The Effect of Organizational Structure on Free Recall and Multiple-Choice Recognition

by

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Table of Contents

Abstract

To determine the effect of organizational structure on recall and recognition performance, subjects were randomly assigned to the following experimental conditions and received an intentional free-recall task followed by an incidental multiple-choice recognition task: (a) A fast rate of item presentation with either simple-structured items or complex-structured items; (b) A slow rate of item presentation with either simple-structured items or complex-structured items.

Recognition performance was systematically the same as recall performance. Under fast presentation, no recall or recognition differences were obtained between simple-structured and complex-structured items. Under slow presentation, simple-structured items were both better recalled and better recognized than complex-structured items. Results were discussed in relation to three theories, but conclusions remain tentative due to the nature of the distractors in the recognition test.

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Wickelgren (1975) provides a careful review of the strength theory of recall and recognition originally proposed in a paper by Wickelgren and Norman in 1966. Strength theory assumes that when a to-be-remembered item is presented, some representation of it becomes activated in memory. This representation is referred to as the memory trace. The accuracy of the memory trace is referred to as trace strength. A particular value of trace strength is arbitrarily chosen and used as a response criterion. If the strength of the memory trace exceeds the criterion, a response is made. Such responses are either hits (i.e. responding with items that were, in fact, presented) or false alarms (i.e. responding with items that were not presented). If the strength of the memory trace does not exceed the criterion, no response is made. No response indicates misses (i.e. not responding with items that were, in fact, presented) and correct rejections (i.e. not responding with items that were not presented). Strength theory asserts that the response criterion is lower for recognition than recall because of specific cues present at recognition. It is because of the lower response criterion that recognition of an item is easier than recall.

Do recall and recognition involve similar processes, or are there essential differences in the processes underlying the two tasks?

Strength theory asserts that recall and recognition involve the same processes. Support for the theory comes from the fact that several experimental variables affect recall and recognition in the same way. For example, variables such as study time, the retention interval, and massing and spacing of presentations have similar effects on recall and recognition which suggests no essential differences in the way items are processed for the two tasks (Kintsch, 1966; Olson, 1969). Other variables differentially affect recall and recognition and therefore, argue against strength theory. For example, while it is known that high-frequency words are recalled better than low-frequency words (Hall, 1954), the opposite holds true for recognition (Gorman, 1961; Shephard, 1967). In a recent study, Tverski (1973) concluded that successful recognition may depend on encoding enough detail about an item to discriminate it from similar items, while successful recall may depend on associative encoding. Although it is possible to treat such a conclusion as "...self-evident truth not requiring any explanation, the challenge of explaining the phenomena (the data) by relating it to other known facts about memory still remains (Tulving and Madigan, 1970, p. 467)." Strength theory, as it now stands, poses no obvious means of interpreting the data since it asserts that items for recall and recognition are processed in a similar way.

Another variable known to differentially affect recall and recognition is task instructions. For example, only specific instructions ensure that subjects will organize material effectively for recall, but almost any instructions are adequate for recognition (Estes and DaPolita, 1964). The finding indicates that some organization of the material is necessary for recall but is not essential for recognition. The finding contradicts strength theory by suggesting that different processes underlie recall and recognition performance.

An alternate theory is provided by Muller (1913) and Kintsch (1970). The two-process theory asserts that recall and recognition involve different processes. Retrieval is considered an important process in recall but not in recognition. In addition, recognition is postulated as a sub-process of recall. That is, in order to recall an item, it must be both retrieved and recognized. If recognition does not involve retrieval, then it follows that experimental variables which facilitate retrieval in recall will have no effect on recognition performance.

Tulving (cited in Norman, 1969) argues that retrieval is the key to memory and the key to retrieval is availability. Organization facilitates retrieval by making items readily available. One way items may be organized is by association within a category: associative organization. Kintsch (1968) points out, if retrieval and recognition are separate as the two-process theory implies, associative organization should have no or little effect on recognition performance. Kintsch (1968) replicated a study by Cofer (1967) and demonstrated that when subjects were presented with items varying in degree of association, recall for highly associated items was best while no difference in recognition was found. That is, associative organization facilitated recall performance but had no effect on recognition performance.

In a second experiment, Kintsch (1968) extended the finding to a different principle of organization: organizational structure. Before discussing Kintsch's findings, 'organizational structure' will be defined and differentiated from other organizational concepts.

Structure will be referred to throughout the remainder of the paper as the principle by which items in a set are organized. An item is defined in terms of its elements. For example, items such as, circle-triangle-circle-square, may be presented for recall or recognition. The items can vary along many dimensions: <u>type</u> of shapes, <u>size</u> of shapes, <u>number</u> of shapes, <u>colour</u>, and so on. If all items to be presented are four circles with each circle of a different colour, then the dimensions of type, number, and size are held constant for all items in the set to be remembered. When dimensions are held constant for all items in a set, the dimensions are correlated (Garner, 1974).

Similarly, <u>elements</u> within a single dimension may be correlated. That is, elements within a dimension may vary together. In the example, all dimensions are held constant except for the dimension of colour. If elements of colour in the first and last position vary together as in,

```
green -red   -blue  -yellow
green -blue  -red   -yellow
green -brown -orange-yellow
  .                   .
  .                   .
  .                   .
purple-brown -orange-black
purple-orange-blue  -black
```

then, elements in the first and last positions of items are correlated along the dimension of colour. When elements of a dimension are correlated in a set, the organizational structure is referred to as simple structure (Garner, 1974). When elements of a dimension are not correlated in a set, as in the case of four shapes where elements of colour appear random, the organizational structure is referred to as complex structure (Garner, 1974).

Garner (1974) states that elements describe the organizational structure of the set to which they belong. For example, the words 'pet' and 'pot' describe a total set of words that begin with 'p', end with 't', and contain a vowel. Conversly, the organizational structure of the set specifies the number and exact items in that set. For example, items that begin with 'p',end with 't', and contain a vowel specify the following set: pat, pet, pit, pot, put. The organizational structure is simple because elements (i.e. letters) of a dimension (i.e. shape) are correlated. An item whose elements describe a simple organizational structure in the set from which it is derived will hense be referred to as a simple-structured item. An item whose elements describe a complex organizational structure in the set from which it is derived will hense be referred to as a complex-structured item.

The word association refers the relationship between items in terms of organizational structure, and should not be confused with other principles by which items within a set may be associated. For example, the words 'pet' and 'pot' are associated by the simple organizational structure described by their elements. However, the word 'pot' may also be associated with the word 'kettle' by the semantic structure of the set: kitchen utensils.

Kintsch (1968) used certain transitional rules to produce consonant-vowel-consonant (CVC's) which had simple structure or complex structure. Simple-structured CVC's were formed such that each consonant was combined (i.e. correlated) with only two other consonants using all five vowels. Complex-structured CVC's were formed such that each consonant followed every other consonant either two or three times, each time with a different vowel.

In addition to organizational structure, intra-list similarity was varied using either five or ten consonants to form the sets of CVC's.

The reason for varying intra-list similarity was that similarity and structure were confounded by Kintsch (1968) and Cofer (1967) in that highly associated items had higher similarity as well as more structure than low associated items. Results of the experiment revealed that high intra-list similarity decreased performance for both recall and recognition, but did not interact with organizational structure.

Simple-structured items resulted in more correct responses for recall than complex-structured items. There was no difference in correct responses for recognition between simple-structured and complex-structured items. The data was in agreement with Kintsch's initial assumption that recall involves retrieval and therefore, is facilitated by organizational structure; recognition does not involve retrieval and therefore, is not facilitated by organizational structure.

When errors were analyzed, it was found that organizational structure had a significant effect for recognition, and the effect was different than that for recall. Simple-structured items resulted in more recognition errors than complex-structured items while complex-structured items resulted in more recall errors than simple-structured items. Kintsch was unable to explain how simple structure could have produced no effect on correct responses and yet produce more recognition errors than complex structure. The error data remains unexplained by two-process theory which asserts that recognition is not facilitated by organizational structure. If recognition is not facilitated by organizational structure, then complex-structured items should not have resulted in fewer errors than simple-structured items.

The proposed difference between recall and recognition. Items for recall may be organized by the structure of the total set from which they are derived (Garner, 1974). That is, recall may involve an attempt to learn the structure of the total set since items are organized by the structure they produce within that set. As experimental evidence suggests, simple-structured items are easier to organize than complex-structured items and therefore, are easier to recall (Garner, 1974; Horowitz, 1961; Whitman, 1966; Whitman and Garner, 1963).

Conversly, Tverski (1973) suggests that recognition may involve an attempt to discriminate items from similar items. If a task involves discrimination, then the advantage of simple structure is lost (Garner, 1974). Discrimination is best when the difference between elements of items is maximum, and worst when the difference between elements of items is minimum. Since elements of items are correlated, simple structure does not provide a large amount of differential information by which items can be discriminated. For example, the words 'paj' and 'poj' can only be discriminated by the vowel. On the other hand, complex structure provides more differential information than simple structure because no correlation exists between elements along a dimension, as in 'paj' and 'lek'. Experimental evidence indicates that complex-structured items are better recognized than simple-structured items because complex structure provides more differential information than simple structure (Donderi, 1967; Postman and Stark, 1969; Waugh, 1961; Wickelgren, 1967). The finding that complex-structured items are better recognized than simple-structured items suggests that recognition involves discrimination since recognition is best when item difference is maximum.

Thus, three theories have been discussed, each differing in its basic assumptions regarding the manner in which items are processed for recall versus recognition. All three theories agree that organizational structure facilitates retrieval by making items readily available. Simple-structured items are better organized than complex-structured items and therefore, are easier to recall. However, the three theories do differ in their basic assumptions regarding the manner in which items are processed for recognition. The proposed theory asserts that recognition involves an attempt to discriminate items from similar items. Complex-structured items provide more differential information than simple-structured items and therefore, are easier to recognize. The two-process theory asserts that recognition does not involve retrieval and therefore, is not facilitated by organizational structure. Thus, there are no recognition differences between simple-structured and complex-structured items. Strength theory asserts that recall and recognition involve similar processes and therefore, simple-structured items, like recall, are easier to recognize than complex-structured items.

The effect of rate of item presentation on recall and recognition performance. One variable commonly employed to investigate the processing of items in recall and recognition is the rate at which items are presented. For example, Aaronson and Sternberg (cited in Aaronson, 1967) presented evidence that subjects receiving a slow rate of item presentation used an immediate recall strategy. Subjects actively rehearsed items during presentation. Subjects receiving a fast rate of item presentation used a delayed recall strategy. Subjects did not have sufficient time to verbally identify and rehearse items during presentation and thus, items were not verbally identified until presentation had ended. More item errors were found for slow presentation than fast presentation. The increase in errors for slow presentation was attributed to interference occuring between successive items during rehearsal. Since subjects could not actively rehearse items during fast presentation, interference (as measured by the number of errors) was lower for the fast rate than the slow rate.

A study by Latonas (1974) obtained similar results for recall but different results for recognition. The study varied three rates of presentation in a free-recall/multiple-choice-recognition experiment. In a fast presentation condition, items were presented at a 2-sec rate (1-sec exposure followed by 1-sec delay before onset of the next item). A slow presentation condition received 7-sec exposure followed by 1-sec delay. In order to determine whether results were due to stimulus exposure (i.e. time available for perception) or to inter-stimulus interval (i.e. time available for rehearsal) a control condition was used that received 1-sec exposure followed by 7-sec delay.

Results showed that recall and recognition errors differentially combined with correct responses to determine accuracy scores (see Table 1). Stimulus exposure increased accuracy for both recall and recognition as indicated by more correct responses for slow presentation than the control,but had no effect on recall and recognition errors. That is errors could not be attributed to insufficient time for perception. For recognition,inter-stimulus interval (i.e. time available for rehearsal) increased accuracy as indicated by <u>more</u> correct responses and <u>fewer</u> errors for the control condition than for the fast condition. Since recognition errors were fewer for the control condition than for the fast condition, interference due to rehearsal did not occur. Results also indicated that fewer errors for the control condition could not be attributed to increased time for perception because there was no difference in errors between the control condition and slow condition while stimulus exposure remained the same between the control condition and fast condition. Thus, it appears that some other process acts to produce fewer recognition errors when the inter-stimulus interval is increased. While it was expected that inter-stimulus interval would increase recall errors because of interference occuring during rehearsal, more recall errors were obtained for the control condition than the fast condition but the difference was not significant due to a floor effect operating on recall errors for fast presentation. Results also indicated that recall errors could not be attributed to insufficient time for perception because there was no difference in errors between the control condition and the slow condition while stimulus exposure remained the same between the control condition and fast condition.

Since recall errors increased when inter-stimulus interval increased, and did not decrease when stimulus exposure increased, recall errors were likely due to interference occuring during rehearsal. Since recognition errors decreased when the inter-stimulus interval increased, and did not decrease when stimulus exposure increased, interference plays no major role in recognition. The results offer some evidence that items are processed differently for recall versus recognition. If recall and recognition are differentially affected by organizational structure as the proposed theory implies, then the following should occur under fast and slow rates of item presentation:
1. If fast presentation does not allow subjects to verbally identify and rehearse items, then the organizational structure by which items

Table 1

Mean Correct Responses, Errors, and Accuracy Scores for Recall and Recognition Under Fast, Slow, and Control Rates of Presentation (Latonas, 1974)

DEPENDENT MEASURE	RECALL			RECOGNITION		
	Fast	Slow	Control	Fast	Slow	Control
Correct Responses	6.2	8.9	11.3	11.4	13.2	15.6
Errors	0.4	0.8	0.9	3.6	1.4	1.5
Accuracy	0.300	0.400	0.525	0.390	0.590	0.715

are associated cannot be identified and used to facilitate recall performance. If items cannot be associated by the organizational structure during fast presentation, then little or no interference should occur between successive items. Consequently, there should be no difference in recall errors between simple-structured and complex-structured items under fast presentation.

2. If subjects can verbally identify and rehearse items during slow presentation, then interference can occur between successive items. Since simple-structured items provide an organizational structure which is more effective in mediating associations than complex-structured items, more interference should occur if the structure is complex as opposed to simple. Consequently, complex-structured items should produce more recall errors than simple-structured items under slow presentation.

3. If successful recognition depends on discriminating between items in memory and complex-structured items are easier to discriminate than simple-structured items, then simple-structured items should produce more recognition errors than complex-structured items.

4. If the significant difference between recall and recognition lies in the fact that interference plays a major role in recall but not recognition, then simple-structured items should produce more recognition errors than complex-structured items under both fast and slow presentation.

The following should hold true for correct responses:

1. If fast presentation does not allow subjects to verbally identify and rehearse items, then the organizational structure by which items are associated cannot be identified and used to facilitate recall performance. If items cannot be associated by the organizational structure, during fast presentation, then there should be no difference in correct responses between simple-structured and complex-structured items.

2. If subjects can verbally identify and rehearse items during slow presentation, then the organizational structure by which items are associated can be identified and used to facilitate recall performance. Since simple-structured items provide an organizational structure

that is more effective in mediating associations than complex-structured items, simple-structured items should produce more correct responses than complex-structured items under slow presentation.

3. If successful recognition depends on discriminating between items in memory and complex-structured items are easier to discriminate than simple-structured items, then complex-structured items should produce more correct responses than simple-structured items.

4. If associations play no major role in recognition, then complex-structured items should produce more correct responses than simple-structured items under both fast and slow presentation.

Alternatively, strength theory predicts the same effect of organizational structure on recognition as that proposed above for recall, with the exception that recognition is superior to recall. That is, strength theory asserts that recall and recognition involve similar processes, except that recognition of an item requires a lower strength threshold than recall.

Two-process theory, on the other hand, predicts the same effect of organizational structure on recall as strength theory and the proposed theory, but a completely different effect of organizational structure on recognition performance. The two-process theory assumes that recognition does not involve retrieval and therefore, is not facilitated by organizational structure. Thus, two-process theory predicts no difference in correct responses and errors for recognition of complex-structured and simple-structured items under both fast and slow rates of presentation.

Although predictions may be made from the theories presented in relation to organizational structure and rate of presentation, the question of underlying processes is complicated by a problem inherent in attempting to <u>directly</u> compare recall and recognition performance. The problem of comparing the <u>amount</u> recalled with the <u>amount</u> recognized has not yet been solved for at least two reasons. First, the number of alternatives from which a response is selected is presumably larger for recall than recognition (Davis, Sutherland and Judd, 1961). Consequently, many correct responses from a small number of alternatives (as is usually the case with recognition) does not necessarily indicate better performance than few correct responses from a large number of alternatives (as in recall). Second, it is possible that subjects use different response criteria for recall and recognition. Response criteria affect performance by influencing the number of correct responses and errors (Norman, 1969). For example, if a subject attempts to maximize correct responses, he may select a low response criterion but at the expense of making many errors. If a subject attempts to minimize errors, he may select a high response criterion but at the expense of missing many correct responses. Thus, it is argued that a common standard of comparison must be established before recall and recognition can be compared in any meaningful way.

If search is an aspect of retrieval as most theorists presume, it may provide the necessary framework by which recall and recognition can be compared. Retrieval of items from memory may involve a search of a number of storage locations looking for a match between stored information (a search set) and the test item. Schiffrin (1970) outlines the search process of retrieval as follows:

1. Decisions are made regarding what memory store(s) to examine and what search set to select. The search set can be conceptualized as a collection of units of information (i.e. elements) organized in interassociated groups called images.
2. A draw, which consists of choosing elements at random, is then made from the selected search set.
3. An image (or images) containing the drawn elements is then examined.
4. On the basis of elements drawn, a decision is made either to emit a response, to continue the search, or to terminate.

The size and nature of the search set is specified by the task set for the subject, the response required, item information given in the test, and overall strategies. Recognition tests in previous experiments have generally differed from recall tests primarily in the size of the search set. It was previously mentioned that if the number of alternatives (i.e. the size of the search set) is different for recall as opposed to recognition, performance cannot be compared in any meaningful way.

However, if the search set remains constant across experimental conditions, then it becomes possible to use signal detection theory to compare recall and recognition performance,

Rationale for the use of signal detection theory in comparing recall and recognition. The study allows for the precise calculation of d' parameters used in comparing recall and recognition performance.

Before signal detection theory can be used in comparing recall and recognition, it is maintained that special care must be given to the underlying theoretical assumptions involved. For example, Freund, Brelsford, and Atkinson (1969) found recognition superior to recall. A correctional procedure for guessing (Hilgard, 1951, p. 556) was used to transform the data so that recall and recognition could be directly compared. They suggested the transformation represented '...a weighted average of those items correctly retrieved from memory and those items correctly guessed' (p. 218). As expected, the transformed data supported conclusions drawn from the raw data. Recognition was superior to recall. The raw data were then transformed to d' scores. While it was expected that the d' transformations would reveal the superiority of recognition over recall, recall was found to be superior to recognition. Obviously, careful consideration must be given to theoretical assumptions underlying the transformation itself.

In addition, no difference between recall and recognition has been reported by Bruce and Cofer (1962). The usual superiority of recognition over recall appears to be related (at least) to the type of items used and the nature of the distractors in the recognition test. For example, simple-structured items may provide an organizational structure which is more effective in mediating associations than complex-structured items thereby improving recall performance. Similarly, making the distractors highly unrelated to test items in a recognition test may tend to improve recognition performance. As Kintsch (1970) points out, it may also lead to category recognition.

The above observations indicate that the size and nature of the search set will influence recall and recognition performance. Since the probability of a false alarm used in the calculation of d' is dependent upon the number of alternative items (i.e. correct rejections), the size of the search set becomes an important variable to control. This point can be easily demonstrated with reference to the diagrams in figure 1.

In figure 1, S_1 and S_2 represent total sets from which items are selected, s_1 and s_2 represent subsets of items drawn at random for item presentation, and T_1 and T_2 represent items selected from the total set to be used as distractors in a recognition test.

In free recall, the subject must generate items in absence of an explicit list of alternative items. Consider figure 1 where the number of items in s_1 equals the number of items in s_2, but the number of items in S_2 is greater than the number of items in S_1. (Numerical examples are provided in Appendix A). If the number of correct responses and the number of errors is held constant, performance on s_1 and s_2 will appear identical. As shown in example 1, Appendix A, the probability of a correct response is the same for recall of s_1 and s_2. However, when the number of alternatives in the total set are considered, d' for recall of s_2 is greater than s_1, as shown in example 2, Appendix A.

In multiple-choice recognition, the subject must select items from an explicit list of alternatives. Typically, the number of distractors in the recognition tests are held constant even though the size of the total sets may vary. The reason rests on an 'independence from irrelevent strengths' assumption which asserts that the decision to make a response is determined by the strength of association between the test item and the test response; the strength of other associations involving the test response and the test items are viewed as being irrelevent to that decision (Wickelgren, 1967). In other words, the assumption is that the search set does not extend beyond the alternatives offered by the recognition test, and whether or not an item is recognized depends upon its own characteristics and not upon other responses which might be associated with it. Now consider figure 1 where the number of items in s_1 equals s_2,

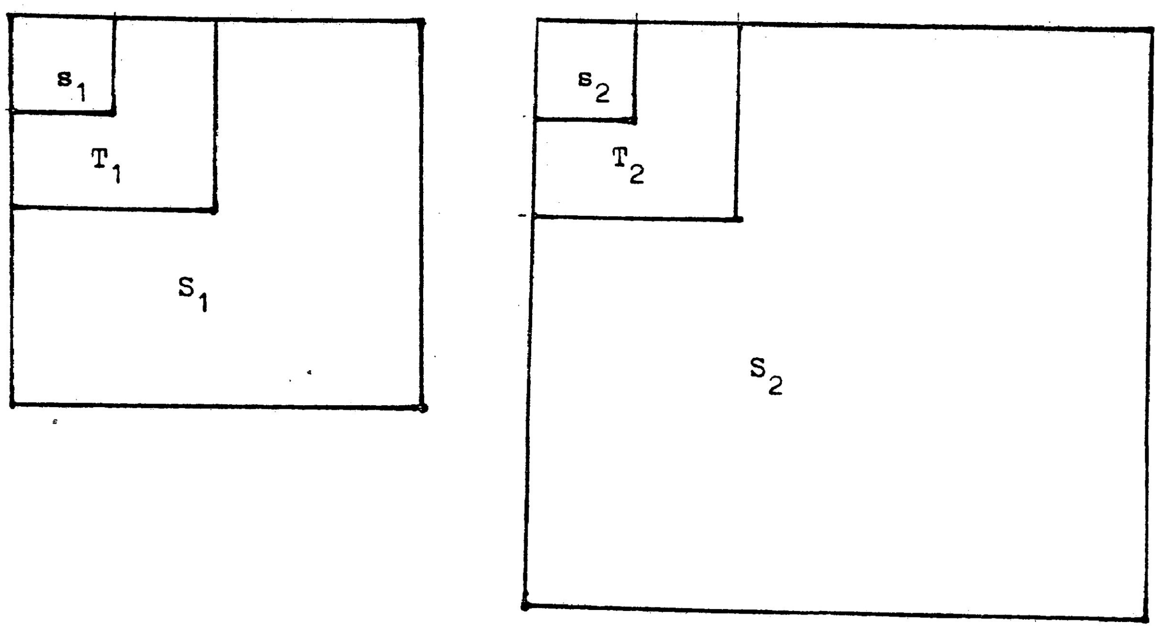

Figure 1 Two sets of stimulus items, where S_1 and S_2 represent total sets from which s_1 and s_2 are drawn at random to be used in a stimulus presentation. T_1 and T_2 represent subsets of items selected from the total sets (S_1 and S_2) to be used as distractors in a recognition test.

the number of items in T_1 equals T_2, but the number of items in S_2 is greater than S_1. If the number of correct responses and the number of errors remains constant for the recognition task (as is postulated by the two-process theory), measures of recognition based on the number of items in the recognition test (T_1 and T_2) would yield the same d' scores for s_1 and s_2, as shown in example 2, Appendix A. However, it is impossible to determine whether or not the recognition test, in fact, defines the search set used during recognition as there is no existing evidence in support of the 'independence from irrelevent strengths' assumption (Wickelgren, 1970).

Recognition performance could also be compared using the total set (S_1 and S_2) as a standard in establishing hit and false alarm rates. Hence, as shown in example3, Appendix A, recognition would be greater for s_2 than s_1. However, in order to perform this comparison, one must assume that the search set extends beyond items in the recognition test (i.e. T_1 and T_2). At present, there is little evidence to suggest that either assumption holds true.

The issue may be resolved most appropriately by careful selection of stimulus items from total sets of equal size.

<u>Comparing recall and recognition performance</u>. The problem of comparing recall with recognition is complicated by lack of a common standard by which comparisons are made. For example, successful recall may depend on searching through a very large search set, while recognition performance is based on some subset of this larger set. In many cases the size and nature of the search set is not taken into account when comparing recall and recognition. That is, the size and nature of the search set may vary across experimental conditions for the recall task but remain the same for the recognition task. In addition, the size of the search set is impossible to determine in many recall experiments. If the number

of alternatives used during recall remains unspecified, information measures such as d' cannot be calculated.

The first attempt to use an information measure to compare recall and recognition is provided by Davis, Sutherland, and Judd (1961) who found that information transmitted increased as the number of alternatives from which selection was made increased. An equal amount of information was transmitted in recognition out of 90 alternatives and in free recall. Information transmitted for recall was higher than for recognition out of 30 and 60 alternatives. Davis, et al. concluded that in previous studies "... recognition is superior to recall only because it usually involves selection from fewer alternatives (p. 427)." The conclusion, however, only holds true if the following assumption underlying the information measure holds true. That is, no information is transmitted by errors because errors are evenly distributed over the search set from which selection is made for each experimental group and condition. No attempt was made to analyze errors to see if the assumption held true. Latonas (1974) has shown that recall and recognition errors differentially combine with correct responses to determine information transmitted. Thus, an information measure such as d' is recommended when making recall-recognition comparisons since it takes into account errors (misses and false alarms) as well as correct responses.

The experiment by Davis, et al. has also been criticized by Field and Lachman (1966) in that the number of alternatives used during recall was overestimated. In an attempt to estimate the number of alternatives used during recall, Field and Lachman used three free-recall conditions. All conditions received exposure to the total set from which items were selected, as well as a verbal discription of items in the total set. Items were consonant-vowel bigrams excluding the consonants q, x, and z. Fifteen items were selected for presentation from the total set of 90 bigrams. One group received a free-recall task after which they were asked to estimate the number of items in the total set. A second free-recall group was asked to write down all items they happened to think of while attempting to recall the stimulus items, and to indicate correct responses with a check mark. A third free-recall group was asked to generate all items in the total set, and to indicate correct responses with a check mark. Recall was then compared to recognition out of 30, 60, and 90 alternatives.

Of main importance, results indicated that subjects grossly underestimated the size of the total set for recall and that the number of alternatives used during recall varied with instructions. Depending upon the number of alternatives used during recall, information transmitted was larger or smaller for recall versus recognition.

Field and Lachman concluded that the number of alternatives used during recall (i.e. the size of the search set) was grossly overestimated in previous research. However, this conclusion is debated by signal detection theory. In terms of signal detection theory, subjects in Field and Lachman's free-recall conditions did not generate a total list of alternatives used during recall. Rather, a list of hits and possible false alarms was produced. Subjects then recognized items presented for recall from the list of hits and false alarms. Since a subject's initial misses and correct rejections were not considered, a new and smaller search set was generated for recall. The information measure of Davis, et al. applied to the smaller set indicated better performance than the same measure applied to the total set. Thus, signal detection theory argues that the size of the search set was not grossly overestimated in previous research, but rather grossly underestimated by Field and Lachman.

An important conclusion may be derived from the experiments of Davis, Sutherland and Judd (1961) and Field and Lachman (1966). That

is, information transmitted in recall and recognition increases as the number of alternative items from which selection is made increases. Depending upon the number of alternatives, information transmitted may be larger or smaller for recall versus recognition. Consequently, the size of the search set must be considered when comparing recall and recognition performance. The problems involved in comparing recall and recognition become evident in the examples supplied in Appendix A.
EXAMPLE 1 (Comparing performance using correct responses): Recognition is superior to recall; performance on s_1 and s_2 is identical.
EXAMPLE 2 (Comparing performance using d', where d' for recall is based on the number of alternatives in S_1 and S_2 and d' for recognition is based on the number of alternatives in T_1 and T_2): Recall is superior to recognition. For recall, performance on s_2 is better than performance on s_1. For recognition, performance on s_1 and s_2 is identical.
EXAMPLE 3 (Comparing performance using d', where d' for both recall and recognition is based on the number of alternatives in S_1 and S_2): There is no difference between recall and recognition performance; performance on s_2 is better than performance on s_1.

The present experiment is an attempt to compare recall and recognition using a common standard. That is, the total set from which items are selected is held constant across experimental conditions. Consequently, measures of recall and recognition reflect subjects' performance on a common search set regardless of task or condition. Because recall and recognition errors may differentially combine with correct responses to determine performance (Latonas, 1974), d' offers a more appropriate measure of comparison than other information measures which assume no information is conveyed by errors. Since d' scores take into account errors (misses and false alarms) as well as correct responses, they describe the combinational effect measured by correct responses and errors. The predictions for correct responses and errors (pp. 8-11) concern the effect of organizational structure on recall and recognition under fast and slow presentation rates, and may now be re-stated in terms of d' predictions:

The Proposed Theory

1. d' for recall of simple-structured items is the same as complex-structured items under fast presentation.

2. d' for recall of simple-structured items is greater than complex-structured items under slow presentation.

3. d' for recognition of complex-structured items is greater than simple-structured items under fast presentation and under slow presentation.

Strength Theory

1. d' for recall of simple-structured items is the same as complex-structured items under fast presentation.

2. d' for recall of simple-structured items is greater than complex-structured items under slow presentation.

3. Strength theory predicts the same effects of organizational structure on recognition performance with the exception that recognition is better than recall.

Two-process Theory

1. d' for recall of simple-structured items is the same as complex-structured items under fast presentation.

2. d' for recall of simple-structured items is greater than complex-structured items under slow presentation.

3. d' for recognition of simple-structured items is the same as complex-structured items under fast presentation and under slow presentation.

The d' scores allow for the direct comparison of recall and recognition performance. In order to compare the effect of organizational structure on recall and recognition, simple-structured and complex-structured items are presented under two rates of presentation. Correct responses and errors are transformed to d' scores so that recall and recognition can be directly compared, and results are put to the initial question: Do recall and recognition involve similar processes, or are there essential differences in the way items are processed for the two tasks?

METHOD

Subjects. Subjects were volunteer Psychology 1100 students from Lakehead University, Thunder Bay, Ontario. Thirty subjects were randomly assigned to four conditions for a total of 120 subjects.

Design. The experiment involved a 2 X 2 X 2 analysis of variance design involving 2 tasks (recall and recognition), 2 organizational structures (simple and complex), and 2 rates of item presentation (fast and slow). Since available evidence indicates no significant effects due to order or sequential learning when a recognition task is proceeded by a recall task (Tverski, 1973; Underwood, 1972), a within-subjects design was used in relation to task such that all subjects performed a free recall task followed by a multiple-choice recognition task. The experimental conditions were as follows: A fast rate of presentation (1-sec exposure followed by 1-sec delay before the onset of the next item) with either simple-structured or complex structured items; a slow rate of presentation (6-sec exposure followed by 1-sec delay) with either simple-structured or complex-structured items.

Procedure. Subjects were tested in groups according to their assigned conditions. All subjects were given the following free recall instructions by the experimenter:

> This is an experiment in memory. I will project on the screen a series of twenty nonsense words, one after the other. Afterwards, your task will be to write down as many of the words as you can remember, in any order.

Depending upon the assigned condition, simple-structured or complex-structured items were then presented under fast or slow presentation. All subjects were supplied with the appropriate sheet and pencils in advance so that no delay occurred after the item presentation. Two minutes were allowed for completion of the recall task. The multiple-choice recognition task was the introduced (incidentally) as follows:

> Before you go, I will pass out these sheets of paper. Each sheet contains a list of nonsense words, some of which appeared on the screen before, and some of which did not. Your task will be to circle as many of the words as you can recognize.

Two minutes were allowed for completion of the recognition test.

Stimulus materials. The stimulus items were consonant-consonant-vowel-consonant (CCVC) nonsense words based on Garner and Whitman's (1965) formulation shown in Table 2. Five consonants were used in position one, two consonants in position two, two vowels in position three, and two consonants in position four to create a total set of 40 CCVC's. The total set contains four subsets. Within each, there are two correlations among elements of items. The first two positions of CCVC are correlated, and the last two positions are correlated. That is, letters in the CC position vary together, and letters in the VC position vary together.

Simple structure (20 S and 20 S') was formed on the vertical plane by combining two subsets of 10 items in which only the C in position four of CCVC was altered. Thus in S, items KLOZ and KLAJ in the first subset became KLOJ and KLAZ in the second subset. Simple structure was produced because CC positions of CCVC were correlated while V and C positions were not correlated.

Complex structure (20 C and 20 C') was formed by combining subsets horizontally. In this case, the C in position two of CCVC was altered as well as the C in position four. Thus in C', KLOZ in the first subset became KROJ in the second subset. Complex structure was produced since no positions of CCVC were correlated.

The subsets S' and C were used as stimuli in the experiment. Stimulus items were typed in black, capital letters on 35 mm slides. Items were projected onto a screen one at a time in random order by means of a Kodak projector. Presentation rate was controlled by two Hunter timers.

The recall data was obtained on $8\frac{1}{2}$" X 11" sheets of paper. Each sheet had the recall instructions printed at the top, and 20 spaces were provided for written responses.

The recognition test consisted of the 40 items of the total set printed in four columns (with written instructions) on $8\frac{1}{2}$" X 11" sheets of paper. The target words appeared in random order.

Table 2

Stimulus Items

(After Garner and Whitman's Formulation, 1965)

KLOZ		KROJ		
KLAJ		KRAZ		
FROZ		FLOJ		
FRAJ		FLAZ		
GLOZ	+	GROJ	=	20 C
GLAJ		GRAZ		
BROZ		BLOJ		
BRAJ		BLAZ		
PLOZ		PROJ		
PLAJ		PRAZ		
+		+		
KLOJ		KROZ		
KLAZ		KRAJ		
FROJ		FLOZ		
FRAZ		FLAJ		
GLOJ	+	GROZ	=	20 C'
GLAZ		GRAJ		
BROJ		BLOZ		
BRAZ		BLAJ		
PLOJ		PROZ		
PLAZ		PRAJ		
20 S		20 S'		

RESULTS AND DISCUSSION

The raw data is reported in Appendix B along with the d' transformations. Separate analysis were performed on each of the three dependent measures: errors (E), correct responses (CR), and d' scores.

<u>Errors</u>. Meaningful recall errors and total recognition errors were analyzed. Meaningful recall errors consisted of intrusions that were not part of the item presentation but were members of the total set from which stimulus items were selected. Table 3 reveals that about 80 per cent of all recall errors could be described as meaningful intrusions. About 15 per cent more were acoustically similar (e.g. CROJ for KROJ) or perceptual errors (CROJ for GROJ). A Chi-square analysis performed on meaningful errors revealed no significant results ($X^2 = .39, < .80 < p < .90$) thus indicating that the proportion of meaningful errors in relation to total errors was evenly distributed across experimental conditions.

Separate ANOVA's were performed, one including total recall errors and another including meaningful recall errors. Performing the ANOVA with meaningful recall errors did not alter the analysis. The finding, along with the results of the Chi-square analysis, provided the necessary rationale for analyzing only meaningful recall errors.

Mean errors are reported in Table 4 and plotted in figure 2. Table 5 summarizes the ANOVA and shows significant effects for structure $F(1,116) = 12.71$, $p < .0005$ and type of task ($p < .0001$). Complex structure resulted in significantly more errors than simple structure. There were significantly more recognition errors than recall errors. No interactions were significant.

The predicted effect of presentation rate on recall errors did not hold true. The number of recall errors under slow presentation were about as many as under fast presentation. Thus, it appears unlikely that associations were formed between items during slow presentation. If organizational structure were used to form

Table 3

Distribution of Meaningful Errors for the Recall Task

	Fast Presentation	Slow Presentation
Complex Structure	75.0%	88.6%
Simple Structure	77.0%	78.9%

Table 4

Mean Errors

STRUCTURE	RECALL		RECOGNITION	
	Fast	Slow	Fast	Slow
Simple	2.57	3.10	6.20	6.67
Complex	3.40	4.67	8.57	7.63

Table 5

Analysis of Variance Summary for Errors

	df	SS	MS	F	p
Subjects	119	1256.60			
Structure (S)	1	123.27	123.27	12.7102	0.00053
Rate (R)	1	6.67	6.67	0.6874	
S X R	1	1.67	1.67	0.1719	
Error (between)	116	1125.00	9.70		
Task (T)	1	881.67	881.67	135.9599	0.00000
T X S	1	3.27	3.27	0.5186	
T X R	1	19.27	19.27	3.0585	
T X R X S	116	730.73	6.30		

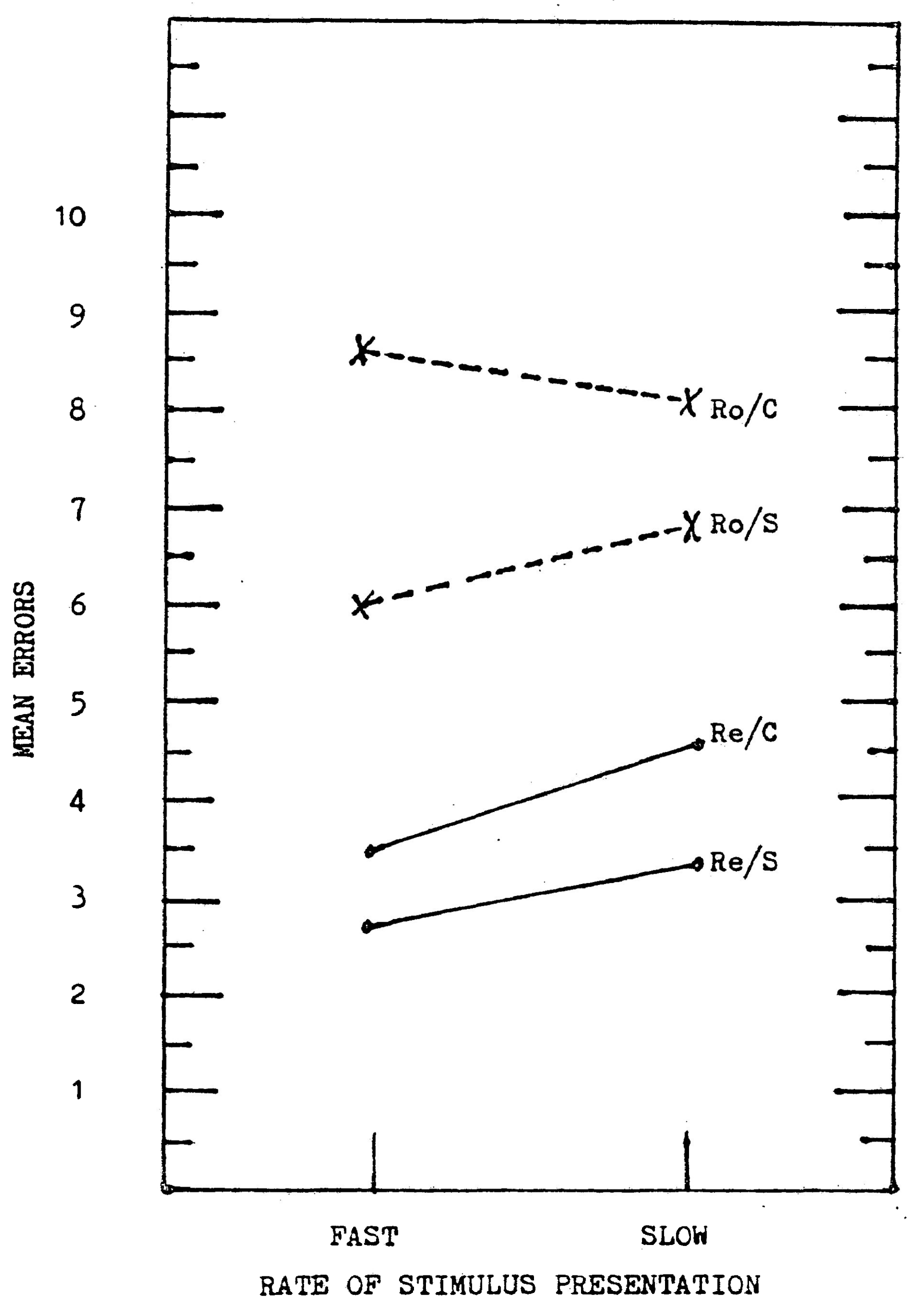

Figure 2 Mean errors for recall (Re) and recognition (Ro) of complex (C) and simple (S) structure under fast and slow rates of stimulus presentation.

associations between items during slow presentation, but not during fast presentation, then more associative interference (as measured by errors) would have been expected under slow presentation than fast presentation due to interference occurring during rehearsal.

The fact that complex-structured items resulted in more recognition errors, as well as more recall errors, than simple-structured items suggests that memory strength for simple-structured items was greater than for complex-structured items. In terms of strength theory, elements of simple-structured items occur together more frequently than with complex-structured items and therefore, have greater trace strength than complex-structured items.

Correct responses. The ANOVA performed on correct responses is presented in Table 6. The rate X structure interaction was significant ($p = .004$), and the rate X task interaction was significant ($p = .009$). There were significant main effects due to structure ($p < .0001$), rate of presentation ($p = .008$), and type of task ($p < .0001$).

The three-way interaction anticipated by two-process theory and the proposed theory was not present, nor was the task X structure interaction significant. That is, the prediction that organizational structure has differential effects on recall and recognition is not supported.

The significant two-way interactions were further explored by means of the Tukey test (see Appendix C). Mean correct responses are reported in Table 7 and are plotted in figure 3.

1. For the recall task, Appendix C indicates no significant differences between simple-structured and complex-structured items under the fast presentation rate. That is, under fast presentation, organizational structure did not facilitate recall performance.

It appears unlikely that recall performance was similar for simple-structured and complex-structured items because of insufficient time to associate items through rehearsal. If this were the case, more associative interference (as measured by errors) would have been expected under slow presentation than fast presentation.

Table 6

Analysis of Variance Summary for Correct Responses

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Subjects	119	1618.83			
Structure (S)	1	209.07	209.07	19.5431	0.00003
Rate (R)	1	77.07	77.07	7.2040	0.00834
S X R	1	91.27	91.27	8.5314	0.00420
Error (between)	116	1240.93	10.70		
Task (T)	1	646.82	646.82	137.0174	0.00000
T X S	1	0.82	0.82	0.1730	
T X R	1	33.75	33.75	7.1494	0.00858
T X R X S	1	2.02	2.02	0.4272	
Error (within)	116	547.60	4.72		

Table 7

Mean Correct Responses

STRUCTURE	RECALL		RECOGNITION	
	Fast	Slow	Fast	Slow
Simple	5.53	8.83	9.63	11.07
Complex	4.97	5.43	8.93	8.27

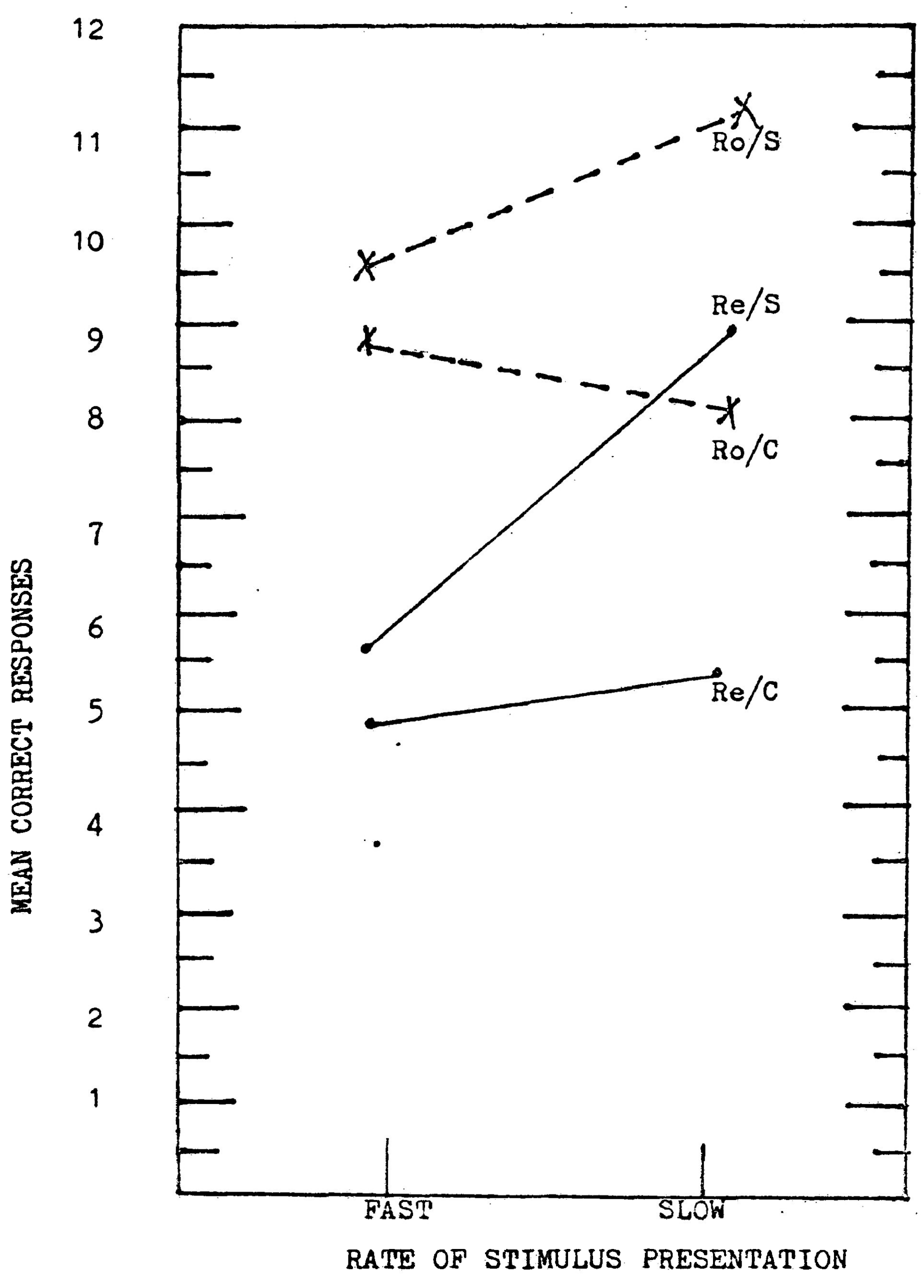

Figure 3 Mean correct responses for recall (Re) and Recognition (Ro) of complex (C) and simple (S) structure under fast and slow rates of stimulus presentation

Errors under slow presentation were about as many as under fast presentation and therefore, the error data has already argued against this assumption.

A similar result of no difference in correct responses between simple-structured and complex-structured items could have been obtained under fast presentation if system overload occurred because of the nature of the stimulus items. That is, items may have transmitted more information than could be processed under the fast presentation rate.

A similar result could have been obtained because the difference between simple-structured and complex-structured items was not great enough to be detected under the fast presentation rate. However, the difference between simple and complex structure was maximum for the particular set of items used in the experiment. A greater difference between simple and complex structure may be obtained by altering other dimensions of items, thereby altering the size and nature of the total set, and reducing the amount of information transmitted. For example, it is possible that a difference in correct responses could be obtained between recall of simple-structured 2-letter words and recall of complex-structured 2-letter words under fast presentation.

2. Similar for recognition, Appendix C indicates no significant difference between simple-structured and complex-structured items under fast presentation. The result of no difference in correct responses between simple-structured and complex-structured items under fast presentation remains decisive: The items varied in the same way except for the principle by which they were organized. The organizational structure, for whatever reason, was detected under fast presentation and therefore, performance was not facilitated. The effect of the particular set of items presented under a fast rate was the same for recall and recognition.

3. For recall, Appendix C indicates that simple-structured items resulted in significantly more correct responses than complex-structured items under slow presentation ($CR = 102$, $p < .01$). As predicted by all three theories, simple-structured items are better organized than complex-structured items and therefore, are easier to recall.

4. Similar for recognition, Appendix C indicates that simple-structured items resulted in significantly more correct responses than complex-structured items under slow presentation (CR = 84, $p < .01$). The result is in conflict with two-process theory which predicts no recognition differences between simple-structured and complex-structured items while maintaining that simple-structured items are better recalled than complex-structured items. Contrary to two-process theory, organizational structure facilitated recognition performance under the slow presentation rate. Since organizational structure is known to facilitate retrieval, the obtained result (contrary to two-process theory) signals the importance of retrieval in recognition memory.

In addition, the obtained result completely contradicts the proposed theory of recall and recognition. The proposed theory predicts that complex-structured items facilitate discrimination and therefore, are better recognized than simple-structured items. The obtained result is opposite to this prediction. Simple-structured items were better recognized than complex-structured items. Thus, it appears unlikely that successful recognition depends on subjects' ability to discriminate between items in memory. Rather, recognition, like free recall, was facilitated by the simple organizational structure in the set of items to be remembered.

Although the results support the prediction of strength theory, simple and complex structure, and therefore the structure of the distractors in the recognition test, are confounded in the total set and thus it is possible that recognition performance was better for simple-structured items than complex-structured items because of class recognition. Subjects may have been able to reject items that did not posses the right structural properties.

The d' analysis. The d' scores may be thought of as measures of sensitivity in detection of items in a memory store, or more precisely, the sum strength of the memory traces. Since the calculation of d' for all experimental conditions is based on the size of a common total set from which stimulus items were selected, recall and recognition can now be directly compared.

The d' scores were calculated on the basis of hit and false alarm rates using the procedure and tables outlined in Hochhaus (1972). The d' scores are reported, along with the raw data, in Appendix B.

The probability of a hit, p(HIT), was estimated by determining the number of correct responses (CR) obtained by each subject in relation to the number of stimulus items. That is, p(HIT) = CR/20.

For recognition, the probability of a false alarm, p(FA), was estimated by determining the number of errors (E) circled in the total set in relation to the possible number of correct rejections, That is, p(FA) = E/20.

For recall, p(FA) was determined using only meaningful errors (ME), or intrusions drawn from the total set, in relation to the number of correct rejections in the total set: p(FA) = ME/20. This step required an additional assumption unique to this experiment. That is, the total set from which items were selected was assumed to be representative of the search set used during recall. The analysis of recall errors provides the necessary support for this assumption in that 80 per cent of the recall errors could be classified as meaningful intrusions while another 15 per cent were acoustically or perceptually similar.

Mean d' scores are reported in Table 8 and plotted in figure 4. Table 9 summarizes the d' analysis and indicates significant effects due to structure ($p < .0001$), type of task ($p = .001$), and structure X rate interaction ($p = .047$).

The significant interaction was explored using the Tukey test (see Appendix D). For recall, there was no significant difference between simple-structured and complex-structured items under fast presentation. Under slow presentation, recall of simple-structured items was significantly better than complex-structured items (CR = 21.68, $p < .01$). Similarly for recognition, the difference obtained between simple-structured and complex-structured items under fast presentation fell below the critical range of significance. Under slow presentation, recognition of simple-structured items was

Table 8

Mean d' Scores

STRUCTURE	RECALL		RECOGNITION	
	Fast	Slow	Fast	Slow
Simple	0.68	0.88	0.41	0.69
Complex	0.42	0.16	0.04	0.11

Table 9

Analysis of Variance Summary for d' Scores

Source	df	SS	MS	F	p
Subjects	119	63.33			
Structure (S)	1	13.96	13.96	34.1398	0.00000
Rate (R)	1	0.30	0.30	0.7259	
S X R	1	1.65	1.65	4.0356	0.04687
Error (between)	116	47.43	0.41		
Task (T)	1	3.01	3.01	10.7175	0.00141
T X S	1	0.00	0.00	0.0167	
T X R	1	1.26	0.26	0.9211	
Error (within)	116	32.58	0.28		

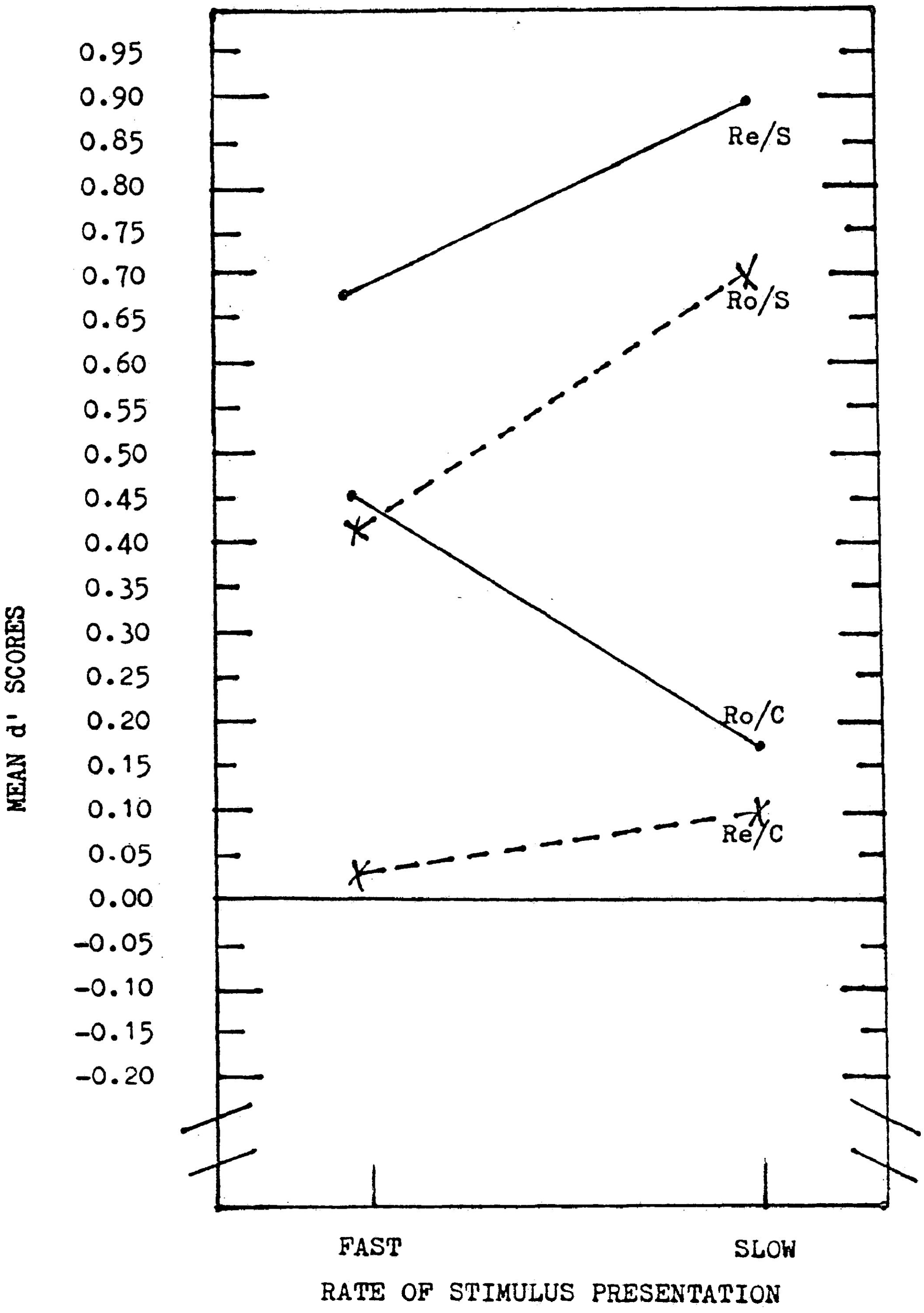

Figure 4 Mean d' scores for recall (Re) and recognition (Ro) of complex (C) and simple (S) structure under fast and slow rates of stimulus presentation.

better than complex-structured items (CR = 17.21, $p < .01$).

It remains possible that recognition was not systematically different than recall because the total set from which items were selected was held constant across experimental conditions and thus provided a common standard by which performance can be compared. Since simple-structured and complex-structured items were derived from the same total set, performance is indicative of subjects' ability to retrieve items from a common search set.

While it was expected that the d' analysis would yield similar results as those found for correct responses, the significant main effect for task indicates that recall performance was significantly better than recognition performance. Although it may be argued that this result is due to 'retroactive interference' in recognition as a result of performing a prior recall task, there is little evidence to suggest significant carry-over effects or interference when recognition is preceeded by recall (Tverski, 1973 ; Underwood, 1972). Consequently, the obtained difference between recall and recognition may be accounted for by decay of the memory trace. Decay increases as a function of time (Norman, 1969). Since there was a delay between item presentation and recognition, it is likely that the delay resulted in lowered trace strength for recognition.

Subject's performance on the recall and recognition tasks were correlated. Results appear in Table 10. The correlations, while positive, are not significant and suggest that no carry-over effects occurred.* In addition, the correlations suggest that different response criteria may have been used for recall and recognition. If a particular value of trace strength is used as a response criterion, and if the strength of the memory trace exceeds the criterion, a response is made (hits and false alarms). If not, no response is

*Similar correlation coefficients between-subjects have been reported by Underwood, 1972.

Table 10

The Correlation of d' Scores for Recall and Recognition

	Fast Presentation	Slow Presentation
Complex Structure	.07	.36
Simple Structure	.19	.26

made (misses and correct rejections). Hence, if a subject attempts to maximize the number of correct responses, he may select a low criterion value but at the expense of making many false alarms. If a subject attempts to minimize false alarms, he may select a high criterion value but at the expense of making many misses. The fact that there were fewer correct responses and errors for recall than for recognition suggests that the criterion value was higher for recall than recognition. However, the concept of a higher strength threshold for recall than recognition still remains tentative. It appears equally probable that the criterion value by which items were selected was higher for recall than recognition because the strength of the memory trace decayed for recognition, and not because recall <u>requires</u> a higher strength threshold.

Conclusions drawn from the d' analysis may be summarized as follows: First, since recall performance was superior to recognition performance, the strength of the memory trace was greater for recall than recognition. Second, the fact that no significant within-subjects correlations were obtained between recall and recognition suggests that different response criteria may have been used for the two tasks as a result of decay in the memory trace at the time of recognition. Third, organizational structure did not have differential effects on recall and recognition performance: Under slow presentation, simple-structured items were both better recalled and better recognized than complex-structured items.

To conclude, recognition was not systematically different than recall performance. There was a possibility that the result occurred because of the nature of the distractors used in the recognition test. Thus, any further conclusions about the equivalence between recall and recognition must remain tentative pending additional research.

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Appendix A

Numerical Examples Comparing Recall and Recognition Using Three Different Standards of Comparison

If S_1 and S_2 represent total sets from which subsets of items s_1 and s_2 are respectfully drawn to be used in a stimulus presentation, and T_1 and T_2 are subsets of items selected from the total sets to be used as distractors in a recognition test,

let s_1 = 10 items
s_2 = 10 items
S_1 = 40 items
S_2 = 80 items
T_1 = 20 items
T_2 = 20 items

and the number of items are held constant except for the size of the total sets.

Now let the number of correct responses and errors for recall of s_1 and s_2 equal 6 and 4, respectfully. Similarly, let the number of correct responses and errors for recognition of s_1 and s_2 equal 8 and 10 items.

Given the above numerical information, there are three standards by which recall and recognition can be compared. Example 1 compares recall and recognition using correct responses. Examples 2 and 3 compare recall and recognition using d' scores. In example 2, the probability of a false alarm, p (FA), for recall is based on the number of items in the total set (S_1 and S_2) while p(FA) for recognition is based on the number of items in the recognition test (T_1 and T_2). In example 3, p(FA) for both recall and recognition is based on the number of items in the total set (S_1 and S_2):

Appendix A (continued)

Numerical Examples Comparing Recall and Recognition Using Three Different Standards of Comparison

		RECALL					RECOGNITION				
		CR	p(CR)	E	p(FA)	d'	CR	p(CR)	E	p(FA)	d'
EXAMPLE 1:	s_1	6	.6	4	–	–	8	.8	10	–	–
	s_2	6	.6	4	–	–	8	.8	10	–	–
EXAMPLE 2:	s_1	6	.6	4	.10	1.54	8	.8	10	.50	0.84
	s_2	6	.6	4	.05	1.90	8	.8	10	.50	0.84
EXAMPLE 3:	s_1	6	.6	4	.10	1.54	8	.8	10	.25	1.52
	s_2	6	.6	4	.05	1.90	8	.8	10	.13	1.97

Appendix B

Raw Data

A. Recall and Recognition of Complex-Structured Items Under Fast Presentation:

	RECALL			RECOGNITION		
	CR	E	d'	CR	E	d'
	2	3	-0.27	7	7	0.00
	3	4	-0.21	8	3	0.73
	9	8	0.08	13	17	-0.63
	10	3	0.88	13	12	0.10
	6	0	1.94	10	10	0.00
	3	2	0.27	3	2	0.27
	3	3	0.00	7	7	0.00
	5	4	0.17	13	10	0.25
	5	1	1.06	8	10	-0.15
	7	5	0.26	10	7	0.25
	7	1	1.31	15	11	0.44
	4	2	0.48	8	10	-0.15
	6	0	1.94	10	8	0.15
	3	0	1.42	10	8	0.15
	3	0	1.42	8	6	0.22
	7	7	0.00	13	10	0.25
	6	3	0.51	12	13	-0.10
	4	3	0.21	10	8	0.15
	5	6	-0.14	8	9	-0.08
	3	4	-0.21	6	5	0.14
	9	2	1.08	7	7	0.00
	4	6	-0.31	10	7	0.25
	3	4	-0.21	3	3	0.00
	3	6	-0.51	10	9	0.07
	3	3	0.00	6	9	-0.30
	5	6	-0.14	4	7	-0.42
	3	0	1.42	8	10	-0.15
	4	5	-0.17	10	10	0.00
	7	4	0.42	7	11	-0.32
	7	7	0.00	11	11	0.00
TOTAL	149	102	12.70	286	257	1.12
MEAN	4.97	3.40	0.42	8.93	8.57	0.04

Appendix B (continued)

Raw Data

B. Recall and Recognition of Complex-Structured Items Under Slow Presentation:

	RECALL			RECOGNITION		
	CR	E	d'	CR	E	d'
	3	4	-0.21	6	5	0.14
	6	8	-0.22	4	5	-0.17
	8	1	1.41	7	5	0.26
	3	3	0.00	9	4	0.60
	7	5	0.26	8	4	0.22
	3	5	-0.38	9	7	0.18
	4	3	0.21	6	9	-0.30
	4	2	0.48	10	9	0.07
	4	6	-0.31	5	5	0.00
	6	4	0.31	11	9	0.14
	8	9	-0.08	9	8	0.08
	3	3	0.00	7	6	0.12
	8	8	0.00	14	12	0.22
	2	1	0.41	12	8	0.30
	3	3	0.00	11	13	-0.18
	9	9	0.00	7	8	-0.10
	5	7	-0.26	9	7	0.18
	8	1	1.41	10	6	0.37
	4	4	0.00	4	6	-0.31
	5	4	0.17	8	5	0.35
	8	3	0.73	9	8	0.08
	5	4	0.17	9	8	0.08
	5	4	0.17	6	9	-0.30
	6	5	0.14	8	10	-0.15
	5	7	-0.26	7	7	0.00
	5	3	0.38	6	2	0.79
	6	7	-0.12	9	6	0.31
	5	5	0.00	8	9	-0.08
	9	7	0.16	12	11	0.08
	6	5	0.14	8	8	0.00
TOTAL	163	140	4.71	248	229	3.38
MEAN	5.43	4.67	0.16	8.27	7.63	0.11

Appendix B (continued)

Raw Data

C. Recall and Recognition of Simple-Structured Items Under Fast Presentation:

	RECALL			RECOGNITION		
	CR	E	d'	CR	E	d'
	8	0	2.15	11	4	0.74
	6	2	0.79	16	10	0.67
	4	1	0.89	5	2	0.65
	3	10	-0.88	17	8	1.03
	7	2	0.90	11	7	0.32
	6	3	0.51	5	5	0.00
	8	4	0.52	9	7	0.18
	4	5	-0.17	12	12	0.00
	7	8	-0.10	10	8	0.15
	7	3	0.63	9	11	-0.14
	7	2	0.90	16	6	1.04
	10	1	1.56	12	3	1.03
	4	3	0.21	8	8	0.00
	7	2	0.90	10	3	0.88
	5	3	0.38	10	8	0.15
	4	5	-0.17	7	5	0.26
	5	4	0.17	10	8	0.15
	3	2	0.28	6	3	0.52
	4	1	0.68	11	12	-0.08
	5	2	0.65	10	4	0.67
	5	0	1.80	7	4	0.42
	6	1	1.20	10	2	1.15
	9	0	2.23	11	10	0.07
	5	1	1.06	5	3	0.38
	3	2	0.27	5	3	0.38
	6	2	0.79	11	8	0.22
	4	2	0.48	7	3	0.63
	3	1	0.68	9	7	0.18
	5	3	0.38	9	6	0.30
	6	2	0.79	10	6	0.37
TOTAL	166	77	20.48	289	186	12.32
MEAN	5.53	2.57	0.68	9.63	6.20	0.41

Appendix B (continued)

Raw Data

D. Recall and Recognition of Simple-Structured Items Under Slow Presentation:

	RECALL			RECOGNITION		
	CR	E	d'	CR	E	d'
	10	3	0.88	8	3	0.73
	5	3	0.38	8	5	0.35
	2	5	-0.65	9	3	0.81
	4	3	0.21	10	7	0.25
	10	4	0.67	10	3	0.88
	7	2	0.90	11	5	0.58
	12	2	1.00	12	4	0.88
	3	0	1.42	10	0	2.30
	11	4	0.60	14	8	0.52
	8	3	0.73	12	6	0.52
	1	9	-2.23	9	9	0.00
	6	0	1.94	3	3	0.00
	15	1	2.07	13	6	0.62
	11	6	0.44	12	5	0.66
	16	0	2.98	12	7	0.40
	7	1	1.31	5	1	1.06
	7	0	2.05	7	5	0.26
	10	2	1.15	7	4	0.42
	12	2	1.31	17	6	1.55
	9	5	0.58	10	8	0.15
	12	8	0.30	14	13	0.12
	10	0	2.30	14	12	0.22
	10	5	0.51	14	11	0.30
	13	5	0.76	12	6	0.52
	10	1	1.56	20	17	3.17
	9	1	1.08	8	1	1.49
	6	4	0.31	9	6	0.30
	8	8	0.00	13	9	0.32
	10	3	0.88	12	8	0.30
	11	3	0.95	17	9	0.95
TOTAL	256	99	26.39	332	200	20.59
MEAN	8.83	3.10	0.88	11.07	6.67	0.69

Appendix C

Summary of Tukey test for between-subject comparisons performed on total correct responses for recall (Re) and recognition (Ro) of complex (C) and simple (S) structure under fast (F) and slow (S) rates of stimulus presentation. For example, Re/CF indicates recall of complex structure under fast presentation.

	Re/CF 149	Re/CS 163	Re/SF 166	Ro/CS 248	Re/SS 265	Ro/CF 268	Ro/SF 289	Ro/SS 332
Re/CF	-	14	17	-	107**	-	-	-
Re/CS		-	3	-	102**	-	-	-
Re/SF			-	-	99**	-	-	-
Ro/CS				-	-	20	41	84**
Re/SS					-	-	-	-
Ro/CF						-	21	64
Ro/SF							-	43
Ro/SS								-

* Critical Range = 65.9, p = .05

** Critical Range = 80.6, p = .01

Appendix D

Summary of Tukey test performed on d' totals for recall (Re) and recognition (Ro) of complex (C) and simple (S) structure under fast (F) and slow (S) rates of stimulus presentation. Re/CF, for example, indicates the treatment total (1.12) for recall of complex structure under fast presentation.

	Ro/CF 1.12	Ro/CS 3.38	Re/CS 4.71	Ro/SF 12.32	Re/CF 12.70	Re/SF 20.48	Ro/SS 20.59	Re/SS 26.39
Ro/CF	–	2.26	3.59	11.20	11.58	19.36**	19.47**	25.27**
Ro/CS		–	1.33	8.94	9.32	17.10*	17.21*	23.01**
Re/CS			–	7.61	7.99	15.77*	15.88*	21.01**
Ro/SF				–	0.38	8.16	8.27	14.07*
Re/CF					–	7.78	7.89	13.69*
Re/SF						–	0.11	5.91
Ro/SS							–	5.80
Re/SS								–

Within-subjects

* Critical Range = 12.84, p = .05

** Critical Range = 14.84, p = .01

Between-subjects

* Critical Range = 15.29, p = .05

** Critical Range = 17.29, p = .01

List of Tables