analyses are performed for this purpose. First, the predictive value of IRTs for future organization is examined. The probability of subsequent occurrences of a pair in S's free recall output is expected to be an inverse function of the duration of the IRT for that pair on early occurrences. Second, the sensitivity of IRT analyses to the contiguity organization, as well as other aspects of organization not specified a priori, is evaluated. To accomplish this purpose IRTs are collected in all of the experimental conditions involving contiguity manipulations in order to determine whether additional information can be obtained concerning the operation of contiguity effects.

CHAPTER II

METHOD

General Experimental Design

Each S participated in a 20-trial free recall learning task, where each trial consisted of the presentation of a list of words followed immediately by the recall of the words in any order (free recall). The list contained 20 words, representing four instances of each of five categories. A category is a group of words defined as such by E. The designation of categories is relevant to both the independent and dependent variables. Item-dependent and item-independent characteristics of the stimuli were manipulated with respect to the defined categories, and IRT and clustering analyses were performed with respect to those categories.

Three dimensions of structure of the lists were manipulated in a between-Ss design. The first factor, Type of Item, was the degree of semantic relationship among words belonging to the same category. Related lists contained groups of words which were members of the same normatively defined, superordinate category, and these groups served as the E-defined categories. In unrelated lists, there were no superordinate or associative relationships among the words. The sets of words defined as categories by E were those words which had been matched with members of the same category in the related list. The two types of items were combined factorially with the six presentation order conditions resulting from the manipulation of Intratrial Contiguity, and nested within that variable, Intertrial Contiguity Constancy. Table 1 contains a schematic representation of the order of presentation on two trials in each of the presentation order conditions. Intratrial Conti-

TABLE 1

SCHEMATIC REPRESENTATION OF PRESENTATION ORDER ON TWO TRIALS FOR SIX PRESENTATION ORDER CONDITIONS. LETTERS REPRESENT CATEGORIES, AND SUBSCRIPTS SPECIFIC INSTANCES OF THE CATEGORY

	Serial Position in Presentation																			
Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Random Constant																				
1	b_3	a_2	d_3	d_1	b_4	d_2	c_4	e_2	a_1	c_3	d_4	a_4	e_1	e_3	e_4	c_2	a_3	c_1	b_2	b_1
2	b_3	a_2	d_3	d_1	b_4	d_2	c_4	e_2	a_1	c_3	d_4	a_4	e_1	e_3	e_4	c_2	a_3	c_1	b_2	b_1
Random Varied																				
1	b_3	a_2	d_3	d_1	b_4	d_2	c_4	e_2	a_1	c_3	d_4	a_4	e_1	e_3	e_4	c_2	a_3	c_1	b_2	b_1
2	a_3	e_4	c_2	e_1	d_1	a_2	c_4	b_4	e_2	d_4	a_1	b_2	b_1	e_3	c_4	c_2	b_3	c_2	d_3	a_4
Blocked Constant-Constant																				
1	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4
2	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4
Blocked Constant-Varied																				
1	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4
2	a_4	a_2	a_3	a_1	b_1	b_4	b_3	b_2	c_4	c_1	c_3	c_2	d_2	d_3	d_1	d_4	e_3	e_4	e_1	e_2
Blocked Varied-Constant																				
1	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4
2	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4	b_1	b_2	b_3	b_4	a_1	a_2	a_3	a_4
Blocked Varied-Varied																				
1	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	c_3	c_4	d_1	d_2	d_3	d_4	e_1	e_2	e_3	e_4
2	c_4	c_1	c_3	c_2	d_2	d_3	d_1	d_4	e_3	e_4	e_1	e_2	b_1	b_4	b_3	b_2	a_4	a_2	a_3	a_1

guity was manipulated by presenting members of the same category either randomly dispersed throughout the list (random), or contiguously (blocked). Nested within random conditions, the order of presentation of words was either constant or varied across trials. In blocked conditions, the constancy of category order and instance order within categories were manipulated independently. The four resulting blocked groups were: order of categories and instances within categories constant across trials (constant-constant); categories constant, but instances within categories varied (constant-varied); categories varied, but instances within categories constant (varied-constant); and both categories and instances within categories varied (varied-varied).

The design was doubled by using two sets of specific presentation orders for each of the 12 conditions to control for order effects of specific words within and between trials.

Stimulus Materials

Word Lists

All words were monosyllabic nouns, beginning with a consonant, containing three to six letters and having a frequency on the Thorndike-Lorge General Count (Thorndike & Lorge, 1944) ranging from 6-AA. Although a number of the words also have verb functions, words were chosen whose noun function was both obvious and dominant.

Related words. The Cohen, Bousfield and Whitmarsh (1957) norms were used to select the categories and instances for the related word list. Five categories, with four instances each, were chosen. The three highest ranking associates of each category were eliminated. Categories which bore relationships to each other were not used (e.g., articles of clothing-parts of body; animals-birds), nor were instances from different categories which might be associated (e.g., mountain-goat). Rhymes were eliminated, and each of the instances within a category began with a different letter. Instances were chosen which would be familiar to all subjects as members of the category. Categories and instances were selected such that control words of the form described below (see Unrelated words) were available. Without violating any of the above constraints, the highest ranking associates of each category were chosen as instances, while trying to keep the distribution of the rank order of association of the instances to the category as similar as possible for all categories.

Unrelated words. The set of unrelated words was constructed by selecting a matching word for each word in the related list. Each word on the unrelated list was of the same length and had the same first letter as its corresponding word in the related list. The Thorndike-Lorge frequencies of each word from the related list and its respective control word were matched as closely as possible. Matching words for different instances of the same category which seemed at all related were eliminated (e.g., toe-bruise for tin-bronze; fog-port for fir-pine), as were obvious relationships between matching words for instances of different categories. Rhymes within the unrelated word list were also excluded. One instance from each category on the related list was selected to serve as its own matching word on the unrelated list. The word chosen from each category was the one that best optimized the list of unrelated words in terms of the characteristics just described. Table 2 contains a list of the categories and instances used in the related word list. The rank order and frequency of association of the instances to the category on the Cohen et al. norms are

TABLE 2

RELATED WORDS BY CATEGORY, AND MATCHING UNRELATED WORDS, WITH THEIR NORMATIVE VALUES

Related Words	Category Rank[a]	Category Frequency[a]	Frequency[b]	Unrelated Words	Frequency[b]
Furniture					
Couch	4	122	28	Couch	28
Desk	5	103	A	Debt	A
Stool	8	33	16	Shrub	17
Bench	12	12	46	Brick	49
Animals					
Cow	4	164	A	Cow	A
Deer	7	47	35	Dart	33
Sheep	12	28	A	Scale	A
Wolf	17	16	A	Wine	A
Trees					
Pine	4	104	A	Pipe	A
Birch	5	98	16	Booth	15
Spruce	6	73	11	Strand	12
Fir	8	52	11	Fir	11
Clothing					
Pants	4	130	6	Prank	6
Coat	5	128	AA	Coal	AA
Skirt	6	123	A	Sword	A
Vest	18	11	21	Vest	21
Metals					
Tin	5	131	36	Toe	35
Gold	6	115	AA	Gate	AA
Zinc	8	83	10	Zinc	10
Bronze	11	29	19	Breeze	29

[a]From Cohen et al. (1967) category norms.

[b]From Thorndike and Lorge (1944).

given for each word in the related list, along with the Thorndike-Lorge frequency for each word. The matching word on the unrelated list for each word on the related test is given along with its Thorndike-Lorge frequency.

Presentation Orders

A set (Set A) of 20 sequences of the 20 items was constructed for each of the six conditions employing the related words. The 20 words were placed in a random order for the random-constant condition and the same order was used on all 20 trials. That order was also used on Trial 1 for the random-varied condition, with a different random order constructed for each of the other 19 trials in that condition. For the blocked conditions, a random order of the categories and instances within each category was constructed to serve as the presentation order on Trial 1 in all four blocked conditions. The blocked-constant-constant condition utilized the identical order on all subsequent trials. The blocked-constant-varied condition utilized the same order of categories on all trials, but the order of instances within each category was determined randomly on each trial. In the blocked-varied-constant condition a different random order of categories occurred on each trial, but the order of instances within each category was the same of all trials. In the blocked-varied-varied condition the order of categories on Trial n was the same as the order of categories on Trial n in the blocked-varied-constant condition, while the order of instances within each category on Trial n was identical to the order of instances within the same category on Trial n in the blocked-constant-varied condition.

A second set (Set B) of presentation sequences was constructed for each of the six related word conditions. The same words were used, but different random orders of words, categories, or instances within categories determined the presentation order on Trial 1. Presentation orders on subsequent trials for each condition in Set B bore the same relationship to Trial 1 order as the corresponding condition in Set A, with different random orders of words, categories or instances within categories selected for appropriate conditions.

The 12 sets of presentation sequences for the unrelated lists were constructed by replacing each word in each set and condition of the related list by its matching word, on all trials. Thus, whatever the order of presentation of the related words was on a particular trial in a particular presentation order condition, the identical order of their matched words was used for the corresponding trial and presentation order condition in the unrelated condition.

The actual presentation orders used on Trial 1 in each of the experimental conditions is shown in Appendix A. Of particular interest is the lag (number of intervening items) in presentation between pairs of words which are members of the same category. The lags are obviously the same for related and unrelated lists because of the correspondence in presentation orders. In a category containing four words, there are six pairs of words. The lag between every pair of words in each category, for Sets A and B, is shown in Table 3. If four category members are blocked, the mean lag for that category must be .67, and therefore the mean lag in all blocked lists was the same. For the two random orders constructed, the mean lag between members of the same category was 5.87 and 6.80.

TABLE 3

PRESENTATION LAG ON TRIAL 1 BETWEEN PAIRS

OF WORDS FROM THE SAME CATEGORY

	Word Pair						
Category	1-2	1-3	1-4	2-3	2-4	3-4	Mean
Random, Set A							
1	4	1	0	6	5	0	2.67
2	4	7	14	2	9	6	7.00
3	7	2	0	4	6	1	3.33
4	18	0	14	17	3	13	10.83
5	10	7	1	2	8	5	5.50
ALL							5.87
Random, Set B							
1	2	2	6	5	3	9	4.50
2	6	8	6	15	13	1	8.17
3	13	1	10	11	2	8	7.50
4	0	9	18	8	17	8	10.00
5	1	6	7	4	5	0	3.83
ALL							6.80
Blocked, Sets A and B							
ALL							.67

Apparatus

The Ss sat against one wall of a dimly lit soundproof chamber, facing the opposite wall, about 1.5 m. away, upon which the display panel was mounted at eye level. The display consisted of ten Burroughs Nixie tubes set in a single horizontal row, spaced approximately 1.6 cm. apart, and covered by colored cellophane to maximize contrast and reduce glare and reflection from elements which were not lit at a particular time. Each Nixie tube, approximately 3.5 cm. high and 1.6 cm. wide, was a 15 bit display, consisting of 15 filaments, which by appropriate selection allowed the presentation of any alphanumeric character, as well as other symbols. A directional microphone was placed on a chair directly in front of S. The subject's recall was recorded on one track of a 4-track stereophonic tape-recorder. The tape-recorder and all control equipment for the display panel were located in the room outside of the soundproof chamber. Except while reading instructions, E was also stationed outside the chamber, where he listened to S's recall over earphones and wrote down all responses made during each recall interval.

The sequence of events during the experimental session was governed by a pre-punched paper tape. The sequence was first typed onto paper tape by means of a Flexowriter in accordance with a Flexowriter coding system, and then converted to binary coded paper tapes on a PDP-1 computer. The paper tapes were fed into the Wang block-tape reader of the apparatus control system, which read blocks of 160 bits at a time. Each of 150 of the bits in each block corresponded to one of the elements in one of the displays. Thus, the set of bits punched in each block determined the set of elements simultaneously enabled on the displays, thereby determining the word or cue presented. The remaining 10 bits in each block were used to control other equipment. Three of these bits determined which of three timing resistors was activated, which determined the duration of each event. One bit controlled the tape-recorder, which was programmed to be "ON" only during recall intervals, and another bit controlled a 1000 HZ tone which was recorded for 150 msec. on the second track of the tape-recorder at the onset of each recall interval.

Subjects

The Ss were 96 undergraduate females attending summer sessions at the University of Michigan. All Ss were paid for their participation.

Procedure

Four Ss were assigned to each of the 24 experimental conditions. Ss were assigned randomly to conditions in the order of their participation in the experiment.

Except for the differences in the set of lists used, the procedure was identical for all Ss in all conditions. The S was seated in the soundproof booth and read the instructions (see Appendix B). She then said her name in order that the E could adjust the microphone gain to the S's speaking volume. A practice trial followed, consisting of a ready signal, eight letter-triads to familiarize the subject with the display, and a recall signal, all occurring at their normal rate of presentation. The S did not recall the items on the practice trial. After any of the S's questions were answered, the 20 trials were run in succession. Each trial consisted of a ready signal for 2 sec., followed by serial presentation of the 20 words at a 1-sec. rate, then a 1 sec. recall signal and finally a 50 sec. recall interval. The ready signal was a row of six dashes. The display was blank during the 50 sec. recall interval. The first letter or symbol of every visual presentation appeared in the same position, on the first display tube on the left of the panel. Each recall interval was immediately followed by the ready signal for the next trial.

The S was told that she could begin her recall as soon as the recall signal appeared, and that she was to recall as many of the words as she could in any order she wished. She was also told that the same words would be presented on each trial, though perhaps in different orders. The S was asked to face the display at all times so as not to miss any signals or words and to enable better recording.

Scoring

Word Recall

The E's written record of responses was checked against the tape-recording of the experimental session. Partial words were omitted from the scoring. All complete words were categorized as correct responses, intrusions (intra- and extra-category intrusions for the related word conditions), and repetitions within the recall interval. The unfamiliar nature of some of the characters as displayed allowed for perceptual errors. If a response could be identified as a perceptual error, it was scored as the correct response. The criteria for such identification were consistent recall of the word on many trials, recall of a word which was graphically similar to a list word without recall of that list word, and a post-experimental interview in which E inquired into the nature of responses which he had identified as potential perceptual errors. The primary instance of perceptual errors was the recall of the word SKIRT in the related word list, instead of the word SHIRT. While having S read the words aloud during presentation would have provided greater opportunity to identify perceptual errors, such a procedure was not used, in order to avoid interfering with S's organizational processes during presentation.

Measurement of Interresponse Times

The measurement of the IRTs was accomplished with the use of a PDP-4 computer which had associated input-output equipment for the analysis of speech recordings. The tape recording of recall intervals was treated as an amplitude record over time. Two general steps were required for the measurement of the appropriate times from this record. The first step was the conditioning of the signal for input to the computer. The tape recordings were played back on a 2-track stereophonic tape-recorder (Ampex, Model 351), and from there fed through an amplifier (General Radio Co., Unit Amplifier Type 1206-13), and then through an amplitude extractor. The amplitude extractor consisted of a full-wave rectifier and low-pass filter which produced an amplitude envelope, a relatively smooth amplitude record over time, with the high frequency changes in amplitude within a word eliminated. The amplitude envelope was then passed through a wide-band DC-1MC 10 watt amplifier (Krohn-Hite, Model DCA-10R) to condition the signal for the computer. The conditioned signal was then fed into the computer where the second step took place, that of identifying the onset and offset of each word and measuring the appropriate times. The computer was programmed so that its clock began at the occurrence of the 1000 Hz tone at the beginning of each recall interval. The computer could be in one of two states, corresponding to the presence or absence of a word. The amplitude of the signal was sampled by the computer every millisecond. A threshold was set at approximately one-tenth of full scale of the highest amplitude peak. The threshold value was selected by trial and error to allow the inclusion of most of the words and the exclusion of most of the extraneous sounds recorded, given the sensitivity of the recordings and the level of background noise on the tapes. The computer changed state from absence of a word to presence of a word every time the amplitude changed from below threshold to above threshold and remained above threshold for 25 consecutive msec. The criterion for changing state from presence of a word to absence of a word was the same, except in the opposite direction. The computer clock measured the time from onset of the recall interval to the first change in state and then the time between each successive change in state, thus providing the latency of the first response, the duration of each response, and the pause time between each response and the next one in S's recall. In addition to printing out these times for each trial, the computer printed out the time from the onset of one response to the onset of the next one by summing the duration of the first response and the time between the first and second response for each pair of responses. All data reported dealing with IRTs employed the latter interval, from onset to onset. Since all words were monosyllabic and could be emitted with approximately equal durations, it was decided that duration of response should be included in the IRT when used as a measure of the organizational processes in recall, in order to include extended durations of response as part of the IRT.

There were two types of errors which the computer could make in measuring the IRTs--incorrectly identifying a signal as a response when it was not a response, and not identifying a signal as a response when it was a response. In addition to the computer printout of times, a pen recording of the amplitude envelope which the computer analyzed was also produced on a Sanborn heat pen recorder moving at a speed of 20 mm./sec. An event recorder on the pen recorder also indicated every time the computer changed states. By listening to the tape recording while monitoring the pen recording the author could identify either of the two types of errors. Incorrectly identified signals were corrected by summing the two IRTs bounding the signal, and missed signals were corrected by marking their location on the pen recording and dividing the IRT which included the missed signal into two times, measured by converting the appropriate distances on the pen recording into times, given the knowledge of the speed of movement of the recording paper.

Clustering Index

Three clustering indices were obtained for each recall trial of each S, all of which are based on the number of category repetitions (r), or contiguous occurrences of two words from the same category observed in the S's recall protocol. The ratio of repetition,

$$RR = \frac{r}{N - 1}$$

where N is the number of items recalled, was developed by Bousfield (1953), and is designed to provide an index which is independent of amount recalled. Although RR takes into account total recall, it does not take into account the specific items recalled, particularly with respect to the categorical representation in recall. Different compositions of recall can allow differential opportunity for category repetitions. Bousfield and Bousfield (1966), and Bousfield and Puff (1964) therefore provided a formula for expected r, given the specific items recalled:

$$E(r) = \frac{\sum_{i=1}^{k} m_i^2}{N} - 1$$

where m is the number of words recalled from category i. They proposed a deviation score representing the difference between observed r and expected r, O-E(r), as an index of clustering. As Shuell (1969) has noted, this measure fails to take into account the maximum possible clustering, M(r), and enables minimally clustered long lists to produce larger clustering scores than maximally clustered short lists. A correction suggested by Shuell is to define a deviation ratio,

$$DR(r) = \frac{O - E\ (r)}{M - E\ (r)}$$

where

$$M(r) = N - k$$

k being the number of categories represented in recall.

Table 4 shows the clustering scores that would be obtained using the three clustering indices described in some example sequences. The sequences were constructed to accentuate some of the differences in the indices. The data from the experiment were analyzed using all three measures. However, since the results from all three measures were essentially equivalent with respect to the experimental manipulations only the data for the DR(r) measure are reported.

TABLE 4

CLUSTERING SCORES FOR EXAMPLE SEQUENCES

USING DIFFERENT INDICES.

LETTERS IN SEQUENCES REPRESENT CATEGORIES

	Clustering Index		
Recall Sequence	RR	O-E(r)	DR(r)
aaaabbbbccccddddeeee	.79	12	1.00
aabbccddeeaabbccddee	.53	7	.58
aaaabbbbccccdddd	.86	3	1.00
aabbaabb	.57	1	.33
aabbccdd	.57	3	1.00

CHAPTER III

RESULTS

Relationship Between Interresponse Times and Measures of Organization

The IRT was measured between every successive pair of words in the recall of all Ss in all conditions. These successive word pairs were divided into mutually exclusive and exhaustive types, defined in terms of the nature of the two words comprising the pair. The two types of word pairs of primary interest are those in which the members of the pair are different correct words from the list. For the within category type (W), both words were members of the same category, while for the between category type (B), the two words were from different categories. The W and B pairs combined accounted for 97.6% of the word pairs in the related conditions, and 98.5% of the pairs in the unrelated conditions. The remaining pair types involved cases where there was an immediate repetition of a word by S, or where one or both members of a pair were extralist intrusions. Because of the paucity of data, little more will be said of pairs involving repetitions or intrusions.

Relationship between IRTs and clustering. There are two basic kinds of evidence available concerning the relationship between IRTs and clustering. The first of these involves a demonstration that the information concerning the degree of organization as measured by an index of clustering in a particular experimental condition, whether in comparison to chance expectations or to another experimental condition, is also manifest in the pattern of IRTs. If IRTs reflect organization, then the extent to which Ss organize according to E-defined categories should be indicated by the magnitude of the difference between IRTs for B pairs and W pairs. The mean IRT for all B pairs and all W pairs was obtained for each S in the related and unrelated conditions. Clustering scores for each S on each trial were obtained using the deviation ratio measure of clustering, DR(r). A mean clustering score was obtained for each S by averaging the S's clustering scores on all trials. Table 5 contains the mean clustering scores of all Ss in related and unrelated conditions, as well as the mean IRTs for B and W pairs of all Ss in those conditions.

TABLE 5

MEAN CLUSTERING SCORE, AND IRT FOR BETWEEN-CATEGORY (B) AND WITHIN-CATEGORY (W) PAIRS, AS A FUNCTION OF TYPE OF ITEM

	Score		
Type of Item	Clustering	IRT for B Pairs	IRT for W Pairs
Related	.909	2.83	1.07
Unrelated	.085	2.36	2.13

The deviation from chance clustering in the related conditions was obviously significant, as all 48 Ss had a positive clustering score. The mean IRT for related B pairs differed from related W pairs by a factor of more than 2.5. For 47 of the 48 Ss in the related conditions, the mean IRT for B pairs was longer than the mean for W pairs. Figure 1 shows the frequency distribution of IRTs for B and W pairs in related conditions. The data are combined for all trials of all Ss in all presentation order conditions. Because of the difference in the frequencies of B and W pairs, the data are presented in Figure 2 as cumulative proportions of pairs of a given type having a maximum IRT as indicated.

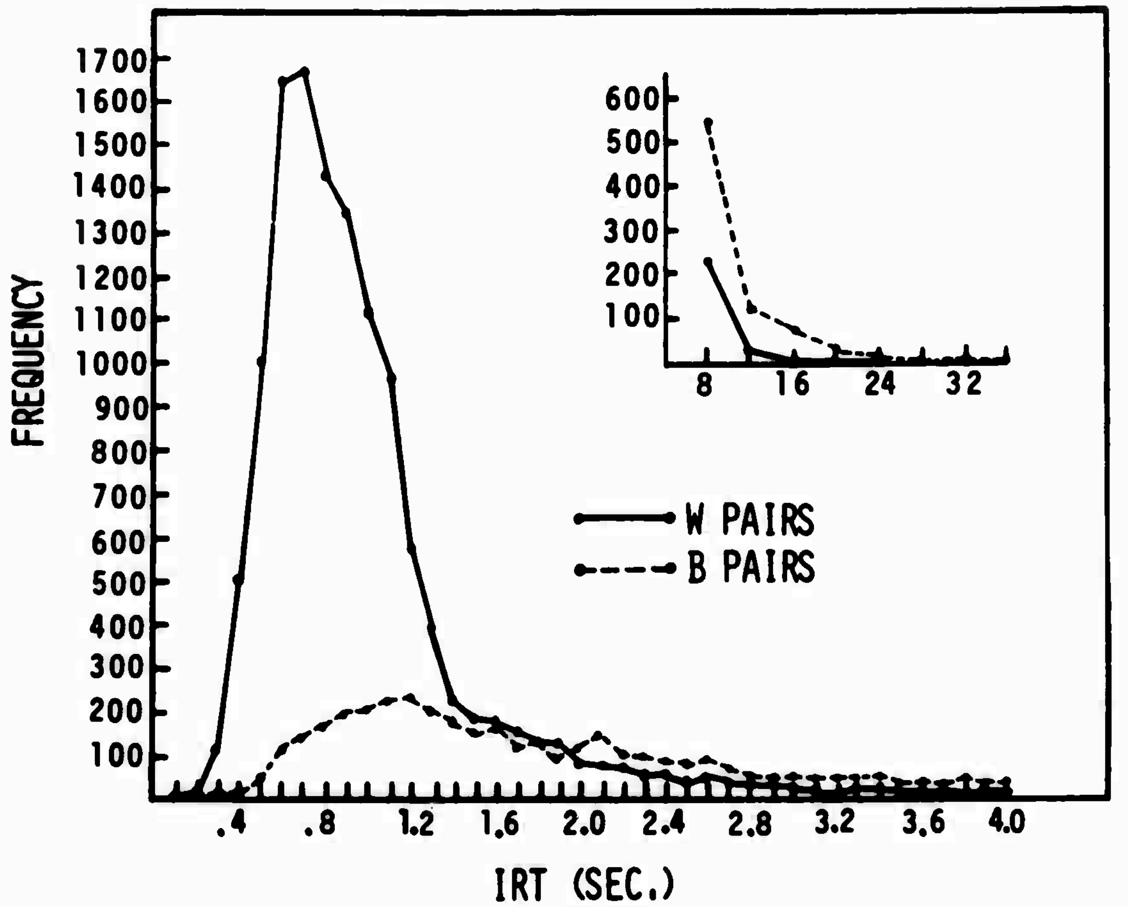

Fig. 1. Grouped frequency distribution of IRTs for B pairs and W pairs in related conditions. The original data were in msecs., and are grouped here such that .8 sec. = 700 msec. to 799 msec. The insert shows the tail of the distribution, with 8 sec. = 4000 msec. to 7999 msec.

A t test indicated a greater than chance degree of clustering in unrelated conditions, $t(47) = 3.148$, $p < .005$. Again, the IRTs for B pairs were longer than for W pairs, although the difference for the unrelated conditions was much smaller than that observed for the related conditions. The difference between the average IRT for B pairs and W pairs in the unrelated conditions was marginally significant, $t(47) = 1.702$, $p < .05$. Figures 3 and 4 contain the frequency distributions and cumulative proportion curves, respectively, of IRTs for B and W pairs in the unrelated conditions.

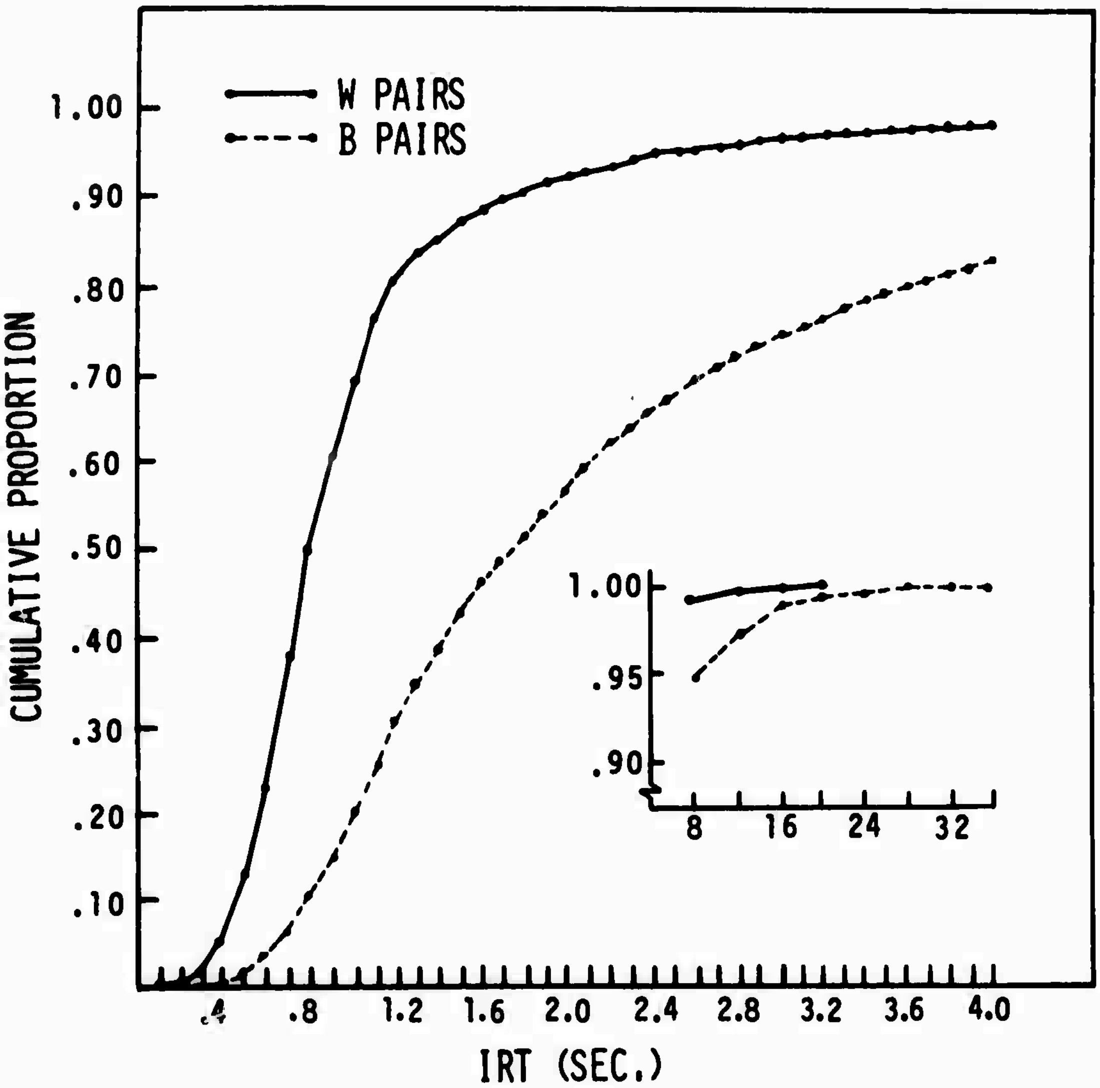

Fig. 2. Cumulative proportion of IRTs for B pairs and W pairs in related conditions, based on the frequency distribution presented in Fig. 1

The difference between the amount of clustering in the related and unrelated conditions was highly significant, $\underline{t}(94) = 21.128$, $\underline{p} < .001$. Two features of the IRT patterns for related as compared to unrelated conditions are of interest. The first is that the difference between IRTs for B and W pairs was greater in the related conditions than in the unrelated conditions. For each $\underline{S}$, a B minus W difference score was obtained. A $\underline{t}$ test comparing related and unrelated B minus W scores yielded $\underline{t}(94) = 9.148$, $\underline{p} < .001$. In addition, it was found

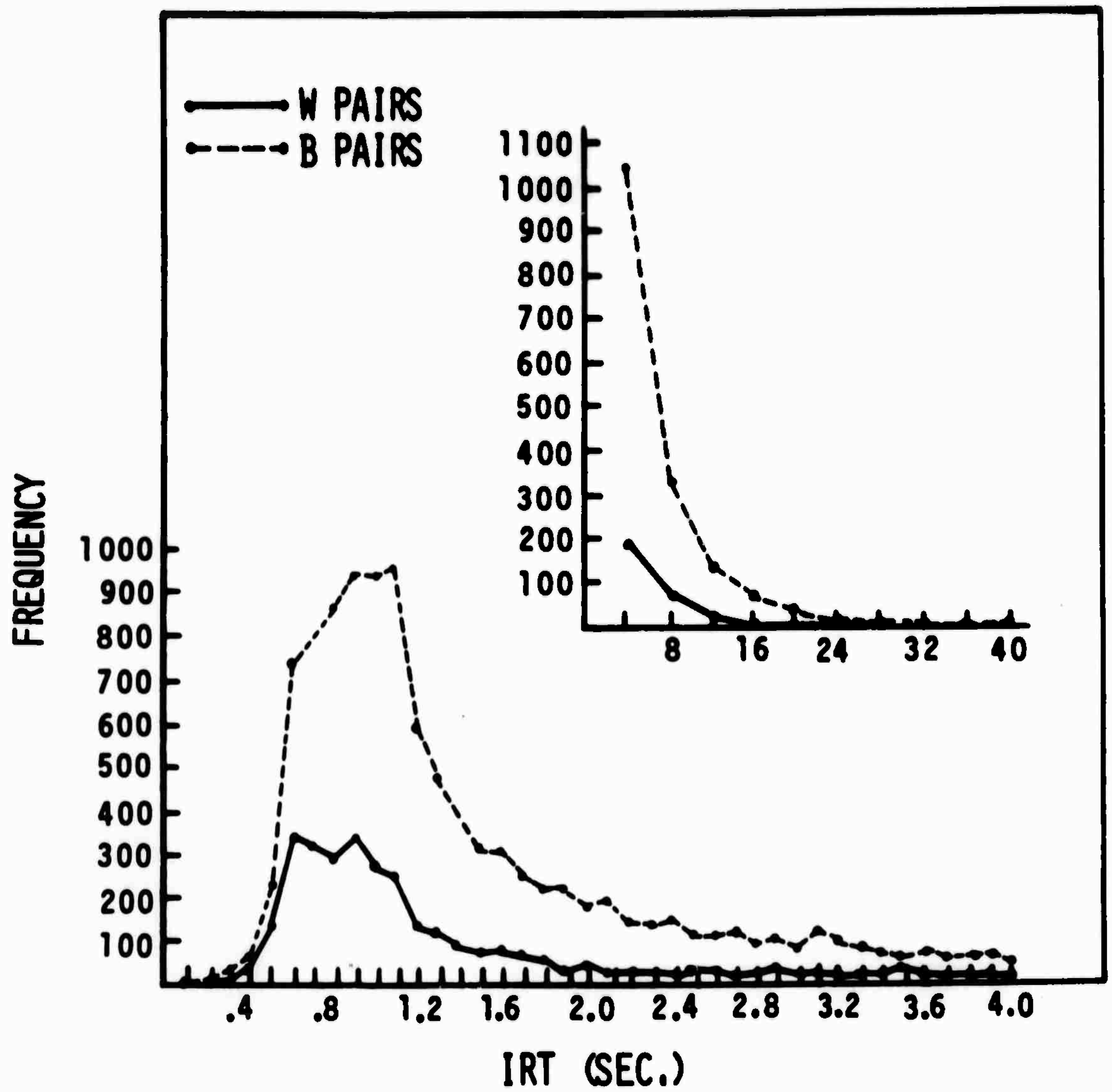

Fig. 3. Grouped frequency distribution of IRTs for B pairs and W pairs in unrelated conditions. The original data were in msecs., and are grouped here such that .8 sec. = 700 msec. to 799 msec. The insert shows the tail of the distribution, with 8 sec. = 4000 msec. to 7999 msec.

that IRTs for B pairs were longer in related than in unrelated conditions, $\underline{t}(94) = 3.722$, $\underline{p} < .001$, but that IRTs for W pairs were shorter in related than in unrelated conditions, $\underline{t}(94) = 8.173$, $\underline{p} < .001$. These results are just what would be expected if more of the between category pairs in the unrelated conditions were truly within category pairs, and more of the within category pairs were truly between category pairs, with respect to $\underline{S}$'s actual organization.

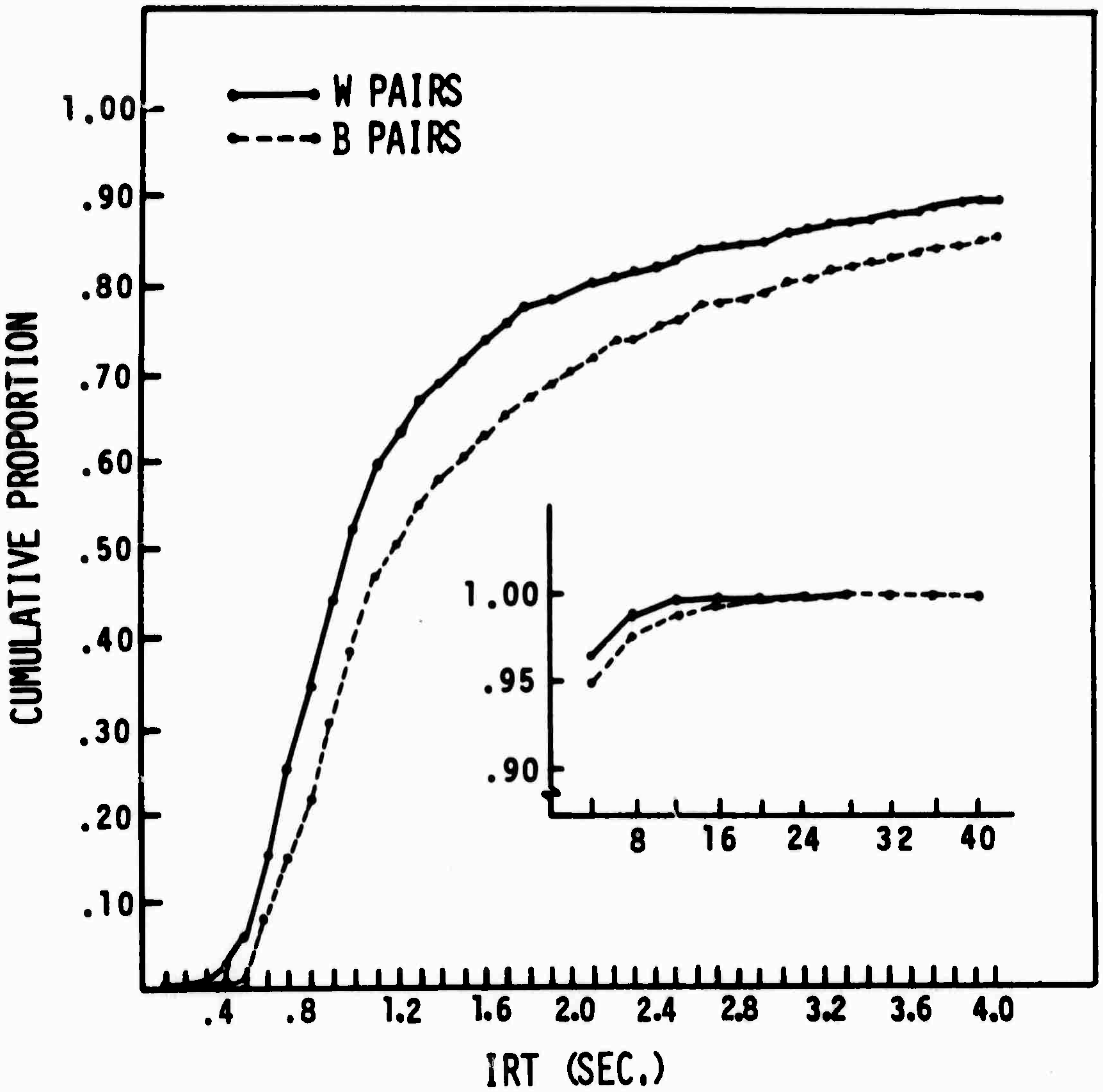

Fig. 4. Cumulative proportion of IRTs for B pairs and W pairs in unrelated conditions, based on the frequency distribution presented in Fig. 3.

The second major type of evidence concerning the relationship between IRTs and clustering is the relationship between clustering scores and B minus W scores within an experimental condition. The Spearman rank correlation coefficient between these two scores for Ss in the related condition was negative, $r_s = -.158$. However, the absence of a positive correlation is not surprising, given that more than 75% of the Ss in the related conditions had mean clustering scores ranging from only .917 to

.996. The S with the lowest clustering score (.213, compared to the second lowest score of .457) was the only S for whom the mean IRT for W pairs was longer than for B pairs. In the unrelated condition, with ties in the rank ordering broken in the conservative direction so as to minimize r_s, $r_s = .766$. The large sample approximation to the t distribution (Hays, 1963, p. 646) indicated a significant relationship between clustering scores and B minus W scores, $t(46) = 8.084$, $p < .001$.

IRTs and output serial position. The relationship between IRTs and output order is of particular interest with respect to S's organizational units. These organizational units are most readily identifiable for Ss in the related conditions. Trials on which Ss recalled all of the list items in a perfectly clustered sequence were selected for analysis. These are trials on which there are five successive categories of four instances each, and IRTs 4, 8, 12, and 16 represent the category transitions. By selecting these output protocols, any recall trial included in the analysis contributes one observation at each output position. Of the 960 trials in the related conditions, 403 satisfied the criteria for selection. Figure 5 presents the mean IRT as a function of output position on the selected trials. The difference between IRTs for B and W pairs, which was previously reported for all trials, is also obvious for all categories in S's output sequence on these selected trials. In addition, there are marked relationships between output position and IRT for both B and W pairs. IRTs of B pairs increase rapidly as a function of the position of the category transition in S's output. Except for one reversal at the end of the first category, there is a monotonic increase in IRTs of W pairs as position within the category

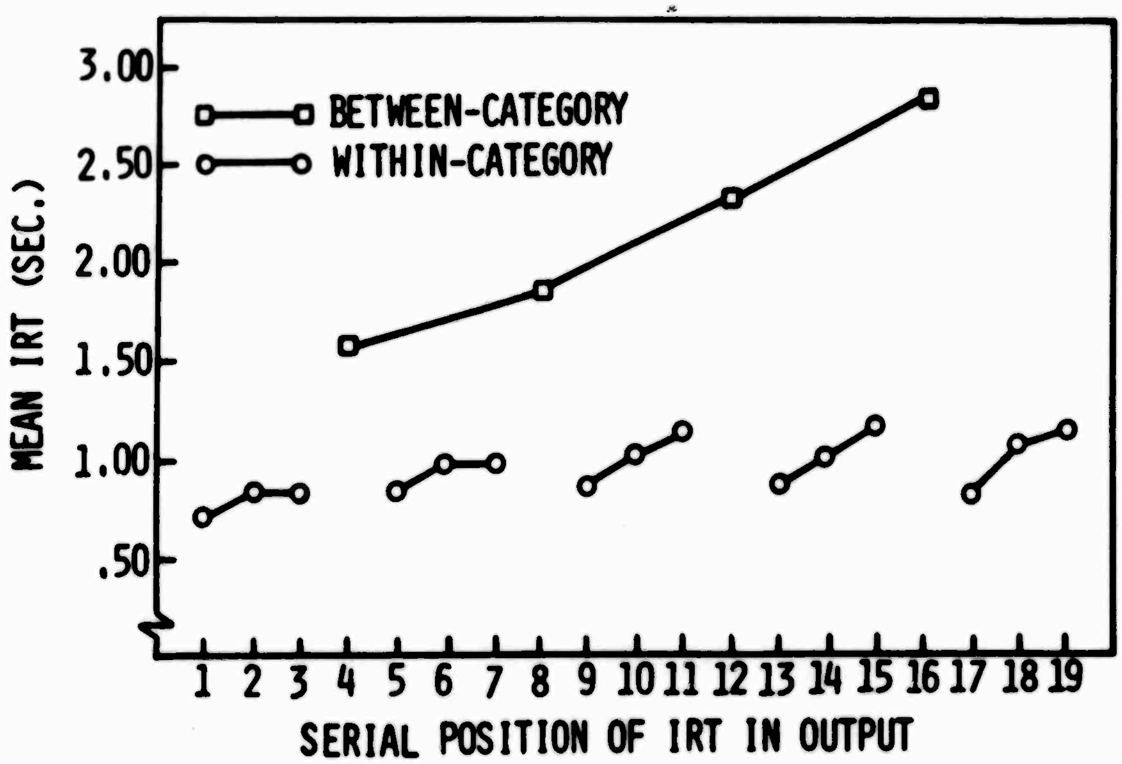

Fig. 5. Mean IRT as a function of output serial position, for trials which were perfect in recall and clustering, in related conditions only.

increases, for all categories. There is also an increase in IRTs of W pairs across categories. In general, the mean IRT at each position within a category increases as a function of the position of the category in the output sequence. However, there is not a monotonic increase in IRTs of W pairs across all output positions. The IRT at the first position within a category is shorter than the IRT at the last position within the previous category. A summary of the output position pattern of IRTs is as follows: As S continues to recall from the same category, the IRT increases gradually. When S shifts categories there is a large increase in IRT. The first within category IRT of the next category decreases below that of the last within category IRT of the previous category, but not as far as the first within category IRT of the previous category.

Relationship between IRTs and subjective organization. Measures of subjective organization are measures of output order stereotypy over trials. Such measures treat an intertrial repetition, or repetition of a pair of words on different trials, as the observable unit of organization. Therefore, an indication of the relationship between IRTs and subjective organization would be the relationship between the IRT between two successive words and the number of previous trials on which that pair had occurred. The grouping of all pairs to determine the relationship between IRT and number of prior occurrences would confound two factors, one being the relationship between IRT and total number of occurrences of a word pair, and the other being the relationship between IRT and number of prior occurrences of a word pair. Word pairs with relatively few prior occurrences would include word pairs with relatively few total occurrences as well as word pairs with many total occurrences. However, word pairs with many prior occurrences could only include word pairs with many total occurrences. In order to preclude any effects of item selection due to differential numbers of total occurrences, the relationship between IRTs and number of prior occurrences was determined separately for items with differing numbers of total occurrences.

Tables 1-4 in Appendix C contain the relevant data for B pairs in related conditions, W pairs in related conditions, B pairs in unrelated conditions, and W pairs in unrelated conditions, respectively. Each table consists of a matrix in which the entry is the mean IRT, summed over all cases in that condition, of the $\underline{m}^{th}$ occurrences of word pairs that occurred a total of $\underline{n}$ times, as designated by the column and row respectively. Entries in the column to the left of the data matrix indicate the number of pairs which occurred n times, for each n; this is the number of observations on which the mean in each corresponding row are based. The effect of number of prior occurrences is shown in the decrease in IRTs within rows, which appears in each condition. In general, a negatively decelerated decline is observed as a function of number of prior occurrences, in all conditions. A summary of the decrease in IRT as a function of number of prior occurrences is provided in Table 6. The mean IRT in the first-half and second-half of occurrences is shown separately for each number of total occurrences and each type of word pair. When there was an odd number of total occurrences, the middle occurrence ($m = n/2$) was divided equally into the first- and second-half. To the extent that the IRT functions are negatively decelerated, the comparison of first- and second-half IRTs is a conservative representation of the decline within a row. Despite the conservative bias, there was a decline from first-half IRT to second-half IRT in 57 of the 65 rows with relevant data (pairs with only one occurrence were not considered).

Of additional interest with respect to the utility of IRTs as a measure of organization is whether the IRT between two words on a particular occurrence differentiates word pairs which will occur different numbers of times on subsequent trials. The relationship between IRT and number of subsequent occurrences can be seen by comparing IRTs within columns of the matrices in Appendix C, which involve comparisons of the m^{th} occurrence of a pair, for pairs with different numbers of total occurrences. Two factors operate against obtaining a decline in IRTs within a column. The first factor is that as total number of

TABLE 6

MEAN IRT (SEC.) IN FIRST- AND SECOND-HALF OF OCCURRENCES OF WORD PAIRS.

DATA REPORTED SEPARATELY FOR BETWEEN (B) AND WITHIN (W)

CATEGORY PAIRS IN RELATED AND UNRELATED CONDITIONS,

AND FOR DIFFERENT TOTAL NUMBERS OF OCCURRENCES.

	Related B Pairs			Related W Pairs			Unrelated B Pairs			Unrelated W Pairs		
Total Number of Occurrences	n	1st Half	2nd Half	n	1st Half	2nd Half	n	1st Half	2nd Half	n	1st Half	2nd Half
1	2291	3.06	3.06	342	1.21	1.21	3420	3.15	3.15	708	2.77	2.77
2	1010	2.89	2.75	760	1.33	1.20	2376	3.05	2.60	542	2.65	2.52
3	414	2.59	2.09	1128	1.29	1.15	1404	2.44	2.13	360	1.95	1.78
4	292	2.27	1.78	1344	1.11	1.05	860	1.92	1.55	220	1.61	1.63
5	140	2.58	1.89	1430	1.23	1.09	680	1.79	1.47	205	1.13	1.17
6	108	1.35	1.75	1356	1.20	.95	666	1.43	1.32	174	1.33	.94
7	70	1.94	1.28	1169	1.05	.98	420	1.29	1.21	98	.93	1.02
8	56	1.57	1.55	1016	1.06	.97	352	1.28	1.30	88	1.97	1.29
9	45	.91	.93	999	1.01	.89	306	1.88	1.33	45	1.17	.79
10	40	.77	.97	820	1.06	.86	230	1.09	1.02	90	1.18	.97
11	22	1.00	.81	660	.91	.83	242	1.22	.96	143	1.21	.95
12	0	--	--	444	.96	.88	180	1.16	.94	120	1.20	1.11
13	0	--	--	234	1.02	.72	182	1.12	.85	78	.58	.54
14	0	--	--	308	.85	.68	140	.91	.84	126	1.01	.76
15	0	--	--	210	.73	.57	120	.75	.67	75	.96	.83
16	0	--	--	208	.82	.59	144	.90	.89	64	.72	.65
17	0	--	--	68	.62	.58	51	1.00	.94	34	1.03	.87
18	0	--	--	90	.71	.42	54	.98	.91	54	.81	.93
19	0	--	--	76	.49	.42	0	--	--	18	.72	.71
20	0	--	--	40	.45	.44	20	1.16	.50	0	--	--
ALL	4488	2.78	2.65	12702	1.10	.97	11847	2.39	2.17	3262	1.86	1.74

occurrences increases, the number of observations decreases. The mean IRT of pairs with large numbers of total occurrences is therefore more susceptible to the effects of any extremely long IRTs. The second factor is that the m^{th} occurrence of pairs with large numbers of occurrences must occur on earlier trials than is required of the m^{th} occurrence of pairs with relatively few total occurrences. As an extreme example, the first occurrence of a pair which occurs 20 times must occur on Trial 1, while the first occurrence of a pair which occurs only once can occur on any trial. If there is any general practice effect on IRTs over trials which is not tied to the specific occurrences of a word pair, it would result in longer IRTs for the m^{th} occurrence of pairs with numerous, as compared to few, total occurrences. Inspection of the matrices indicates a fairly consistent decline in IRTs within columns which is of sufficient magnitude to overcome the sources of negative bias described.

A more restricted test of the predictive capabilities of IRT measures was performed using the data from Trials 1 and 2 only. For each S, the pairs of contiguous items occurring in S's recall protocol on Trial 1 were divided into three groups, on the basis of whether the IRT between the two words was in the fastest, middle, or slowest third of the IRTs produced by that S on that trial. If the number of pairs emitted by the S on Trial 1 was not evenly divisible by three, the pairs were allocated to thirds of the distribution so as to keep the distribution symmetrical, and as nearly rectangular as possible. The probability that a pair of items was repeated in S's protocol on Trial 2, conditional upon its having occurred with a fast, medium, or slow IRT on Trial 1 was determined separately for pairs occurring contiguously in the same order and in opposite orders on Trials 1 and 2. Weighted mean conditional probabilities were then determined by combining across Ss. The data for related and unrelated conditions are reported in Table 7. Two aspects of the data which are irrelevant to the predictive

TABLE 7

PROBABILITY OF INTERTRIAL REPETITION ON TRIALS 1 AND 2, CONDITIONAL UPON TRIAL 1 IRT DURATION. PROBABILITIES REPORTED FOR RELATED AND UNRELATED CONDITIONS, AND FORWARD AND REVERSE RECALL

	IRT Duration		
Response Order	Fast	Medium	Slow
Related			
Forward	.26	.15	.10
Reverse	.14	.13	.07
Unrelated			
Forward	.18	.09	.06
Reverse	.07	.05	.05

capabilities of IRTs are that the probability of a pair being repeated in recall on successive trials is higher for related than for unrelated conditions, and that the probability that a pair will be repeated in the same order is higher than the probability that it will be repeated in reverse order. Of primary interest however, is the conditional probability of an intertrial repetition as a function of IRT on Trial 1, and it can be seen that there is a uniform decrease in this probability as IRT increases, in related conditions as well as unrelated, and for same as well as reverse recall order. Thus, IRT on Trial 1 is predictive of output order stereotypy, which is the basis for the measurement of subjective organization.

Effects of Contiguity on Organization and Recall Performance

For the purposes of analysis of variance, the 24 groups of the experiment constitute a partially nested design. The two levels of Type of Item (related and unrelated) are combined factorially with the six Presentation Order conditions. Five orthogonal comparisons were planned to evaluate particular factors of interest associated with the six Presentation Order conditions. The first of these factors is Intratrial Contiguity, comparing random and blocked presentation. The remaining four comparisons involve effects of Intertrial Contiguity Constancy. One of these variables is Constancy nested within random orders, comparing random constant with random varied conditions. The other three comparisons are the two main effects and one interaction resulting from the independent manipulations of Category Constancy and Instance Constancy nested within blocked conditions. Two Specific Orders were nested within each of the six Presentation Order levels. However, Specific Orders do combine factorially with Type of Item, since whatever the order of presentation is in a particular condition involving related words, the order is the same for their matched words in the corresponding condition involving unrelated words.

Specific Orders is a random effect, and therefore constitutes the appropriate error term for testing the effects of Type of Item and Presentation Orders. However, preliminary tests were carried out on the effect of Specific Orders pooled across Presentation Orders, as well as the interaction of pooled Specific Orders and Type of Item. In all of the analyses to be presented, all effects involving Specific Orders were negligible. The data were therefore collapsed across Specific Orders; all variation involving Specific Orders was combined with the within cell variation to form a residual error term for testing the effects of the remaining variables.

Trial 1 performance. On Trial 1 there was no opportunity for Intertrial Constancy to be a functional variable. The only Presentation Order manipulation was between blocked and random orders of presentation. Therefore, the data were collapsed across the various levels of Intertrial Constancy, and performance on Trial 1 was analyzed as a 2 x 2 factorial design, the variables being Type of Item and Intratrial Contiguity. The same analysis was performed for two dependent variables, clustering scores and recall performance.

Figure 6 presents mean clustering scores as a function of Type of Item and Intratrial Contiguity. That related words increase clustering scores was confirmed by the significant effect of Type of Item, $F(1,92) = 40.23$, $p < .001$. There was no main effect of Intratrial Contiguity, $F(1,92) = 2.62$, $p > .10$. Of primary interest is the interaction of Type of Item and Intratrial Contiguity, which was significant, $F(1,92) = 6.90$, $p < .025$. Tests of the simple main effects of blocking for the two different types of items indicated that blocking did have a significant facilitative effect on the clustering of related words, $F(1,92) = 9.12$, $p < .005$. The small decrease in clustering of unrelated words as a function of blocking did not approach significance, $F(1,92) < 1$. The fact that blocked presentation enhanced clustering to a greater extent in related conditions than in unrelated conditions

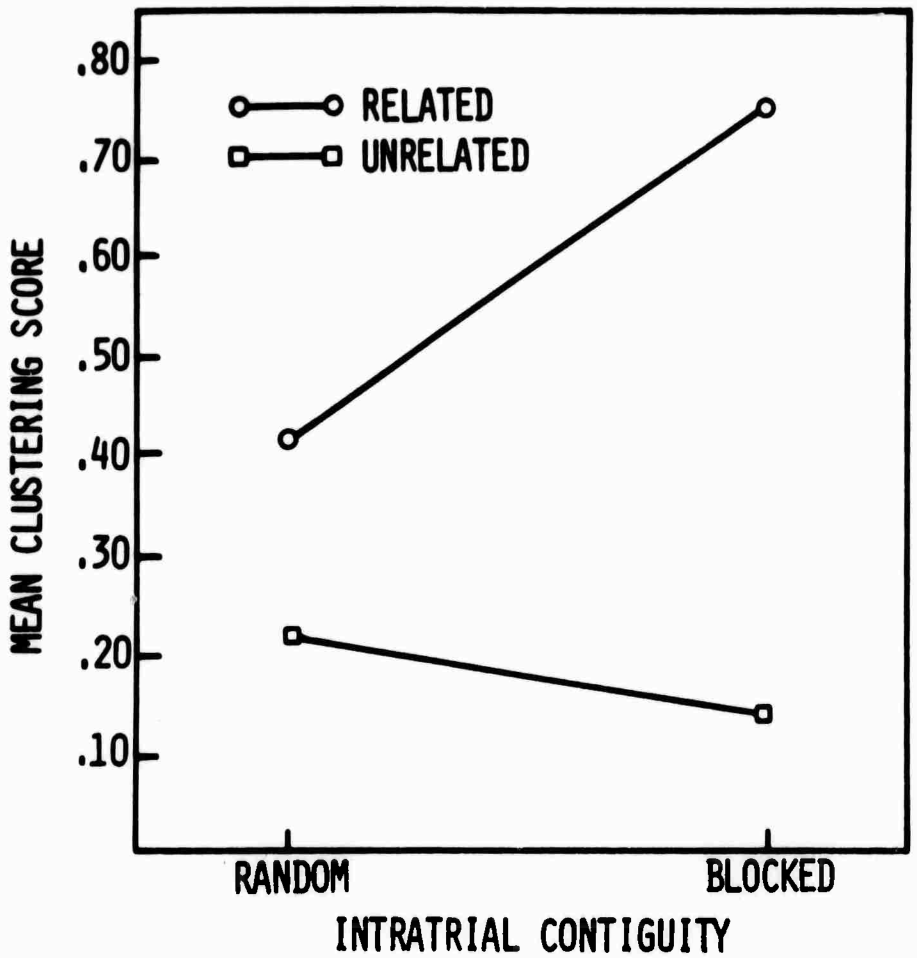

Fig. 6. Mean clustering score on Trial 1, as a function of intratrial contiguity. Type of item is the parameter.

suggests that blocking has at least the indirect effect of increasing the item-dependent organization of contiguous items. The presence of indirect effects does not in itself rule out the possibility of additional direct effects of contiguity. However, the lack of any facilitative effect of blocking on clustering scores--if anything, there is an opposite effect--does argue against such direct effects.

Mean recall scores are presented in Figure 7. The analysis of variance indicated only an effect of Type of Item, $F(1,92) = 71.99$, $p < .001$. There was no effect of Intratrial Contiguity, $F(1,92) =$

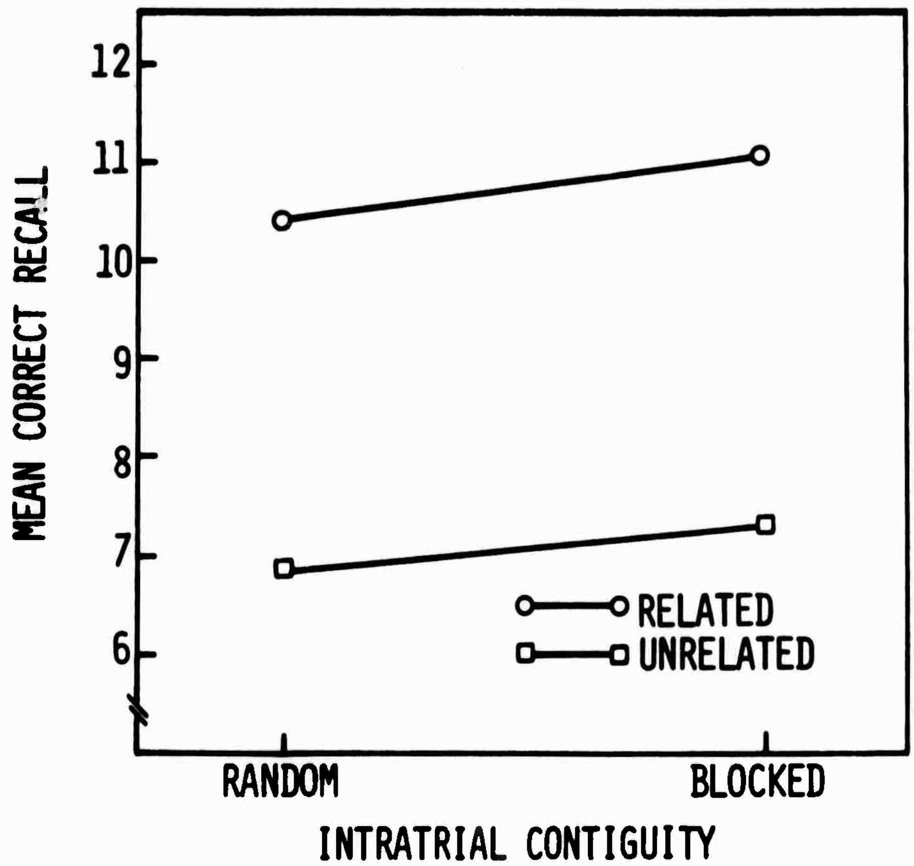

Fig. 7. Mean correct recall on Trial 1, as a function of intratrial contiguity. Type of item is the parameter.

1.51, p > .20, nor any interaction of Type of Item and Intratrial Contiguity, $F(1,92) < 1$. There were no simple effects of blocking on recall with either type of item, $F(1,92) = 1.13$, $p > .25$, for related items, and $F(1,92) < 1$, for unrelated items.

The discrepancy in the effects of blocking on clustering and recall scores in the related conditions would seem difficult to resolve for theories which assume that recall is mediated by organization. No artifactual basis is apparent for the increased clustering in blocked related conditions with no equivalent increase in recall. One explanation of the results would recognize the limited aspect of organization which is tapped by clustering scores. Since clustering only measures the organization which is consistent with the E-defined categories, one would have to postulate the existence of other bases of organization, functionally more powerful in the random related condition, which were compensating for the lower E-defined organization and producing equivalent levels of recall as in the blocked related condition.

Two kinds of evidence are available in additional analyses of performance in related conditions to suggest the operation of such alternative modes of organization. The first kind of evidence is obtained by separating recall into number of categories recalled, and number of words per category. For those categories represented in recall, the average number of words recalled per category is slightly greater in the blocked condition. This again suggests the use of these categories, and therefore their increased clustering in the blocked condition. In addition, the number of categories represented in recall is greater in the random condition, suggesting greater organization of members of different categories in that condition. This evidence is not very convincing, since the near equality of total recall in the two conditions requires differences in category recall to be balanced out by opposite differences in words recalled per category. More powerful and independent evidence of the existence of other bases of organization is provided by the analysis of IRT data in related conditions. Figure 8 shows the mean IRT for B and W pairs in the random related and blocked related conditions. The overall difference between B and W pairs is again indicative of the significant clustering in related conditions; and the larger difference between B and W pairs in the blocked condition is consistent with the higher

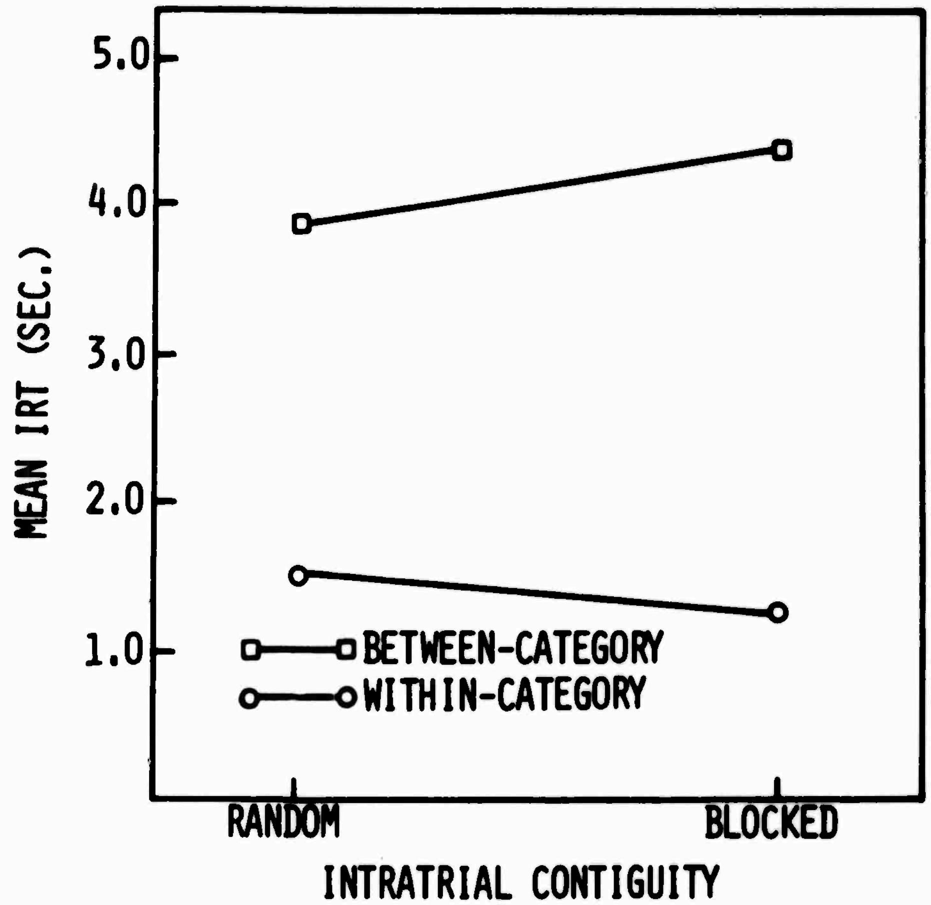

Fig. 8. Mean IRT on Trial 1 as a function of intratrial contiguity in related conditions only. Type of pair is the parameter.

clustering in that condition. What is particularly relevant to the present discussion is the form of the interaction between the effects of blocking and the type of pair. IRTs for random W pairs are longer than for blocked W pairs. Again, this comparison indicates that Ss in the blocked conditions organize together words from the same category to a greater extent than do Ss in the random conditions. If this were the only difference in organization between the two groups, or if overall organization in blocked conditions were greater than in random conditions, then we would expect IRTs for random B pairs to be equal to, or longer than for blocked B pairs. However, the IRTs for random B pairs are shorter than for blocked B pairs, a result which would be expected only if more of the B pairs are organized together by Ss in the random condition than by Ss in the blocked condition.

Contiguity effects across trials. The contiguity effects are most readily presented by dealing with each of the planned comparisons with respect to both recall performance and clustering. Table 8 contains the mean recall and clustering scores, averaged across trials, as a function of Type of Item and Presentation Order. Type of Item had a strong effect on both amount recalled and clustering, $F(1,84) = 107.97$ and 931.89, $p < .001$ for both, with related conditions consistently superior

TABLE 8

MEAN CLUSTERING AND CORRECT RECALL, AVERAGED OVER TRIALS, AS A FUNCTION OF TYPE OF ITEM AND PRESENTATION ORDER CONDITION

	Clustering		Correct Recall	
Presentation Order	Related	Unrelated	Related	Unrelated
Random				
Constant	.777	.010	17.79	17.30
Varied	.834	-.064	18.03	14.40
Blocked				
Constant-Constant	.960	.345	18.98	16.39
Constant-Varied	.957	.114	18.56	15.41
Varied-Constant	.964	.103	18.24	14.63
Varied-Varied	.963	-.013	18.73	14.94

to unrelated.

The effect of intratrial contiguity is observed by combining the various constant and varied conditions nested within random conditions and comparing performance to the combined performance in the various constant and varied conditions nested within blocked conditions. There was no main effect of Intratrial Contiguity on recall performance, $\underline{F}(1,84) < 1$, but there was an interaction with Type of Item, $\underline{F}(1,84) = 4.35$, $\underline{p} < .05$. Blocked orders were superior to random orders with related items, but with unrelated items random orders were slightly superior. The superiority of random orders in unrelated conditions seems to be primarily artifactual. As will be shown later, the most influential presentation order variable in unrelated conditions is constancy of order. Half of the random conditions involved a constant order, while only one-fourth of the blocked conditions were constant. These effects are manifest in the clustering scores, where there is a main effect of Intratrial Contiguity, $\underline{F}(1,84) = 31.01$, $\underline{p} < .001$, but no interaction with Type of Item, $\underline{F}(1,84) < 1$. The constant order in random conditions is not consistent with the $\underline{E}$-defined categories, and thus would not be expected to result in increased clustering scores for the random unrelated condition. The obvious ceiling effects of clustering scores in the blocked related conditions may be masking the interaction of Intratrial Contiguity and Type of Item. The IRT data, presented in Figure 9, may be suffering from the same sort of ceiling effect. The direction of the differences between IRTs for B and W pairs in the unrelated conditions further confirms the existence of contiguity organization. In blocked conditions, where contiguity is consistent with the $\underline{E}$-defined categories, B pairs have longer IRTs than

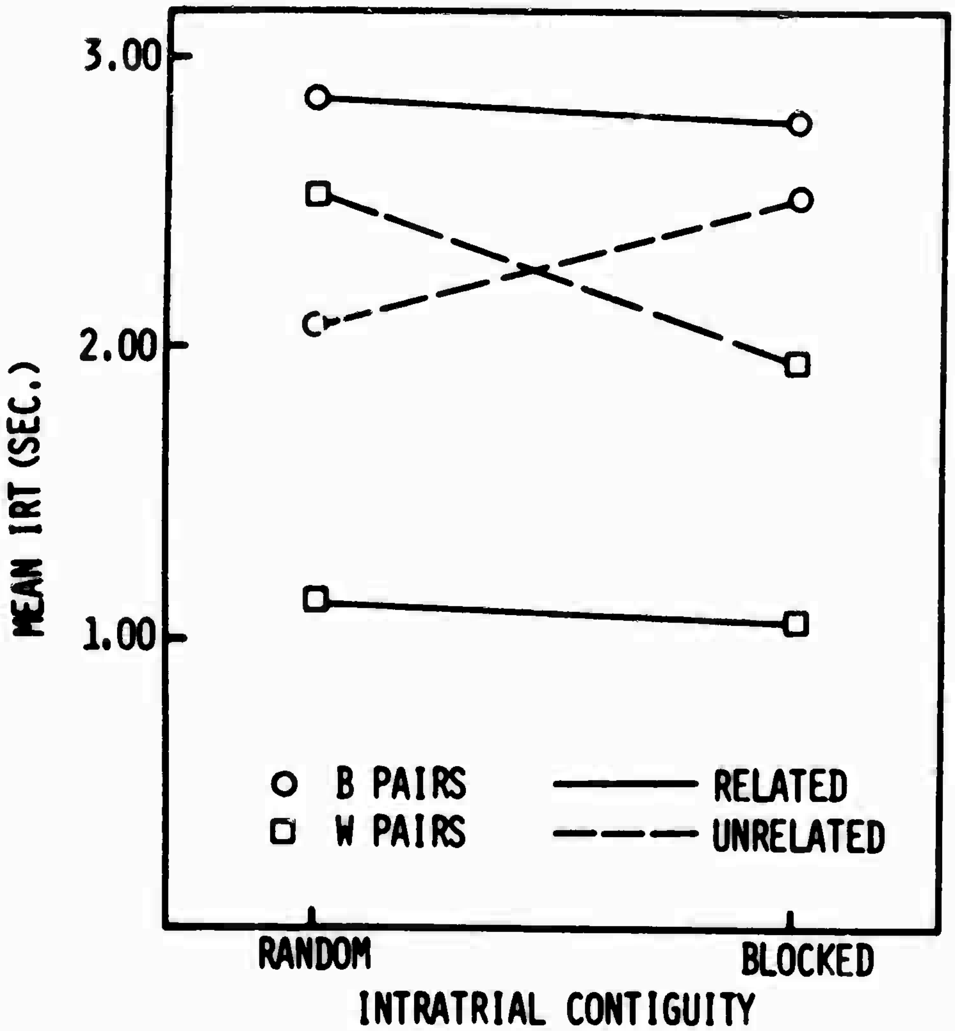

Fig. 9. Mean IRT, averaged across trials, as a function of intratrial contiguity. The parameters are type of item and type of pair.

W pairs, while in random conditions, where contiguity is incompatible with the categories, B pairs are shorter than W pairs. However, the IRTs in the related condition do not reflect the greater clustering in the blocked conditions nor the interaction of Intratrial Contiguity and Type of Item. This may be due to the IRTs for W pairs in the blocked related condition having reached their minimum.

Nested within the random conditions is the comparison of constant and varied presentation over trials. Constant order leads to significantly greater recall, $F(1,84) = 7.75$, $p < .01$. The interaction with Type of Item is also significant, $F(1,84) = 10.67$, $p < .005$, constancy being beneficial in unrelated conditions and ineffective in related conditions. There are no effects of constancy within random orders on clustering scores, which is to be expected, since both constant and varied random orders are inconsistent with the contiguity of category members. For the main effect of Constancy, $F(1,84) < 1$, and for the interaction with Type of Item, $F(1,84) = 1.94$, $p > .10$.

The factors of Category Constancy and Instance Constancy were nested within blocked conditions. There were main effects of both Category Constancy and Instance Constancy on clustering, $Fs(1,84) = 7.35$ and 7.05, $p < .01$ for both. Their interactions with Type of Item were also significant, $F\ (1,84) = 8.16$, $p < .01$ for Category Constancy and $F(1,84) = 6.68$, $p < .025$ for Instance Constancy. The only significant variable affecting recall performance was Category Constancy, which had a marginal effect, $F(1,84) = 4.34$, $p < .05$. For the interaction of Category Constancy and Type of Item, $F(1,84) = 1.50$, $p > .10$, and for the main effect and interaction involving Instance Constancy, $Fs(1,84) < 1$. There were no significant effects of the interaction of Category Constancy and Instance Constancy on either recall or clustering. The only F which was greater than 1 was for the effect of the two way interaction on recall, $F(1,84) = 2.60$, $p > .10$.

CHAPTER IV

DISCUSSION

The purpose of this investigation was twofold--to determine the validity and utility of IRT analyses as measures of organization, and to determine the nature of contiguity effects on organization and recall.

IRTs and Organization

Validity and utility of IRT analyses. The data are uniform in supporting the validity of IRTs as a measure of organization. Whatever findings were obtained concerning the degree of organization with respect to the E-defined partition of the list, as measured by clustering scores, were accompanied by similar findings when IRT measures were examined. Differences in IRTs between pairs of words that were members of the same category and pairs that were members of different categories reflected the magnitude of clustering scores. IRTs were also related to subjective organization, as indicated by the relationship between IRTs and number of prior occurrences of a word pair in recall.

The utility of measuring organization by IRT patterns was demonstrated in cases where information concerning organization not readily available through other measures was derived from the analysis of IRTs. The duration of IRTs for early occurrences of a word pair was found to be related to the number of future occurrences of that pair. This relationship holds whether all trials are considered, as in the tables in Appendix C, or whether only intertrial repetitions on Trials 1 and 2 are examined, as in the conditional probability analysis in Table 7. While it might be argued that this simply demonstrates a relationship between IRT and pair difficulty, it should be recognized that difficulty does not constitute an explanation, and facility of organization may be the cause of pair difficulty. The potentiality of using IRT patterns to detect organization that is inconsistent with some E-defined partitioning of the list was also suggested by the comparison of IRTs for random and blocked related conditions on Trial 1 (Figure 8).

The major difficulty inherent in the use of IRT patterns as an index of organization is the specification of criteria for identifying a pair as being a within- or between-unit pair on the basis of their IRT. Since there is at present no absolute basis for a criterion, relative criteria must be employed. Comparisons have to be made for different pairs to determine which pairs are more likely to be members of the same organizational unit. No restrictions need be placed on the basis for the choice of pairs (or sets of pairs) to compare. In the present experiment pairs were chosen on the basis of the relationship between the pair members with respect to category norms, contiguity of presentation, and their occurrence as pairs on previous output trials. McLean and Gregg (1967) compared pairs occurring at different positions in a serial list to determine size of organizational units in different input grouping conditions.

Implication of a common underlying process. Organization must be measured by some aspect of a subject's behavior. There are a number of measures employed in the current literature, which focus on different behaviors. What is sometimes problematic is that organization is equated with its index (e.g., clustering or subjective organization), leaving the impression that there are different kinds of organization, reflected by the different measures. From a theoretical point of view, perhaps the critical contribution of the IRT analyses in the present study is the suggestion that there is a common underlying process or mechanism which results in the variety of behaviors typically identified as organization. This suggestion derives from the similarity of IRT behavior with respect to both clustering organization and subjective organization. Thus, organization is seen as the internal representation of the information by S, which is the result of his coding and unitizing behaviors. The nature of the coding behaviors is no doubt a joint function of the task demands and S's prior experiences with the information presented, as well as with other information. The nature of the internal representation has potential consequences for a variety of S's overt behaviors. Which consequences E observes depends upon S's organization, the task demands and constraints, and the behaviors E chooses to observe. Among others, behaviors which are viewed as resulting from S's organization are output orders in free recall, transitional error probabilities in serial recall (cf. Johnson, 1968; Bower & Winzenz, 1969), and the time between successive responses. Clustering organization and subjective organization do not differ in terms of the mechanisms or processes that eventuate in the observed behaviors, but rather in terms of E's ability to identify (or willingness to restrict himself to), a priori, the composition of S's organizational units (Tulving, 1968). The measures therefore require different procedures for determining the reliability, or organizational basis, of sequential responses--in terms of their compatibility with normative data or with S's previous sequential responses (also a kind of normative data).

If organization is to be treated as an internal process, or hypothetical construct, an additional problem is presented. The choice is not always clear as to which behaviors are to be considered direct manifestations of the unobserved process, and which behaviors are to be studied to determine their empirical relationship to the unobserved process. In the context of organization, there seems to be reasonable agreement that behaviors involving sequential ordering, and perhaps temporal relationships, in recall are assumed to be direct reflections of organization. On the other hand, most researchers apparently prefer to treat amount recalled not as a measure of organization, but as a behavior whose relationship to organization is to be determined empirically. This approach is manifest both in experimental investigations of the relationship between recall and the aforementioned accepted measures of organization, as well as in attempts to develop clustering and subjective organization indices which are independent of amount recalled.

There have been reports of apparent independence of recall and organization (cf. Cofer, Bruce, & Reich , 1966; Dallett, 1964). Results suggesting independence are also reported in the present experiement. On Trial 1, blocked related conditions showed significantly greater clustering than random related conditions, but there was no significant difference in amount recalled. In the analysis of all trials, there was no significant difference in clustering for random constant and random varied orders of presentation, with either type of item. Yet, random constant orders showed superior recall to random varied orders of presentation for unrelated words, with a slight opposite recall effect for related words. These comparisons, as well as all others in the literature purporting to demonstrate the independence of organization and recall, employ clustering as the index of organization. Rather than demonstrating independence, these studies may signify the inadequacy of clustering as an index of total organization, the measure being insensitive to organization according to a partition of the list other than the one observed by E. Thus, the IRT analysis suggested the presence of other modes of organization in the random related condition on Trial 1 with potential compensating effects on amount recalled. In the analysis of all trials, the basis for organization which differentiated random constant and random varied conditions was not detected by the clustering analysis. Given the possibility that particular modes of organization may go undetected, and therefore that total organization would not be measured, it is not apparent what response to a finding of independence of organization and recall is appropriate. Does one accept the independence, or assume that total organization was not measured? If the latter alternative is adopted, it would imply an underlying assumption that amount recalled is a direct manifestation of organization.

Some measures of clustering go beyond equating for amount recalled, and equate for the specific subset of items recalled. The O-E(r) measure (Bousfield & Bousfield, 1966; Bousfield & Puff, 1964), as well as the DR(r) measure used in the present study, follow such a procedure, in that the observed number of category repetitions is compared to the number of category repetitions that would be expected in a random order of a list with the same categorical structure as the one recalled by S. Thus equal numbers of category repetitions can result in different clustering scores, and unequal numbers can result in identical clustering scores, depending on the categorical structure of recall. An example would be if one S recalled four words all from the same category, and another S recalled four words all from different categories. The first S would have three category repetitions and the second would have none. However, their respective expected numbers of category repetitions would also be three and zero, and therefore, for both Ss, O-E(r) = 0. If there are no such occurrences in recall, there would seem to be no need for measures which are independent of the specific items recalled. If there are such occurrences, then differences in the categorical structure of the specific subsets recalled would seem to require some explanation, and it is reasonable to expect that the explanation would lie within the domain of the organizational process. Although it may be desirable to separate organization which is manifest in the recall of different subsets from that which is manifest in differences in the sequential ordering of the subset recalled, some aspects of organization may be overlooked if we restrict our observations to the latter behaviors only.

Implications for the representation of organization. Little has been said until now concerning how organization is realized in the internal representation of information. This is partially due to the fact that a number of representations are functionally equivalent in their ability to produce organized recall, suggesting the presence of organizational units, with members of the same unit more closely related than members of different units. The relationships between items may derive from associative connections or a hierarchical arrangement of categories resulting from common coded representations. Retrieval based organization is not ruled out either, although it would seem that any retrieval scheme, in order to be effective, must be combined with coded representations in storage that enable S to carry out the retrieval scheme. Any of the organizational systems described would be expected to result in clustered recall of members of S's functional units, and patterns of IRTs with respect to these units of the form reported in the present study.

Although the data reported in the present experiment do not allow a choice between the alternatives, the output serial position curves (Figure 8) for IRTs do place further restrictions on the form of the representations or of retrieval from those representations. Three hypotheses will be offered to account for the increases in within- and between-category IRTs across serial positions. Two of these hypotheses attribute the output position effects to characteristics of the organizational representation, while the third one deals with the recall process itself.

Let us first consider the case in which organization is represented by a hierarchical structure of categories (organizational units) within a list, and instances (individual items) within each category. Categories, as well as instances within categories, may differ in terms of their "strength," or accessibility. The more accessible a category, or an instance within a category, the earlier in the output sequence it is retrieved, and the shorter the time taken to retrieve it. Such a system could be realized by a parallel search beginning at one level of the hierarchy along different paths, in search for items at the next level. As soon as something is found at the end of a path, it is recalled, and then a search must be carried out again. It could also be accomplished through the use of a retrieval plan, which "knows" the length of paths, and searches down the shortest path. A useful physical analogy might be to consider the retrieval process as a sampling process. Recall is accomplished by reaching into a vat (memory) which contains a number of urns (categories) each of which contains a number of balls (instances). The IRT would be represented by how far down into the vat one had to reach before picking up an urn (or how far into an urn to pick up a ball). The more accessible urns are at the top and are grabbed first. It takes less time to find a ball in a small urn than it does to find an urn in a large vat, thus accounting for the differences in IRTs for within- and between-category pairs. When an urn is exhausted of balls, another urn must be retrieved. The later urns are farther down in the vat and therefore take more time to be retrieved than the earlier ones. Thus, between-category IRTs are longer for later categories. It is also the case that within-category IRTs increase across categories. In the language of the analogy, the more accessible urns at the top may be smaller than the ones at the bottom. The larger the urn, the longer it takes to find the balls inside it. Urn size can be thought of as category cohesiveness, which may be the determinant of accessibility. The increasingly longer IRTs between categories may then derive from two sources. If later urns are larger than earlier ones, it may take longer after the last ball is removed to discover that a new urn must be sampled. And, since it is a later urn which is being sampled, it is farther down and therefore requires more time to reach.

In the hierarchical representation just described urns are not connected directly, nor are balls within urns; their respective connections are indirect, due to their inclusion in a common vat, or urn. The operation of an associative representation would not be very different, except that there would be direct connections between items.

The strengths of the connections would vary. Retrieval order would be guided by the associative connections, whose strength would affect the IRT. One way to differentiate the hierarchical and associative models would be to alter the retrieval order. Consider a hypothetical S who recalls 10 categories in the order 1, 2, ..., 10. Suppose that same hypothetical S were instructed to recall Category 9 first. The hierarchical theory would predict that he would then recall Category 1 or 2 with an IRT equal to or shorter than that between the first and second category in his uninstructed recall. The associative theory would predict that he would recall Category 10 after Category 9, with the same IRT between them as was observed in his uninstructed recall. Similar manipulations can be performed on the order of instance recall, with the same predictions for hierarchical and associative theories.

One aspect of recall behavior that has received little attention is that Ss rarely repeat items within the same recall interval. Some mechanism must account for this relative infrequency of repetitions. Two types of mechanism are possible. To extend the sampling analogy a step further, they might be considered as schemes which treat the sampling process as without replacement or with replacement. The notion of sampling without replacement places the mechanism for avoiding repetitions in the learning process itself. Part of learning, or the development of retrieval schemes, would include learning in such a way that repetitions in retrieval do not occur. This can be most readily seen in an associative theory, wherein associations would not lead back to earlier items. However, it is possible that the sampling, or retrieval from memory, is done with replacement, and the infrequency of repetitions is due to processes occurring during retrieval.

As S recalls items, or categories, he may store them in memory as having been recalled. When a new item or category is retrieved from memory as having been presented, S may then have to determine in addition, whether it is also stored in memory as having been recalled. If the item has been recalled, he must retrieve another presented item, until he finds one which has not been recalled, which he then emits overtly. One indication of such a process is the occasional occurrence of partial ("pa") or complete ("pants") responses, followed by a response of "Oops, I already said that." If such a process does occur, it can account for the output position effects on IRT, without resorting to the accessibility interpretations discussed earlier. The greater the number of items or categories already recalled, the greater the set of items S must search through to determine whether an item he retrieved as having been presented was recalled previously, and therefore the longer the IRT. This step may not be necessary. If "already recalled" is stored as a tag with the item that was presented, then when S retrieves the item he can check for the tag. Time to check for the presence of the tag would not be a function of the number of items having such a tag. However, it would still be the case that the more items already recalled the greater the probability that an item which is retrieved as having been presented would already have been recalled. The number of retrievals required, and therefore the IRT, before an item was found which has not yet been recalled would increase as a function of number of items recalled.

The existence of such a process during recall may explain why recall trials serve as learning trials (cf. Lachman & Laughery, 1968; Tulving, 1967) or as organizing trials (cf. Cofer, Bruce, & Reicher, 1966). Recall may consist not only of the output of information, but also of the storage of the information to prevent repeated outputs.

A final point which should be made concerning the three hypotheses advanced to account for the IRT data is that they are not mutually exclusive. Thus, accessibility factors, as well as editing processes during recall, may be affecting IRTs. Pollio, Richards, and Lucas (1969) adopt a form of this mixed model. In an experiment reported after the present one was conducted, they investigated single trial free recall of a categorical word list following three presentations of each item. The IRT data they report replicates the present findings, both in terms of the difference between IRTs for within- and between-category pairs, and in the effects of output position on IRTs for within- and between-category IRTs. They attribute the effects of position within the category to accessibility factors, and the effects of position of the category to editing processes during retrieval. They consider two hypotheses for this editing process. In their fixed sequential model, the categories are learned in a fixed sequence. If this is so, it is not clear why editing must occur, since the completion of one category should lead S to the next one, without having to check previous ones. If categories are learned in a fixed sequence, it would seem more reasonable to attribute the increase in IRTs to accessibility factors associated with categories at different positions in the sequence. Their probabilistic retrieval model is the same form of sampling with replacement model as was described above. They attribute the increase in within-category IRTs across positions to the difficulty of reconstructing instances of the category. Accessibility is a characteristic of the reconstructive process, rather than the storage process. The one difficulty with such a view is that it would seem to predict more intrusions than are typically observed in recall. In order to eliminate intrusions from the reconstructive process, the categories would have to consist of the collection of attributes unique to the set of instances of the category which were presented.

The Nature of Contiguity Effects

The presentation order manipulations were introduced in an attempt to identify the source of contiguity effects on organization. The distinction between direct and indirect effects of contiguity is in terms of how item-independent characteristics and item-dependent characteristics combine to affect organization. The direct hypothesis implies an independent, additive rule, while the indirect hypothesis suggests an interactive, multiplicative rule. The assumptions made in conducting the experiment, combined with the clustering data as a function of Type of Item and Intratrial Contiguity on Trial 1 lead to three conclusions concerning intratrial contiguity: 1) there is an indirect effect of intratrial contiguity; 2) there is no direct effect of contiguity; and 3) there is insufficient potentiality of item-dependent relationships among unrelated words to be actuated or increased by their contiguity. However, further analyses involving other dependent variables, particularly correct recall and IRTs, suggest the need for modifying or supplementing the conclusions, or the assumptions on which they are based.

The recall data indicated no significant effect of blocking on recall of related words, despite the large difference in clustering. The incompatibility of this result with the hypothesis of dependence of recall and organization prompted the search for alternative organizational modes employed in the random related condition. These alternative relationships would have to involve words from different categories, because otherwise they would have been manifest in the clustering data. The analysis of IRT data did suggest that Ss in the random related condition were organizing together words from different categories to a greater extent than were Ss in the blocked related condition, in that the IRT between two words from different categories was shorter in the former condition than in the latter. What is not certain is whether the magnitude of the differences in organization of members of different categories exactly compensates for differences in organization of members of the same category, implying a dependence of recall and organization, or whether total organization is still not equal, and recall and organization are not totally interdependent.

Although the discovery of differential amounts of between-category organization provides a potential resolution of the problem of independence of recall and organization, it raises other questions concerning the source of the between-category organization. If the increased between-category organization in the random related group is not due to the greater contiguity of members of different categories, why is there more of this organization in the random condition than in the blocked condition? The solution would seem to require a third combination rule for different sources of organization. In discussing how contiguity and semantic relationships combine, the two rules offered were an independent, additive combination rule, and an interactive, multiplicative combination rule. Two sources of organization might also combine in an interactive, reciprocal fashion. To the extent that a subject employs one mode of organization, his processing capacities at the time of encoding may be unable to take advantage of other bases for relating items. Thus, to the extent that Ss in blocked conditions take advantage of contiguity relationships, they may be unable to organize items from different categories; or, to the extent that indirect contiguity is not useful in the random condition, S increases his use of other organizational bases which allow him to relate members of different categories. If processing capacity factors determine which bases of organization are utilized in related conditions, they may also play a role in determining the bases for organization in unrelated conditions as compared to related conditions. If Ss always try to utilize semantic relationships, less of their capacity would be required to do so in related conditions. This in turn would free more of their processing resources to deal with nonsemantic organizational bases, such as contiguity.

It may seem more reasonable to presume that the increased between-category organization in the random related group is due to the greater contiguity of members of different categories. This would readily account for the greater between category organization in random related than in blocked related conditions, but would require additional assumptions in order to explain the lack of similar effects being manifest in the form of increased clustering in the blocked unrelated condition. Even if contiguity effects are indirect, the degree of semantic relationship between members of different categories on the related list is no greater than between two words on the unrelated list. Although item-dependent contiguity organization should be equal in the random and blocked unrelated conditions, only in the latter should this organization facilitate clustering scores, since the contiguous items are members of the same E-defined category. There is no increased clustering in the blocked unrelated condition, so how can we assume contiguity organization of members of different categories (unrelated words) on the related list? One possible explanation is that the item-dependent relationships between words from different categories on the related list are in fact stronger than the item-dependent relationships between words from the same category on the unrelated list. The presence of semantic relationships among words from the same category may modify the degree of semantic relationship among words from different categories. For example, the presence of other articles of furniture may increase the likelihood that BENCH is coded as a piece of furniture, and the presence of other trees may increase the likelihood that FIR is coded as a tree. Finally, BENCH as a piece of furniture and FIR as a tree may be more semantically relatable than if they are not so coded, and therefore more able to benefit from indirect effects.

An alternative explanation would involve the reciprocal rule for combining bases of organization described earlier. To the extent that semantic relationships are more difficult to develop for unrelated words, attempts to organize on such bases may occupy more of S's resources, thereby minimizing or eliminating his opportunity to utilize contiguity relationships.

The existence of a reciprocal interactive combination rule between item-independent and item-dependent stimulus characteristics may seem to be equivalent to a multiplicative interactive rule in implying indirect effects of contiguity, but the interactions operate at different levels of behavior. The multiplicative rule assumes that S is always using contiguity relationships to relate items, but the degree to which contiguity is effective is a function of the item-dependent relationships between items. To test this rule, in contrast to the additive independent rule, contiguity relationships and item-dependent semantic relationships were manipulated factorially to determine whether interactions were present. However, such a test is only appropriate if Ss in all conditions are utilizing contiguity relationships. The reciprocal rule suggests that the degree to which S utilizes a particular basis for organizing depends on his use of other bases. In the context of the present experiment, the extent to which S uses semantic relationships, and the ease of using them, may affect the degree to which he has the opportunity to use contiguity relationships, or vice versa. In that sense, there are indirect effects of contiguity. However, this does not imply that when S does use contiguity, the way such characteristics are effective is through their effects on item-dependent coding. There may be direct contiguity effects. The presence of indirect effects at the level of choice of coding or organizing dimensions nullifies the design as a basis for distinguishing additive and multiplicative combinations of item-dependent and item-independent bases of organization.

Thus, if the data are relevant to the distinction between direct and indirect contiguity effects, they indicate the presence of indirect effects and the absence of direct effects. This does not deny that contiguity is an effective source of organization, but only suggests that the reason for the effect of contiguity resides in the effects of contiguous presentation on item-dependent coding. Nor does the absence of direct contiguity effects deny the possibility that temporal and spatial properties are one of the many coded dimensions of stimuli (Underwood, 1969). Rather, these coded properties do not seem to provide the basis for the relating of items which would eventuate in their organization and the behaviors typically observed as a consequence of such organization.

However, the possibility has been suggested that the data are not relevant to the distinction, and that instead they imply that the use of one mode of organization affects the opportunity to use another. This interpretation is best presented in the context of a limited capacity viewpoint of the behaviors which result in organization. Organizing along a particular dimension occupies processing capacity and retards organizing along some other dimension. Furthermore, if S organizes along a particular dimension, his opportunity to organize along other dimensions in addition, will depend upon his ability or speed of organizing along the first dimension. Finally, there may be priorities established in the order of dimensions organized, due to their salience and task demands. In some cases, nonutilization of, or inability to benefit from the use of one dimensional basis may be compensated for by the use of an alternative basis, as was suggested for the random and blocked related conditions. In other cases, the weakness of one dimension cannot be overcome by the use of other bases, as is apparently the case for difference in semantic bases for organization in the related and unrelated conditions. This interpretation extends the notions that stimulus representations are multidimensional (Underwood, 1969; Wickens, 1970), that limited processing capacities necessitate the selection of dimensions to be encoded, and that priorities of encoding are established by dimensional salience and task demands (Shulman, 1969; Tversky, 1969), from the encoding of individual items to the related encodings of groups of items.

Similar processes can be seen operating in the effects of contiguity across trials in the present experiment. The simplest description of the results is that intratrial contiguity was the primary dimension affecting the organization of related words, and intertrial contiguity constancy was the primary dimension affecting the organization of unrelated words. These contiguity effects were manifest in differences in recall, and when the contiguity characteristics were consistent with the E-defined categories, they appeared in the clustering scores as well. The apparent difference in the mode of organization employed, dependent of the type of item, again prevents a distinction between direct and indirect coding of any particular contiguity characteristic. In the unrelated condition, where intertrial contiguity seems to be important, intratrial contiguity must also obviously be coded. The S would be unable to know that the contiguity relationships were consistent across trials unless he knew what they were on individual trials. But, it is only when the contiguity relationships are consistent that they are effective. Constancy of categories and instances seemed to be equally effective (if anything, the former were more effective), despite the fact that the contiguity relationships were more consistent with instance constancy than with category constancy. One possible explanation of this effect is that in the category constancy condition the serial position of the items remain relatively constant. This factor may be relatively important for items in early positions, since Bower and Winzenz (1969) have shown that constancy of early list items is critical for the recognition and utilization of constant orders. In the conditions involving related words there are definite indications that intratrial contiguity is an effective factor in organization. The absence of any intertrial effects may be due to the selection of dimensions of organization, but this interpretation must be qualified by the ceiling effects present in the blocked conditions.

CHAPTER V

CONCLUSIONS

Organization is an internal process which refers to the functional representation by an individual S of a set of nominally discrete items such that groups of items are encompassed in a single memory unit or retrieval unit, due to relationships which exist or are imposed upon the items comprising the group. With this orientation, it is possible to focus upon three aspects of the organizational process, the antecedents of S's functional representation, the nature of the organizational process itself, and the consequences of the functional representation for S's behavior in a learning and memory task. The experiment reported has implications for all three aspects, and they will be treated in reverse order.

The study reported was most successful in confirming that the functional representation of a set of items affects the temporal pattern of output in a free recall task. Specifically, the time between two words which were identified as being members of the same functional unit by measures of clustering and subjective organization was shorter than the time between two words which were members of different units. This relationship between IRTs and functional organization suggests that IRTs can be employed to infer the amount and specific nature of functional organization of a set of items. It was further demonstrated that the assessment of organization via IRTs has the potential for providing information concerning organization which is not readily obtainable by other measures.

The IRT data obtained do not implicate any one form of functional representation, since there are a number of representations which would be functionally equivalent in producing the observed behaviors. However, restrictions on the nature of the representation are imposed by the IRT patterns. As already indicated, the IRT between elements of the same unit is shorter than between elements of different units. This perhaps simply confirms the reality of the units at some level of the organizational process, but does not indicate whether the relationships between unit members derive from associative connections, hierarchical coding processes, or retrieval plans. In addition, IRTs between categories as well as within categories showed orderly increases as a function of position in S's output sequence. Two explanations of this effect were offered. The first is that the changes in IRT across output position are related to the functional representations. This would require differential accessibility or strength of units and elements within units, and output order to be a function of accessibility. The alternative is that output order effects are independent of characteristics of memory and that increased IRTs as a function of output order are due to processes introduced by recall itself. One requirement of recall, at least implicitly, is to not repeat oneself. The further along in the output sequence a particular item is retrieved from memory as a potential item for recall, the greater the number of items which must be checked in order to determine whether it was already recalled, and the greater the likelihood that the retrieved item was recalled, necessitating another retrieval from memory. Both of these recall processes would lead to increased IRT as a function of position in the output sequence.

As to the question of the antecedents of functional organization the data suggest that there are multiple characteristics of the stimulus situation which determine the relationships established among items. Some of the sources derive from the nature of the items themselves. Thus the semantic relationships between items in the related conditions led to greater clustering and enhanced recall than was observed in the unrelated conditions. In addition, item-independent characteristics of the stimuli, such as contiguity relationships, affected the functional representation. This can be seen in the increased clustering on Trial 1 for blocked presentation of related words, as well as in the effects of blocking on related words and constancy of presentation on unrelated words in the multitrial situation.

Of primary interest is how the various stimulus characteristics combine to determine the functional representation. On the first trial and in the multitrial situation interactions were obtained between item-dependent and item-independent characteristics, in terms of their effects on organization and recall. Two possible reasons for the interaction were proposed. The first is that the only functional relationships between items in memory are based upon item-dependent characteristics. Item-independent characteristics have only an indirect effect on organization in that they affect the degree to which particular item-dependent relationships are established. The alternative is that the extent to which, and ease with which, a particular organizational basis is utilized affects the degree to which an alternative basis is employed. If two stimulus characteristics are potentially available, one may be utilized at the expense of the other. In addition, certain bases may have priority in the sequence of information processing utilized by S. The ease with which early characteristics are processed, e.g., semantic relationships in related versus unrelated conditions, may affect the opportunity for S to process the information with respect to other stimulus dimensions, such as contiguity. The latter explanation of the interaction of item-dependent and item-independent characteristics has two further implications. It suggests that the interaction is not unequivocal in its implication that item-independent characteristics are not utilized in the functional relationships established between items. And, it suggests the existence of multiple sources of organization whose existence may have to be identified by different measures of organization. The possibility for multiple sources of organization to interact at different levels of processing makes the task of devising analytic techniques for determining the nature of the interactions all the more complex. Paradigms will first have to be established which enable us to determine the priority of relational dimensions employed and the factors that affect whether particular characteristics of the stimulus situation are effective. Then, given that a particular characteristic is effective in a particular situation, analytic techniques must be developed to determine whether it has a direct or indirect effect on the functional representation of information.

APPENDIX A

PRESENTATION ORDERS ON TRIAL 1

TABLE 1

ORDER OF PRESENTATION OF RELATED AND UNRELATED WORDS ON TRIAL 1 IN RANDOM CONDITIONS. PRESENTATION ORDERS FOR SETS A AND B ARE GIVEN.

	Set A		Set B	
Position in Presentation	Related	Unrelated	Related	Unrelated
1	Gold	Gate	Bronze	Breeze
2	Vest	Vest	Gold	Gate
3	Bench	Brick	Skirt	Sword
4	Stool	Shrub	Bench	Brick
5	Zinc	Zinc	Vest	Vest
6	Desk	Debt	Desk	Debt
7	Fir	Fir	Sheep	Scale
8	Deer	Dart	Spruce	Strand
9	Skirt	Sword	Pine	Pipe
10	Pine	Pipe	Cow	Cow
11	Couch	Couch	Tin	Toe
12	Pants	Prank	Coat	Coal
13	Cow	Cow	Deer	Dart
14	Wolf	Wine	Fir	Fir
15	Sheep	Scale	Stool	Shrub
16	Spruce	Strand	Birch	Booth
17	Coat	Coal	Wolf	Wine
18	Birch	Booth	Couch	Couch
19	Tin	Toe	Pants	Prank
20	Bronze	Breeze	Zinc	Zinc

TABLE 2

ORDER OF PRESENTATION OF RELATED AND UNRELATED WORDS ON TRIAL 1 IN BLOCKED CONDITIONS. PRESENTATION ORDERS FOR SETS A AND B ARE GIVEN.

Position in Presentation	Set A		Set B	
	Related	Unrelated	Related	Unrelated
1	Skirt	Sword	Bench	Brick
2	Vest	Vest	Desk	Debt
3	Coat	Coal	Couch	Couch
4	Pants	Prank	Stool	Shrub
5	Bronze	Breeze	Birch	Booth
6	Tin	Toe	Fir	Fir
7	Gold	Gate	Pine	Pipe
8	Zinc	Zinc	Spruce	Strand
9	Birch	Booth	Sheep	Scale
10	Spruce	Strand	Wolf	Wine
11	Pine	Pipe	Deer	Dart
12	Fir	Fir	Cow	Cow
13	Stool	Shrub	Skirt	Sword
14	Desk	Debt	Vest	Vest
15	Bench	Brick	Pants	Prank
16	Couch	Couch	Coat	Coal
17	Cow	Cow	Zinc	Zinc
18	Deer	Dart	Tin	Toe
19	Wolf	Wine	Gold	Gate
20	Sheep	Scale	Bronze	Breeze

APPENDIX B

INSTRUCTIONS

"Seat yourself comfortably in this chair, facing the screen. This is a simple experiment which should only take about half-an-hour. A list of words will be presented to you, one at a time, on this screen. After the list is presented, your task will be to recall as many of the words as you can remember by saying them aloud in any order you wish. Then the list will be presented again and you will recall again. We will repeat the same procedure a number of times.

"The actual sequence of events will be as follows: First, a row of stars will appear on the screen for a couple of seconds, indicating that the list is about to begin. The words, which are all nouns, will then be presented on the left-hand side of the screen, one at a time. Following the last word in the list, a row of dashes will appear momentarily, and then the screen will go blank for an interval of time. You may begin to recall the words as soon as the dashes appear on the screen, and will have the entire time that the screen is blank to recall the words. The interval should be long enough for you to complete your recall. Try to say aloud as many of the words as you can. You may say the words in any order you wish. At the end of the recall time the row of stars will appear again indicating that your recall time is up and the next presentation of the list is about to begin. The same words will be presented again although perhaps in a different order, and again your task will be to recall as many words as you can in any order you wish. We will keep going through the same list a number of times.

"Please direct your attention towards the screen at all times so that you do not miss any words or ready and recall signals and also in order that the microphone can pick up your recall better.

"Do you have any questions?

"Before we begin the actual experiment we will do two things. First, I will ask you to say your name while facing the screen so I can check that I can hear you. Then we will go through a practice trial with a ready signal, a series of letter combinations and then the recall cue. This will give you an idea of what the symbols and letters look like on the screen and also an idea of the pacing of events. You will not have to recall the letters on the practice trial.

"Okay, I will tell you when to say your name."

The E then left the experimental booth and told S to say her name. The practice trial was then run, and E returned to the booth.

"Were you able to see the items that appeared on the screen? Did you have any trouble with any of the letters? Do you have any other questions?

"Fine. Just remember that a list of words will be presented and when the dashes appear you may start to say the words which were presented. You may recall the words in any order. Remember to face the screen at all times. I will let you know when we are about to begin."

APPENDIX C

MEAN IRT (SEC.) FOR PAIRS OF WORDS AS A FUNCTION OF THE NUMBER OF PRIOR OCCURRENCES OF THE PAIR, FOR PAIRS OCCURRING DIFFERENT TOTAL NUMBERS OF TIMES. EACH TABLE PRESENTS THE DATA FOR A DIFFERENT TYPE OF PAIR AND TYPE OF ITEM. THE COLUMN LABELED n GIVES THE TOTAL NUMBER OF OCCURRENCES OF PAIRS IN THE CORRESPONDING ROW, AND THE COLUMN LABELED Obs. GIVES THE NUMBER OF OBSERVATIONS UPON WHICH EACH MEAN IRT IN THE CORRESPONDING ROW IS BASED.

TABLE 1

BETWEEN-CATEGORY PAIRS OF RELATED ITEMS

		Number of Prior Occurrences																			
n	Obs.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	2291	3.06																			
2	505	2.89	2.75																		
3	138	2.78	2.19	2.04																	
4	73	2.43	2.11	1.83	1.74																
5	28	3.60	1.90	1.87	2.02	1.77															
6	18	1.48	1.39	1.18	2.04	2.08	1.14														
7	10	2.24	1.72	2.09	1.45	1.26	1.26	1.21													
8	7	1.63	1.32	1.55	1.77	1.45	1.72	1.73	1.28												
9	5	1.10	.74	.91	.76	1.16	.84	1.01	.86	.90											
10	4	.97	.84	.69	.83	.53	.94	.53	.94	1.30	1.16										
11	2	1.38	.94	1.12	.94	.72	.75	.82	.75	.75	.90	.84									
12	0	--	--	--	--	--	--	--	--	--	--	--	--								
13	0	--	--	--	--	--	--	--	--	--	--	--	--	--							
14	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--						
15	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--					
16	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--				
17	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			
18	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		
19	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
20	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 2

WITHIN-CATEGORY PAIRS OF RELATED ITEMS

n	Obs.	Number of Prior Occurrences																			
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	342	1.21																			
2	380	1.33	1.20																		
3	376	1.32	1.24	1.10																	
4	336	1.18	1.05	1.05	1.04																
5	286	1.30	1.22	1.09	1.16	1.01															
6	226	1.46	1.06	1.08	1.03	.89	.92														
7	167	1.01	1.21	.99	.97	1.05	.99	.92													
8	127	1.04	1.13	1.05	1.04	.97	.99	1.00	.92												
9	111	1.26	1.15	.90	.79	.87	.96	.87	.84	.90											
10	82	1.18	1.08	1.09	1.02	.94	.90	.87	.90	.82	.82										
11	60	.94	.98	.93	.92	.78	.93	.87	.78	.81	.79	.86									
12	37	1.16	.97	.80	.91	1.07	.86	.86	.72	.88	1.14	.75	.96								
13	18	1.49	1.69	.78	.78	.82	.69	.70	.69	.73	.70	.99	.62	.60							
14	22	.71	.86	.80	.70	1.34	.72	.84	.87	.67	.65	.67	.62	.60	.69						
15	14	.78	1.04	.83	.69	.67	.66	.54	.59	.65	.68	.51	.58	.52	.51	.49					
16	13	1.08	1.11	.80	.72	.96	.68	.60	.61	.61	.80	.61	.53	.60	.54	.52	.54				
17	4	.58	.62	.67	.64	.64	.75	.61	.52	.48	.64	.53	.56	.52	.60	.60	.62	.62			
18	5	.78	.91	1.13	1.19	.56	.45	.55	.41	.45	.39	.46	.38	.44	.44	.39	.43	.38	.45		
19	4	.53	.38	.58	.60	.45	.50	.47	.50	.44	.41	.38	.44	.36	.38	.38	.52	.42	.52	.38	
20	2	.44	.38	.40	.44	.40	.47	.60	.47	.47	.44	.40	.56	.50	.47	.44	.44	.38	.34	.53	.32

TABLE 3

BETWEEN-CATEGORY PAIRS OF UNRELATED ITEMS

		Number of Prior Occurrences																			
n	Obs.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	3420	3.15																			
2	1188	3.05	2.60																		
3	468	2.55	2.23	2.08																	
4	215	2.09	1.76	1.56	1.55																
5	136	2.12	1.61	1.46	1.47	1.48															
6	111	1.50	1.46	1.32	1.28	1.29	1.39														
7	60	1.36	1.30	1.23	1.24	1.26	1.15	1.21													
8	44	1.35	1.24	1.27	1.25	1.30	1.28	1.21	1.40												
9	34	3.04	1.69	1.50	1.52	1.44	1.38	1.65	1.20	1.01											
10	23	1.31	1.05	.96	1.10	1.03	.87	1.24	1.08	.99	.94										
11	22	1.63	1.12	1.26	1.07	1.15	.97	1.14	.94	.83	.89	.99									
12	15	1.44	1.59	.98	1.08	1.02	.89	.88	1.04	1.19	.84	.88	.78								
13	14	1.91	1.28	.93	1.14	.70	.77	1.05	.85	1.12	.76	.74	.81	.69							
14	10	.94	1.21	.78	1.06	.77	.76	.83	.94	.88	.75	.68	.89	.85	.90						
15	8	.74	.65	.93	.66	.66	.88	.66	.92	.66	.71	.78	.69	.55	.62	.57					
16	9	.83	1.16	.88	1.01	.83	.73	.91	.88	.79	.83	.85	.80	1.03	.78	.83	1.22				
17	3	.92	1.10	1.04	.79	1.04	1.50	.79	.85	.90	1.06	1.06	.79	.96	.90	.75	1.15	.85			
18	3	1.13	1.06	1.06	1.00	.92	.98	.92	.85	.94	.88	.92	1.04	.96	.88	.85	.98	.75	.90		
19	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
20	1	.44	.56	.88	.81	.56	.75	.44	4.81	1.50	.88	.38	.44	.88	.44	.50	.50	.44	.44	.50	.44

TABLE 4

WITHIN-CATEGORY PAIRS OF UNRELATED ITEMS

		Number of Prior Occurrences																			
n	Obs.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	708	2.77																			
2	271	2.65	2.52																		
3	120	2.09	1.69	1.82																	
4	55	1.47	1.76	1.56	1.71																
5	41	1.17	1.17	.98	1.29	1.15															
6	29	1.45	1.25	1.28	.92	.90	.99														
7	14	1.03	.90	.83	1.01	1.02	.96	1.07													
8	11	2.82	1.47	2.17	1.43	1.53	1.41	1.39	.84												
9	5	1.06	.79	2.16	.88	.78	.66	1.05	.79	.68											
10	9	1.61	1.19	.94	.99	1.15	.81	1.06	.75	.88	1.36										
11	13	1.47	2.11	.97	.94	.78	.78	.91	.71	1.18	1.04	1.00									
12	10	1.59	1.08	.96	1.08	1.50	.99	1.01	1.01	1.10	1.49	1.06	1.02								
13	6	.76	.62	.45	.72	.43	.56	.49	.50	.55	.47	.64	.53	.59							
14	9	.81	1.89	.84	1.28	.78	.87	.62	.67	.94	.71	.85	.64	.71	.78						
15	5	.93	.95	1.58	1.03	.75	.86	.79	.68	.78	.78	1.01	.79	.74	.84	.94					
16	4	.84	.97	.80	.62	.69	.58	.64	.62	.74	.72	.58	.56	.72	.64	.61	.67				
17	2	.72	.78	.78	.88	.69	.72	3.12	.69	.78	.78	.78	.60	1.19	1.53	.66	.72	.72			
18	3	.90	.79	.71	.69	.88	.79	.73	.73	1.06	.73	.90	.83	.65	.75	.79	.67	2.25	.77		
19	2	.60	.78	.75	.72	.72	.72	.78	.75	.69	.62	.69	.72	.75	.66	.69	.66	.60	.92	.78	
20	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

REFERENCES

Atkinson, R. C., & Shiffrin, R. M. Human memory; A proposed system and its control processes. In K. W. Spence, & J. T. Spence (Eds.), The psychology of learning and motivation. Vol. 2. New York: Academic Press, 1968.

Bourne, L. E., & Parker, B. K. Interitem relationship, list structure, and verbal learning. Canadian Journal of Psychology, 1964, 18, 52-61.

Bousfield, W. A. The occurrence of clustering in the recall of randomly arranged associates. Journal of General Psychology, 1953, 49, 229-240.

Bousfield, W. A., Berkowitz, H., & Whitmarsh, G. A. Associative clustering in the recall of minimally meaningful geometric designs. Canadian Journal of Psychology, 1959, 13, 281-287.

Bousfield, A. K., & Bousfield, W. A. Measurement of clustering and of sequential constancies in repeated free recall. Psychological Reports, 1966, 19, 935-942.

Bousfield, W. A., Cohen, B. H., & Whitmarsh, G. A. Associative clustering in the recall of words of different taxonomic frequencies of occurrence. Psychological Reports, 1958, 4, 39-44.

Bousfield, W. A., Esterson, J., & Whitmarsh, G. A. A study of developmental changes in conceptual and perceptual associative clustering. Journal of Genetic Psychology, 1958, 92, 95-102.

Bousfield, W. A., & Puff, C. R. Clustering as a function of response dominance. Journal of Experimental Psychology, 1964, 67, 76-79.

Bousfield, W. A., Puff, C. R., & Cowan, T. M. The development of constancies in sequential organization during repeated free recall. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 489-495.

Bousfield, W. A., & Sedgewick, C. H. W. An analysis of sequences of restricted associative responses. Journal of General Psychology, 1944, 30, 149-165.

Bower, G. H., Lesgold, A. M., & Tieman, D. Grouping operations in free recall. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 481-493.

Bower, G. H., & Winzenz, D. Group structure, coding, and memory for digit series. Journal of Experimental Psychology, 1969, 80, (2, Pt. 2).

Cofer, C. N. A study of clustering in free recall based on synonyms. Journal of General Psychology, 1959, 60, 3-10.

Cofer, C. N., & Bruce, D. R. Form-class as the basis for clustering in the recall of nonassociated words. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 386-389.

Cofer, C. N., Bruce, D. R., & Reicher, G. M. Clustering in free recall as a function of certain methodological variations. Journal of Experimental Psychology, 1966, 71, 858-866.

Cohen, B. H. An investigation of recoding in free recall. Journal of Experimental Psychology, 1963, 65, 368-376.

Cohen, B. H., Bousfield, W. A., & Whitmarsh, G. A. Cultural norms for verbal items in 43 categories. Technical Report No. 22, 1957, University of Connecticut, Contract Nonr 631(00), Office of Naval Research.

Cohen, B. H , Sakoda, J. M., & Bousfield, W. A. The statistical analysis of the incidence of clustering in the recall of randomly arranged associates. Technical Report No. 10, 1954, University of Connecticut, Contract Nonr 631(00), Office of Naval Research.

Cowan, T. M. The semantic differential as a basis for obtaining clustering. Unpublished doctoral dissertation, University of Connecticut, 1964. (Dissertation Abstracts, 1965, 25, 4824-4825)

Dallett, K. M. Number of categories and category information in free recall. Journal of Experimental Psychology, 1964, 68, 1-12.

Deese, J. Influence of inter-item associative strength upon immediate free recall. Psychological Reports, 1959, 5, 305-312.

Fagan, J. F., III. Measuring verbal recall II: The ITR score expressed as a ratio. Psychonomic Science, 1968, 11, 205.

Garner, W. R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962.

Garner, W. R., & Degerman, R. L. Transfer in free-recall learning of overlapping lists of nonsense words. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 922-927.

Glanzer, M. Distance between related words in free recall: Trace of the STS. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 105-111.

Glaze, J. A. The association value of nonsense syllables. Journal of Genetic Psychology, 1928, 35, 255-267.

Goldman-Eisler, F. The measurement of time sequences in conversational behavior. British Journal of Psychology, 1951, 42, 355-362.

Goldman-Eisler, F. The determinants of the rate of speech and their mutual relations. Journal of Psychosomatic Research, 1956, 2, 137-143.

Goldman-Eisler, F. Speech production and the predictability of words in context. Quarterly Journal of Experimental Psychology, 1958, 10, 96-106.

Goldman-Eisler, F. Hesitation and information in speech. In C. Cherry (Ed.), Information Theory. Washington: Butterworths, 1961.

Hayes, J. R. M. Memory span for several vocabularies as a function of vocabulary size. In Quarterly Progress Report, Cambridge, Mass.: Acoustics Laboratory, Massachusetts Institute of Technology, Jan.-June, 1952. Cited by G. A. Miller, The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Hays, W. L. Statistics for psychologists. New York: Holt, 1963.

Jenkins, J. J., Mink, W. D., & Russell, W. A. Associative clustering as a function of verbal association strength. Psychological Reports, 1958, 4, 127-136.

Jenkins, J. J., & Russell, W. A. Associative clustering during recall. Journal of Abnormal and Social Psychology, 1952, 47, 818-821.

Johnson, N. F. Sequential verbal behavior. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Jung, J., & Skeebo, S. Multi-trial free recall as a function of constant vs. varied input orders and list length. Canadian Journal of Psychology, 1967, 21, 329-336.

Katona, G. Organizing and memorizing. New York: Columbia University Press, 1940.

Lachman, R., & Laughery, K. R. Is a test trial a training trial in free recall learning? Journal of Experimental Psychology, 1968, 76, 40-50.

Lounsbury, F. G. Sequential psycholinguistics. In C. E. Osgood (Ed.), Psycholinguistics: A survey of theory and research problems. Journal of Abnormal and Social Psychology, 1954, 49 (4, Pt. 2).

Mandler, G. Organization and me[illegible]. In K. W. Spence & J. T. Spence (Eds.), The Psychology of learning and motivation. Vol. 1. New York: Academic Press, 1967.

Mandler, G., & Dean, P. J. Seriation: Development of serial order in free recall. Journal of Experimental Psychology, 1969, 81, 207-215.

Marks, M. R., & Jack, O. Verbal context and memory span for meaningful material. American Journal of Psychology, 1952, 65, 298-300.

Marshall, G. R., & Cofer, C. N. Associative indices as measures of word relatedness: A summary and comparison of ten methods. Journal of Verbal Learning and Verbal Behavior, 1963, 1, 408-421.

Martin, J. G. Hesitations in the speaker's production and listener's reproduction of utterances. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 903-909.

Mathews, R. Recall as a function of number of classificatory categories. Journal of Experimental Psychology, 1954, 47, 241-247.

McGeoch, J. A., & Irion, A. L. The psychology of human learning. (2nd ed.) New York: Longmans, Green, 1952.

McLean, R. S., & Gregg, L. W. Effects of induced chunking on temporal aspects of serial recitation. Journal of Experimental Psychology, 1967, 74, 455-459.

McNulty, J. A. The measurement of "adopted chunks" in free-recall learning. Psychonomic Science, 1966, 4, 71-72.

Melton, A. W. Review of G. Katona, Organizing and memorizing. American Journal of Psychology, 1941, 54, 455-457.

Melton, A. W. Implications of short-term memory for a general theory of memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 1-21.

Melton, A. W. The situation with respect to the spacing of repetitions and memory. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 596-606.

Melton, A. W., & Shulman, H. G. Further studies of a distributed practice effect on probability of recall in free recall. Paper presented at Psychonomic Society, Chicago, October, 1967.

Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97. (a).

Miller, G. A. Human memory and the storage of information. IRE Transactions on Information Theory, 1956, IT-2, 129-137. (b)

Miller, G. A., & Selfridge, J. A. Verbal context and the recall of meaningful material. American Journal of Psychology, 1950, 63, 176-185.

Murdock, B. B., Jr. The immediate retention of unrelated words. Journal of Experimental Psychology, 1960, 60, 222-234.

Musgrave, B. S., & Allen, S. Clustering with two word stimuli each composed of a categorized and a noncategorized word. Psychonomic Science, 1968, 11, 289-290.

Noble, C. E. Meaningfulness and familiarity. In C. N. Cofer & B. S. Musgrave (Eds.), Verbal behavior and learning. New York: McGraw-Hill, 1963.

Paivio, A. Mental imagery in associative learning and memory. Psychological Review, 1969, 76, 241-263.

Pollack, I. The assimilation of sequentially coded information. American Journal of Psychology, 1953, 66, 421-435.

Pollio, H. R. Composition of associative clusters. Journal of Experimental Psychology, 1964, 67, 199-208.

Pollio, H. R., Richards, S., & Lucas, R. Temporal properties of category recall. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 529-536.

Puff, C. R. Clustering as a function of the sequential organization of stimulus word lists. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 503-506.

Robinson, E. S. Association theory today. New York: Appleton-Century-Crofts, 1932.

Robinson, J. A. Category clustering in free recall. Journal of Psychology, 1966, 62, 279-285.

Rothkopf, E. Z., & Coke, E. U. The prediction of free recall from word association measures. Journal of Experimental Psychology, 1961, 62, 433-438.

Rozov, A. I. Formation and dynamics of topic clusters in free recall. Soviet Psychology and Psychiatry, 1964, 2, 19-26. (transl. from Voprosy Psikhologii, 1961)

Shuell, T. J. Clustering and organization in free recall. Psychological Bulletin, 1969, 72, 353-374.

Shulman, H. G. Presentation rate, retention interval, and encoding in short-term recognition memory for homonyms, synonyms, and identical words. Ann Arbor: Human Performance Center Technical Report No. 18, 1969, University of Michigan.

Sohn, D. Effect of spatial stability of the stimulus on free recall ability. Journal of Psychology, 1967, 66, 87-92.

Stevens, S. S. Mathematics, measurement and psychophysics. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951.

Stimmel, D. T., & Stimmel, N. S. Free recall as a function of intralist similarity and order of presentation constraints. Psychological Reports, 1967, 21, 541-544.

Suci, G. J. The validity of pause as an index of units in language. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 26-32.

Thorndike, E. L., & Lorge, I. The teacher's word book of 30,000 words. New York: Teacher's College, Columbia University Press, 1944.

Tulving, E. Subjective organization in free recall of "unrelated" words. Psychological Review, 1962, 69, 344-354. (a)

Tulving, E. The effect of alphabetical subjective organization on memorizing unrelated words. Canadian Journal of Psychology, 1962, 16, 185-191. (b)

Tulving, E. The effect of order of presentation on learning of "unrelated" words. Psychonomic Science, 1965, 3, 337-338.

Tulving, E. The effects of presentation and recall of material in free-recall learning. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 175-184.

Tulving, E. Theoretical issues in free recall. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Tulving, E., & Patkau, J. E. Concurrent effects of contextual constraint and word frequency on immediate recall and learning of verbal material. Canadian Journal of Psychology, 1962, 16, 83-95.

Tulving, E., & Pearlstone, Z. Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 381-391.

Tversky, B. G. Pictorial and verbal encoding in short-term memory. Ann Arbor: Human Performance Center Technical Report No. 10, 1968, University of Michigan.

Underwood, B. J. Stimulus selection in verbal learning. In C. N. Cofer & B. S. Musgrave (Eds.), Verbal behavior and learning. New York: McGraw-Hill, 1963.

Underwood, B. J. Attributes of memory. Psychological Review, 1969, 76, 559-573.

Underwood, B. J., & Schulz, R. W. Meaningfulness and verbal learning. Philadelphia: Lippincott, 1960.

Wallace, W. P. Clustering in free recall based upon input contiguity. Psychonomic Science, 1969, 14, 290-292.

Wallace, W. P. Consistency of emission order in free recall. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 58-68.

Wallace, W. P., & Nappe, G. W. Subjective organization following constant input order in multitrial free recall. Psychonomic Science, 1970, 18, 115-117.

Waugh, N. C. Free versus serial recall. Journal of Experimental Psychology, 1961, 62, 496-502.

Wickens, D. D. Encoding categories of words: An empirical approach to meaning. Psychological Review, 1970, 77, 1-15.

Woodworth, R. S. Experimental psychology. New York: Holt, 1938.