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A Test of the Multiple Trace Hypothesis: The Effects of Temporal Cues and Presentation Modality

William H. Macey
Loyola University Chicago

A TEST OF THE MULTIPLE TRACE HYPOTHESIS: THE EFFECTS OF TEMPORAL CUES AND PRESENTATION MODALITY

by

WILLIAM H. MACEY

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CHAPTER I

Introduction

When asked to do so, Ss are able to report a great amount of information regarding the manner in which to be remembered (TBR) verbal events were presented for study, with or without prior instructions to retain such information. Some of the memorial representations of verbal units that have been investigated, for example, are the temporal aspects of item presentation (Hinrichs, 1970), the modality that items are presented in (Madigan & Doherty, 1972), the spatial representation of TBR items (Zechmeister & McKillip, 1972), the orthographic qualities of verbal items (Brown & McNeil, 1966), and the frequency with which items are presented (Hintzman, 1969b).

Thus, Underwood (1969b), and Wickens (1970), and others have proposed that a memory for a verbal event consists of a collection of attributes or features which represent the variety of aspects about a verbal event that allow an event to be made public (retrieval attributes), and that serve the purpose of differentiating different memories (discriminative attributes). In reference to the studies mentioned above, for example, it might be argued that the temporal, orthographic, spatial, etc. qualities of a TBR event are all encoded as independent attributes of a memory; some of those possibly serving as retrieval attributes and others serving primarily as discriminative attributes.

Unfortunately, the demonstration that Ss are able to retain such information does not necessarily constitute evidence that the information is encoded as a specific attribute of a memory. This can be seen, for example, when considering the ability of a S to report the temporal aspects of item presentations, such as the elapsed time since a particular item was presented relative to other items in the same list. It is conceivable, for instance, that Ss are able to base such temporal judgments on the degree to which the retrieval attributes of that item have been forgotten. That is, as real time elapses, forgetting occurs, and Ss may base temporal judgments on the relative degree of strength (or weakness) of a memory for that item. While this example will not be pursued further, it serves to illustrate the type of difficulties that may be encountered when attempting to isolate the specific attributes of memory. Specifically, certain measurable aspects of a memory may be positively correlated and/or may not be independent of each other.

The present paper constitutes an exploration of one such proposed attribute in reference to these interpretive difficulties. In particular, the present study was designed to determine whether information about item repetitions, or frequency information, is encoded as a specific attribute of a memory.

The Frequency Attribute

Underwood (1969b) has suggested that the frequency attribute serves solely a discriminative function. Hence, Ss' reliance on a frequency attribute has been proposed to be the underlying basis both in verbal discrimination (VD) learning (Ekstrand, Wallace, & Underwood, 1966), and recognition memory (Underwood & Freund, 1970d). Much of what is subsequently discussed is related directly to these two experimental paradigms.

Before digressing further into these topics, however, it is necessary to demonstrate that Ss are able to assimilate event frequency. Two types of frequency knowledge have been distinguished. The first, termed background frequency, refers to the assimilation of frequency information through natural language usage over an extended period of time. The second, termed situational frequency, refers to the assimilation of frequency information specific to a particular experimental context.

Judgments of Background Frequency. Shapiro (1969) utilized two scaling methods in assessing Ss' abilities to assimilate background frequency. In the first method, Ss were instructed to rank groups of words varying in their frequency of occurrence in the written language according to their relative frequency. In the second method, Ss gave numerical estimates to those words which they felt to be proportional to their relative frequency. The words that Ss scaled were selected from the Kucera-Francis (1967) as well as the Thorndike-Lorge (1944) tabulations. Results from both scaling methods indicated that at least 80% of the variance in Ss' judgments could be accounted for by the actual frequency of occurrence of the words in the natural language. Thus, Ss were highly accurate in their ability to judge the background frequency of a sample of words.

Judgments of Situational Frequency. Hintzman (1969b), using two different test procedures, demonstrated that Ss are able to assimilate situational frequency. The first method, referred to as the method of absolute frequency judgments, involves having Ss give numerical estimates of the number of times that a word was presented for study. The second, termed the method of comparative frequency judgments, involves having Ss make a choice between two words as to which was presented more frequently in the study list.

Hintzman (1969b) presented Ss with a study list where words were presented 1, 2, 4, 6, or 10 times. Immediately following list presentation, Ss were first given the comparative judgment task, then the absolute judgment task. In the comparative judgment task, there were 30 pairs of words representing all pairwise permutations of the frequency conditions. In the absolute judgment task, Ss were given the same 60 words and were asked to supply numerical estimates of the number of times each word had been presented for study. The Ss were not informed prior to the judgment tasks of the nature of the tests.

Results from the comparative judgment task indicated that discriminability increased with the logarithm of the intrapair frequency differences. That is, the proportion of correct choices increased with the logarithm of the differences in situational frequency of the test alternatives. The results from the absolute judgments paralleled those of the comparative tests, median frequency judgments increasing linearly with the logarithm of situational frequency.

Frequency Theory

It was mentioned earlier that Ss' abilities to assimilate and discriminate situational frequency suggest a basis by which both recognition memory and VD learning may be accounted for.

In a typical recognition memory task, Ss are first presented a long list of words to study, usually being informed only that their memory for these words will later be tested. Two basic test procedures are commonly employed. The first procedure involves presenting Ss the same words presented for study ("old" words), in addition to a set of words that were not presented for study ("new" words). The S's task is to declare which words are old words and which are new words. The second test procedure involves presenting to Ss pairs of words, one of which is an old word, the other word being a new word. The Ss are subsequently required to choose the old word from each pair. The latter procedure is commonly referred to as a "forced-choice" paradigm.

The frequency theory of recognition memory (Underwood, 1969b; Underwood & Freund, 1970d) asserts that the major attribute involved in discriminating between old and new words is the frequency attribute. In particular, the theory assumes that old words have a situational frequency of at least unity, and new words have a situational frequency of zero. The Ss are assumed to then base their old and new responses or forced-choice decisions on the basis of situational frequency.

In VD learning, Ss are presented a list of paired verbal units. The S's task is to discover which of the verbal units is arbitrarily designated as the "correct" (C) unit. Typically, the pairs are presented on a memory drum, Ss making a choice as to which alternative they believe to be the C alternative. Following S's choice, the E then informs the S as to the correctness of his choice. Such "learning" then proceeds for a number of such trials on the same list to some specified criterion.

Frequency theory accounts for VD performance by asserting that Ss choose the C alternative on the basis of subjective differences in situational frequency between the C and "incorrect" (I) alternatives in each VD pair. In particular, frequency theory asserts that as trials proceed, at least a 2 to 1 ratio of frequency differences accrues in favor of the C alternative.

Frequency theory assumes that situational frequency accrues to the C and I alternatives (or the old and new alternatives in the recognition memory task) by means of four types of responses: (a) the representational response (RR); (b) the pronunciation response (PR); (c) the rehearsal of the response (RCR); and (d) the implicit associative response (IAR). In the VD task, for example, it is assumed that Ss make RCRs (and possibly PRs) to the C items. When tested on the next trial, Ss are then able to choose between the C and I alternatives on the basis of subjective frequency differences between the alternatives that were established on the preceeding trial(s). Thus, although Ss make RRs to both alternatives, there is a frequency difference between the alternatives in favor of the C alternative because it can be assumed that Ss would rehearse only the C alternative.

Two types of evidence have been marshalled in support of frequency theory. The first involves controlled differences in the situational frequency of test alternatives. The second involves the correlational procedure of demonstrating qualitatively similar effects of independent variables on discrimination performance (i.e., in the VD and recognition memory paradigms) and frequency judgment tasks *per se*.

Controlled Differences in Situational Frequency

Frequency theory clearly predicts that discrimination should be most difficult when the differences in situational frequency between test alternatives (C and I alternatives in VD learning, and old and new items in recognition memory tasks) is minimized. This effect may be accomplished by means of incrementing situational frequency of the I alternatives in the VD paradigm or the new responses in the recongition memory paradigm. Empirical investigations of this sort have been conducted in both contexts.

VD Learning. It will be remembered that frequency theory asserts that PRs serve to increment the situational frequency of verbal items. Hence, if Ss are required to pronounce both the C and I alternatives in a VD task, the frequency differential between the alternatives should be reduced with the result that discrimination would become more difficult. Frequency theory likewise predicts that if Ss pronounce only the C alternative, discrimination between alternatives should be enhanced on the basis of a greater frequency differential between the alternatives. Precisely these results have been obtained by Underwood and Freund (1968, Exp. II).

Other means of incrementing the situational frequency of the C and I alternatives have also been investigated. Underwood and Freund (1968, Exp. I) familiarized Ss with either the C or I alternatives by presenting Ss with these words in a free recall learning task prior to presentation of the VD list. Frequency theory predicts that by incrementing the situational frequency of the C alternative in such a manner, subsequent VD performance should be facilitated. Also, when the situational frequency of the I alternatives is increased by the same means, performance should at first be high and then decrease. This is because Ss should be able to discriminate between the C and I alternatives on the basis of choosing the alternative with the lower situational frequency. As trials proceed, however, the frequency differential of the alternatives should decrease and the frequency discrimination should break down. The authors' results supported the predictions of frequency theory, in that when the words used in the free recall task were the C alternatives in the VD task, performance was essentially perfect on all trials. When the words from the free recall task became the I alternatives, VD performance was initially at a high level but essentially failed to improve over trials.

Two other predictions of frequency theory have received only equivocal support, however. It will be remembered that frequency theory predicts that an IAR will increase the situational frequency of a word in the same manner as an RR. Direct tests of this hypothesis, however, have provided only limited support for the theory. Cole and Kanak (1972), for example, manipulated the situational frequency of the C and I alternatives of VD pairs by prior free recall learning, where either the C or I alternatives were normative primary associates of the items presented in the free recall task. Frequency theory predicts that when the C alternatives are the associates of the items in the free recall task, subsequent performance should be enhanced, and conversely, when the I alternatives are associates of the items in the free recall task, subsequent performance should be hindered for the same reasons that familiarization serves to increase situational frequency. Contrary to the predictions of frequency theory, Cole and Kanak (1972) found that VD performance was hindered when the C alternatives were normative associates of the items in the free recall task, and that when Ss were informed of the nature of the relationship between the free recall and VD tasks, performance was facilitated regardless of whether the C or I alternatives were associates of the items in the free recall task.

The second failure of frequency theory regards transfer performance between two VD lists in which the pairs remain intact but the assignment of C and I functions is reversed within each pair. That is, the C alternatives of the first list become the I alternatives of the second list, and the I alternatives of the first list become the C alternatives of the second list. According to frequency theory, Ss respond on the first list by means of Rule 1; namely, always select the more frequent alternative. When the second list is presented, Ss begin to respond on the basis of Rule 2; that is, select the less frequent alternative. Frequency theory clearly predicts that as the number of trials on the second list increases, the frequency difference between the C and I alternatives becomes nonexistent, and performance should drop to a chance level. Whereas the high degree of initial transfer on the first trial of the second list typically found (e.g., Underwood, Shaughnessy, & Zimmerman, 1972) confirms the predictions of frequency theory, the drop to chance performance has not been found to occur, although a decrease in performance on the second list following an initial high level of performance has been found (Raskin, Boice, Rubel, & Clark, 1968).

In summary, frequency theory has received substantial support for its ability to predict the gross qualitative effects of several independent variables in VD learning but has seemingly failed in others. It is these failures with which later portions of the present paper shall be concerned.

Recognition Memory. Whereas the predictions of frequency theory regarding IARs have not always been supported in reference to the VD paradigm, results from recognition memory studies have been consonant with frequency theory.

It will be remembered that the prediction of frequency theory regarding IARs is essentially that Ss confuse RCRs with IARs. A direct test of this prediction was conducted by Underwood (1965) using a continuous recognition memory paradigm. The Ss were presented with a long list of words. As each word was read, S made a decision as to whether the word had been previously read to him (i.e., whether it was an old or new word). If frequency theory is correct, Ss should make more false alarms (calling a new word an old word) to words which are primary normative associates of words presented earlier in the list than to words presented to Ss for the first time or to words which are associatively unrelated to words previously presented in the list. Underwood's results supported frequency theory's prediction when the words assumed to be IARs were superordinates or converging associates of words presented earlier in the list. The same results were also found for antonyms of words that had been presented three times previously in the list.

The predictions of frequency theory regarding IARs have also been confirmed in a recognition memory study conducted by Underwood and Freund (1970d), who found that forced-choice recognition performance was hindered when both old and new words were of high linguistic frequency relative to when both old and new words were drawn from pools differing in linguistic frequency (i.e., high or low). This result was expected because IARs to high frequency words should also elicit more IARs than low frequency words and IARs to high frequency words should be other high frequency words. Thus, when both old and new words are high frequency words, there is an increased probability that the new words will be IARs to the old words. Hence, frequency theory predicts that the difference in situational frequency between pairs of old words should be minimized, with a concommitant increase in the number of recognition errors relative to the other conditions.

Frequency theory would also predict that when old words are paired with more than one new word in a forced-choice paradigm, recognition performance should decrease as the number of new words within each discrimination set increases. Underwood (1972) found this to be the case, noting that it would be expected since as the number of new words paired with each old word increases, there would be an increased probability that one of those new words would be an IAR to the old word.

Underwood and Freund (1970a) obtained further support for the frequency theory of recognition in a study where following presentation of the study list, Ss made forced-choice discriminations when some of the new words were paired with more than one old word. According to the authors, frequency theory would predict that as the number of different pairs a new word occurs in increases, discrimination between new and old words would become more difficult since the situational frequency of the new words would increase with each successive presentation of that new word in a test pair. The authors' predictions were supported, although there was no difference in forced-choice discrimination between the condition where new words were used a second time and the condition where new words were used a third time.

In summary, those studies which have produced interference in discrimination by means of decreasing the differential situational frequency of test alternatives have provided substantial support for the frequency theory of recognition and VD learning.

Correlational Evidence

The second type of test of frequency theory involves comparison between frequency judgments and those tasks which are presumed to be dependent primarily on the use of the frequency attribute. In particular, frequency theory must predict that those variables which affect performance on frequency judgment tasks must affect VD learning and recognition performance in a qualitatively similar fashion. While positive evidence of such relationships does not serve to prove the correctness of frequency theory, a failure to find such evidence would argue strongly against acceptance of the theory.

Apparent Frequency and Weber's Law. As was mentioned earlier, Hintzman's (1969b) results demonstrate that apparent frequency increases with situational frequency. It is significant to note, however, that the relationship is not linear. Specifically, apparent frequency was found to increase with the logarithm of situational frequency. It becomes apparent, then, that S's ability to discriminate between words differing in situational frequency should be a function of both the frequency difference between the two words and the base frequency, defined as the situational frequency of the word presented least often, as well.

To test this hypothesis, Underwood and Freund (1970b) manipulated situational frequency by presenting Ss with a list of 45 words where 4 words were presented once; 5 twice; 6 words, 3, 4, 5, 6, and 7 times; 3 words, 8 times; 2 words, 9 times; and 1 word, 10 times. Following list presentation, one-half the Ss were given an unpaced comparative frequency judgment task where the base frequencies used were 0 through 7, and the differences in frequency were 1, 2, or 3. The remaining half of the Ss were given a paced test where the pairs were presented on a memory drum and Ss were required to tell the E which word had been presented more frequently in the list. Following this test, Ss were given five trials in a VD task using the same pairs. The Ss were informed of the relationship between the VD task and the study list.

Underwood and Freund (1970b) suggested that if Weber's law holds true, then errors in discrimination should increase as the base frequency increases and errors should decrease the absolute frequency difference between the pair members increases. This essential relationship was reflected in the data from both the unpaced test and the paced test, although the effect was somewhat masked by a large degree of variability. The authors further suggested that if Ss do use frequency as the dominant attribute in VD learning, performance across the five trials should be better for those pairs with low base frequencies than those pairs with high base frequencies. This relationship was also evident in the data when considering the frequency differences of 2 and 3. Furthermore, this relationship was found in a second experiment when Ss were not informed of the relationship between the study list and the VD task.

The results obtained by Underwood and Freund (1970b), then, provide support for the hypothesis that the frequency attribute is dominant in VD learning provided that a frequency discrimination is possible, that is, when the base frequency of pair members is relatively low.

Apparent Frequency and the Pronunciation Response. As was mentioned earlier, frequency theory asserts that the PR to a verbal unit increases that item's situational frequency. The results of the Underwood and Freund (1968) study, reviewed above, supported this hypothesis. It should be noted, then, that PRs should also influence apparent frequency when measured by both comparative and absolute frequency tests.

Hopkins, Boylan, and Lincoln (1972) directly tested this hypothesis using both test procedures. Whereas pronunciation was a significant source of variance when Ss pronounced some but not all of the items, there were no effects of pronunciation when Ss pronounced all list members. Furthermore, Hopkins et al. found that the PR did not serve to increase the apparent frequency of an item as much as an actual repetition of the item. The authors concluded that their results supported frequency theory with the reservation that the increment in apparent frequency is relative only to those items that are not pronounced.

Apparent Frequency and the Spacing of Repetitions. When verbal items are repeated within a study list, the probability of recall increases as the number of presentations intervening between successive presentations of the same item increases. Kintsch (1966) has found the same effect in recognition and Hintzman (1969a) has found that recognition time decreases with the spacing of repetitions. Clearly, then, frequency theory must predict that apparent frequency, as measured by comparative and absolute tests, increases with the spacing of repetitions. Relevant data to this issue have been reported by Hintzman (1969b), who, using both test procedures, found results as predicted by frequency theory. Similar results have also been obtained by Underwood (1969a).

Retention of Frequency Information. Underwood and Freund (1970c) investigated the relationship between VD learning and the length of the retention interval. The authors found that as the retention interval increased (1 day or 7 days), a small amount of forgetting occurred, reaching a maximum of approximately 20% in 7 days. The authors suggested that the forgetting of a VD is primarily the result of the assimilation of situational frequency into background frequency over time.

Underwood, Zimmerman, and Freund (1971) compared frequency judgments and recognition tests following retention intervals of 0, 1, or 7 days. The authors tested the assimilation hypothesis by means of comparative tests in which pair members had equivalent situational frequency but widely different background frequency. Underwood et al. suggested that the assimilation hypothesis would predict an increase in the probability of Ss choosing the pair member with the highest background frequency as the retention interval increases. Contrary to this prediction, the probability of choosing the verbal unit with the higher background frequency was near chance (.50) for all three retention intervals.

The authors did find, however, that the loss in discrimination that occurred over time paralleled losses in recognition probabilities (i.e., assigning words on test sheets that were not presented in the study list a numerical frequency estimate greater than zero). Hence, support for the frequency theory of recognition was obtained. This conclusion was also strengthened by the fact that Underwood et al. were able to use individual S abilities in making discriminations to predict individual recognition scores.

Instructional and Individual Difference Variables. Frequency theory must assert that VD learning should be equivalent regardless of whether or not Ss are instructed to use frequency information as a discriminative basis in the VD task. Data from the previously cited Underwood and Freund (1970b) study confirm this prediction. The authors' results indicated that S's knowledge of the relationship between the prior familiarization task and the VD task had essentially no effect relative to the situation where Ss were not informed of the relationship between the two tasks, although the comparison was between separate experiments.

Similarly, frequency theory must predict that there should be no difference in recognition performance between conditions where Ss are instructed to retain information for a later test or are instructed to retain information for a later recognition test. Underwood (1972) made such a comparison, obtaining results that were consistent with the expectations of frequency theory.

Frequency theory must also predict that individual S abilities in frequency judgment tasks correlate highly with recognition and VD learning abilities. Evidence on the first issue is found in the Underwood, Zimmerman, and Freund (1971) study, in that individual recognition scores could be predicted from frequency discrimination data. Underwood, Shaughnessy, and Zimmerman (1972) conducted a similar analysis with respect to VD performance, demonstrating that the ability to discriminate frequency differences correlated highly with the ability to learn VD lists.

Summary. The data from studies that have shown qualitatively similar effects of independent variables on both frequency judgments and VD learning and recognition tasks support frequency theory. It is important, however, to reiterate the fact that such studies do not serve as independent tests of frequency theory. Furthermore, while the data from those studies controlling the situational frequency of test alternatives argues strongly for the assumption that Ss use frequency information as the predominant means of discrimination in VD and recognition tasks, it remains to be demonstrated that frequency information is encoded as a distinct attribute of a memory for an event, or whether frequency information is derived from some other encoded aspect of a verbal event.

Frequency and "Strength"

Frequency, as Underwood (1969a) has pointed out, is the major independent variable underlying learning, since the greater the frequency, the better the learning as measured by retention tests. Underwood further suggested that recall seems to be primarily due to associative aspects of the encoded event. Thus, the use of the term "strength" in relation to retention in recall tasks is used in reference to the establishment of such associative attributes. The question arises, then, as to whether Ss might base their frequency judgments on "associative strength."

Several studies can be cited as evidence that frequency and associative strength are independent. In particular, these studies have been concerned with the manipulation of variables that have been shown to affect recall and discrimination tasks in a distinctly different fashion.

First, it is known that as exposure duration increases, the probability or recall increases (the so called "total-time law"; cf. Cooper & Pantle, 1967). Hintzman (1970) manipulated both frequency and exposure duration. His results indicated that only the frequency variable was significant source of variance in frequency judgments although estimates of exposure duration were influenced by both variables.

Underwood (1969a) presented Ss long lists of words in which frequency was varied. Of interest here is those words that were presented only once. While recall is markedly affected by the serial position in which an item is presented, Underwood demonstrated that frequency judgments were not.

Underwood, Shaughnessy, and Zimmerman (1972) varied list length and two methods of presenting VD lists. The Ss learned lists that contained either 15 or 45 pairs by either the study test or anticipation methods. Frequency theory holds that list length should have no effect on VD learning since Ss are presumed to base their choices on intra-pair frequency differences. While recall is markedly affected by list length (e.g., Postman & Phillips, 1956), Underwood et al. found that list length was not a significant source of variance when using the study test method although it was when using the anticipation method.

These three studies, then, have at least partially broken the correlation between "associative strength" and frequency judgments. These same studies, however, do not necessarily provide evidence that frequency is encoded specifically as an attribute of memory. In particular, at least two alternatives have been suggested relating frequency input and apparent frequency. The first hypothesis suggests that frequency information is encoded specifically in a memory for an event. Repetitions of an event serve to increment what might be termed a "frequency index," that is, each repetition of an event serves to increase the value (in numerical terms) of some feature which represents frequency information. Thus, Ss are seen as making frequency judgments on the basis of a single undifferentiated and unidimensional continuum of frequency information. Hintzman and Block (1971) have suggested that such a hypothesis be identified as a "strength" hypothesis. It should be noted, however, that the use of the term "strength" in such a context is not synonymous with the meaning of "associative strength" as defined above. Rather, the use of "strength" in reference to frequency information refers to the undifferentiated character of the encoded information. In order to avoid difficulties of interpretation, this hypothesis will henceforth be identified as the "encoding" hypothesis.

The second hypothesis relating frequency input and apparent frequency has been identified as the "multiple-trace" hypothesis (Hintzman & Block, 1971). This hypothesis suggests that a single memory trace is formed for each presentation of an item. The greater the frequency with which an item is presented, the greater the number of traces in memory for that item. According to this hypothesis, then, frequency judgments are derived from the number of different traces which exist in memory for an event.

Evidence for the Multiple-Trace Hypothesis

At an operational level, the two hypotheses can be distinguished in terms of the degree of specificity in which frequency information may be assimilated. The encoding hypothesis allows for the fact that background and situational frequency may be distinguished, but seemingly predicts that within an experimental context, frequency information may not be distinguished since frequency is encoded only along a single undifferentiated dimension.

The multiple-trace hypothesis, on the other hand, asserts that the specificity of frequency information is limited only by the limits of trace discrimination, discrimination being dependent on other features or attributes of the encoded event. Hintzman and Block (1971) further suggested that these attributes are established hierarchically, the temporal attribute being the predominant basis of discrimination. Other attributes, then, serve only secondarily to aid or supplant the temporal attribute.

On the basis of these assumptions, Hintzman and Block conducted three experiments as tests of the two alternative hypotheses. The first two experiments were investigations of within task discrimination; the third related to between tasks discrimination.

In the first experiment, Ss were presented a list of 55 high frequency nouns. Following list presentation, the Ss were then asked to indicate in which portion of the list items had occurred. This was accomplished by having Ss judge in which ordinal tenth of the list items had appeared in. The results indicated a typical serial position curve in that the increase in serial position judgments was greatest for earlier portions of the list, and conversely, list discrimination was poorest for the middle and later portions of the list.

Using the first experiment as preliminary evidence, the authors conducted a second experiment where half of 50 items were repeated within the list and the other half were presented only once. The list was divided into four defined zones, where zones A, B, C, and D referred to serial positions 3-8, 9-14, 15-20, and 43-48 respectively. These zones were chosen on the basis of the results from the first experiment so that a high degree of discrimination between the zones would be possible. Following list presentation, Ss were asked to give mean position judgments for items presented only once and for items repeated in zones AC, AD, BC, and BD. The authors stated that according to the encoding hypothesis, Ss should not be able to distinguish between repetitions as to their individual serial positions (i.e., serial position judgments for a given presentation of an item should not be independent of the serial position of the other presentation of that same item). The multiple-trace hypothesis, on the other hand, asserts that Ss should be able to make such discriminations. The results supported the multiple-trace hypothesis in that serial position judgments for the first presentations of items repeated in zones AC and AD were essentially identical. Likewise, judgments for the second presentations of items repeated in zones AD and BD were identical.

A further prediction of the multiple-trace hypothesis is that when items are repeated in two lists, frequency judgments for the first list should be independent of the frequency with which the same items are presented in the second list. Similarly, frequency judgments for the second list should be independent of the frequency with which the items are presented in the first list. That is, within list frequency judgments should be independent of the frequency with which the items are presented in another list. The third experiment conducted by Hintzman and Block (1971) conformed to such a design, where items were assigned to one of nine factorial combinations of first and second list frequency (0, 3, or 5 within each list). The Ss participated in a 5 min. filler task between the presentation of the two lists. Following presentation of the second list, Ss gave absolute frequency judgments for each item separately for each list.

The results indicated that the frequency with which items were presented in the first list accounted for 90% of the variance in the first list frequency judgments and only 10% of the variance for the second list frequency judgments. Likewise, second list frequency accounted for only 7% of the variance in first list frequency judgments and 86% of the variance in the second list frequency judgments. These results, then, indicate that Ss are able to distinguish recent frequencies from remote frequencies within the same experimental session, which is in accord with the multiple-trace hypothesis but not with the encoding hypothesis.

Jacoby (1972) conducted further tests of the multiple-trace hypothesis by varying the semantic context that critical items were repeated in as well as their frequency of presentation. The Ss were presented a series of simple sentences containing a single adjective, a noun, and a verb. In regard to the nouns, some of the sentences were repeated intact, whereas other sentences were repeated using synonyms of the nouns used in the original sentences. The context within which the nouns were repeated was also varied by using the same, different, or similar adjectives at each repetition of the critical sentences. In addition, the spacing of sentence repetitions was varied, either 0, 3, or 8 other sentences intervening between successive presentations of the critical sentences. Following presentation of the study list, Ss gave absolute frequency judgments for either the nouns from the critical sentences or the sentences themselves.

Jacoby (1972) suggested that whereas it would be assumed that the encoding hypothesis would predict only an effect of spacing on frequency judgments (following Underwood, 1969a), the multiple-trace hypothesis would predict that frequency judgments for repeated sentences in which some words were the same but others differed should be equivalent to judgments for once-presented filler sentences. The results indicated that the effect of spacing on repetitions on noun frequency judgments had an effect only when the adjectives were identical in the successive repetitions. Overall frequency judgments of nouns, however, were higher when the adjectival modifiers were similar in the sentence repetitions.

In regards to the sentence tests, repetition of nouns with identical modifiers resulted in frequency judgments that were higher than any other condition of noun and modifier similarity. Once again, spacing had a significant effect only when nouns were repeated with identical modifiers.

In summary, Jacoby (1972) found an effect of repetition on frequency judgments only when the experimental context (as defined by the adjectival modifiers) was the same under each repetition of the nouns. Jacoby interpreted these results as support for the multiple-trace hypothesis in that apparent frequency of the nouns was shown to be highly specific to the context in which the nouns were presented.

Other Considerations. It will be remembered that one failure of the frequency theory of VD learning is the failure to find the predicted deterioration in performance on the second VD list of a transfer task where the assignment of C and I items has been reversed from that used in the first list. Hintzman and Block (1971) suggested that the multiple-trace hypothesis can adequately account for the data typically obtained. Their argument suggests that early in the learning of the second, or transfer list, Ss ignore recent (second list) frequencies and make discriminations on the basis of choosing the alternative with the lower situational frequency. As trials proceed, however, this task becomes more difficult and Ss change "rules" and begin to discriminate between pair items on the basis of the situational frequency accrued to items only in the second list. Thus, a deterioration to chance level of performance would not be expected. The fact that both Hintzman and Block (1971), and Jacoby (1972), have demonstrated that frequency information can be highly specific to a given task seemingly support such an interpretation.

Summary. Hintzman and Block (1971) have suggested an alternative hypothesis to that of the theory that assumes frequency is an encoded attribute. Their hypothesis assumes that with each presentation of an item, a unique trace for that presentation is established in memory. The primary basis upon which these traces are discriminated is a temporal one, each trace having its own "time tag" or temporal attribute. Results from an experiment conducted by these authors indicated that Ss were able to make accurate intra-list frequency judgments regardless of the frequency with which those same items occurred in another list in the same experimental session. Further data collected by Jacoby (1972) supported the Hintzman and Block hypothesis, showing that contextual or semantic information can be used as a basis upon which item traces can be discriminated. Finally, Hintzman and Block have demonstrated that a multiple-trace hypothesis can adequately account for the failure of frequency theory to adequately predict performance on VD transfer tasks.

The Present Study

While the Hintzman and Block (1971), and Jacoby (1972) studies have shown that there is a high degree of specificity in the assimilation of experimental frequency, neither study tested the assumption of the multiple-trace hypothesis that the temporal attribute is predominate in trace discrimination. Thus, although Jacoby varied spacing as well as semantic cues, the critical sentence passages were either always similar, the same, or dissimilar. The fact that spacing was significant variable only when semantic context remained the same for all sentence presentations testifies to the fact that the effects of the temporal variable (the spacing variable) were constrained by the effects of the contextual variable. In particular, since the sentences which were not identical were apparently encoded as being different, there would not be multiple traces of the same item in memory, and therefore, the prediction that a temporal attribute is predominant in discriminating between memory traces for identical events could not be tested.

It would seem, then, that an adequate test of the multiple-trace hypothesis could best be realized in a paradigm where alternative cues are provided to S for discriminating between identical events in addition to the provision of temporal cues.

The present study employed a between tasks design similar to that of the Hintzman and Block (1971) third experiment while varying both temporal and non-semantic contextual cues. In particular, Ss were presented two lists of words with some of the words repeated in both lists and/or repeated within each list. Between the presentation of the two lists, Ss participated in 0 or 7 min. of filler activity. According to the multiple-trace hypothesis, between list discrimination should be superior in the condition where 7 min. elapsed between presentation of the two lists.

Presentation modality (either auditory or visual) was varied in addition to the manipulation of the frequency and temporal variables. Madign and Doherty (1972) have shown that Ss are able to identify the modality that items are presented in as well as the frequency with which an item is presented. This variable was manipulated in the present study in such a fashion that for those items repeated in both lists, one-half of the Ss had first list auditory items presented in the visual mode in the second list (and first list visual items presented as second list auditory items), and the remaining Ss were presented first list auditory and visual items in the same modality in both lists. While the multiple-trace hypothesis predicts that the modality attribute could aid in list discrimination, it must also predict that the temporal attribute is dominant in discrimination. That is, in terms of the variability present in the results, the temporal variable should account for a higher proportion of the total variance than the proportion of the variance accounted for by the modality variable.

CHAPTER II

Method

Design. All Ss were presented two lists of words, some words being common to both lists, before being asked to make absolute frequency judgments. Frequency of presentation, presentation modality, and temporal separation of lists were the variables of interest.

Procedure. All Ss were presented two lists of 110 words each. Within each list there were 48 experimental items. Additionally, there were 7 items serving as a primacy buffer, and 7 items comprising a recency buffer. Of the 24 experimental items, one-third (or 8 items) were presented 1 time, 4 times, or 7 times. Therefore, there were 96 presentations of experimental items in each list. Buffer items were presented only once yielding the 110 total item presentations per list.

Of the 24 experimental items used in the first list, 18 were also used as experimental items in the second list. In the first list, 6 of these 36 items were presented at each frequency level (1, 4, 7). Of each set of 6 items, one-third (or 2 items) were presented 1 time, 4 times, or 7 times in the second list.

Eighteen of the 24 experimental items within each list have been accounted for. There were also 6 items that were presented only in the first list, and 6 items that were presented only in the second list. One-third (2 items) of each of these sets of 6 items were presented with the same frequency (1, 4, 7) as the items that appeared in both lists.

Modality of presentation was also varied between Ss. In each list, one-half the words at each frequency level were presented in the auditory (A) mode, and one-half were presented in the visual (V) mode. Of the items which were presented in both lists, half the Ss (condition Different) had the first list A items presented as V items in the second list, and first list V items presented as second list A items. The remaining Ss (condition Same) had the first list A items presented as A items in the second list, and first list V items presented as V items in the second list. Therefore, one-half the Ss had items presented in the same (S) modality in the two lists (AA or VV), and one-half the Ss had items presented in a different (D) modality in the two lists (AV or VA).

The V items were presented by means of a Carousel projector and A items were presented by means of an externally coordinated tape recorder. All items were presented at a 3 sec. rate with A items being spoken once during the interval. During the presentation of a V item, a blank slide was projected. Approximately 0.8 sec. elapsed during the time the projector changed slides. Thus, visual items were actually presented for approximately 2.2 sec. on the projection screen.

Elapsed time between presentation of the two lists was also manipulated as a between-Ss variable. In particular, either 0 or 7 min. elapsed between presentation of the two lists. In the 7 min. condition, Ss participated in an arithmetic task that was sufficiently difficult to prevent rehearsal during the interlist interval. In the 0 min. condition, immediately following presentation of the first list, Ss were instructed that they were to be presented a new list.

Immediately following presentation of the second list, Ss were given a test booklet with the 18 items presented in both lists, the 6 first-list-only items, the 6 second-list-only items, and the 6 additional items that were not presented in either list. The purpose of these latter mentioned items was to obtain an index of false recognition. The test list was typed in random order. After each item, two blank spaces were provided corresponding to column headings labeled "first-list" and "second-list." The Ss were instructed that items had been presented in only one modality within a given list, and that they were to give absolute frequency judgments for each item for both lists by writing down the number of times they felt that the words had occurred in each list. The Ss were instructed that if they felt a word had not been presented in a given list, or in either list, they were to assign a frequency of zero to that item.

Stimulus materials. A pool of 120 two-syllable nouns with frequency count of 10-25 per million (Thorndike & Lorge, 1944) was formed. Two sets of 50 words were then randomly selected from this pool. From each set, 18 items were then randomly chosen to be used as those words to be presented in both lists, 12 items were chosen to be used as items appearing in only one list, 14 items were chosen to be used as buffer items for the two lists, and an additional 6 items were chosen to be presented in the test booklet although they were not presented in either list.

Each list was arbitrarily divided into two blocks. Items that were presented in both lists were assigned to the same block in both lists. Of the 18 items that were presented in both lists, there were 2 items representing each possible combination of first and second list presentation frequency (1-1, 1-4, ..., 7-4, 7-7 etc.). One of each of these nine possible combinations was used in each of the two corresponding blocks in the two lists. The 6 items within each list that were not presented in the other corresponding list were evenly distributed over the two blocks, 1 item at each frequency level per block. All repetitions of items that were repeated within a list were separated by at least three presentations of other items.

For each set of words, two sets of corresponding lists were formed using the same items and the criteria mentioned above. In one of the two lists, items were always presented either in the auditory modality or the visual modality. In the remaining set of two lists, items were presented in the auditory modality in one list and the visual modality in the other list. Within each set of two lists, each list was used equally often as the first list presented to *S*s. In the analyses reported in Chapter III, the two sets of words were used as levels of a between-*S*s variable.

Subjects. The *S*s were 80 undergraduate volunteers enrolled in introductory psychology courses at Loyola University of Chicago. Ten *S*s were assigned to each of the eight possible between-*S* conditions. The *S*s were run in small groups of size 4-6 and were randomly assigned to conditions on the basis of order of appearance with the restriction that at least one group of *S*s be run under each possible between-*S*s condition before another group was assigned to one of those conditions.

CHAPTER III

Results

Items Presented in Both Lists

The variables of interest in the present analyses were modality change (Same vs. Different), temporal separation between presentations of the study lists (0 vs. 7 min.), first-list item frequency (1, 4, and 7), and second-list item frequency (1, 4, and 7). Additionally, the two sets of words employed in the present study were also treated as levels of a between-Ss variable. Therefore, the combination of these variables, represents a 2 (Same vs. Different) X 2 (0 vs. 7 min.) X 2 (First set of words vs. Second set of words) X 10 (Subjects) X 3 (First list item frequency; 1, 4, or 7) X 3 (Second list item frequency; 1, 4, or 7) design. The first three of these variables were between Ss, and the latter two variables were within-Ss. However, separate analyses were performed on first-list and second-list judgments.

It should be noted that the Same (S) vs. Different (D) comparison was obtained by averaging over combinations of input modalities. That is, in the S conditions, an item may have been presented either in the auditory modality in both lists (AA), or in the visual modality in both lists (VV). Similarly, items in the D conditions may have been presented in the auditory modality in the first list and visual modality in the second (AV), or in the visual modality in the first list and auditory modality in the second (VA). The data for each S in the S conditions yielded one observation for both the AA and VV items at each level of first- and second-list item frequency. Similarly, the data from each S in the D conditions yielded one observation for both the AV and VA items at each level of first- and second-list item frequency. The data for the present analyses, then, were obtained by averaging frequency judgments to the AA and VV items for each S in the S conditions, and by averaging frequency judgments to the AV and VA items for each S in the D conditions.

First-list judgments. Mean first-list frequency judgments for items presented 1, 4, and 7 times in the first list are plotted as a function of second-list frequency (1, 4, and 7) in Figure 1. Each panel represents one of the four possible combinations of the modality change and temporal separation variables (S-0, S-7, D-0, and D-7). Within each panel, the three sets of connected treatment means represent the three levels of first-list item frequency. Hence, each data point is based on 40 observations (20 Ss X 2 observations per S).

It was mentioned earlier that the multiple-trace hypothesis predicts that first-list frequency judgments should be affected by first-list item frequency, but not by second-list item frequency. Graphically, this prediction suggests that the functions depicted in Figure 1 should be a set of parallel lines with zero slope. Alternatively, then, the extent to which these functions deviate from these predictions can be said to provide evidence in favor of an alternative to the multiple-trace hypothesis.

The mean first-list frequency judgments for items presented 1, 4, and 7 times in the first list were 1.67, 3.30, and 3.80 respectively. This increase was reliable, $F(2,144) = 92.28$, $p < .001$. First-list judgments also increased as a function of second-list item frequency; the mean judgments for items repeated 1, 4, and 7 times in the second list were 2.74, 2.87, and 3.25 respectively. Although the effect of second-list item

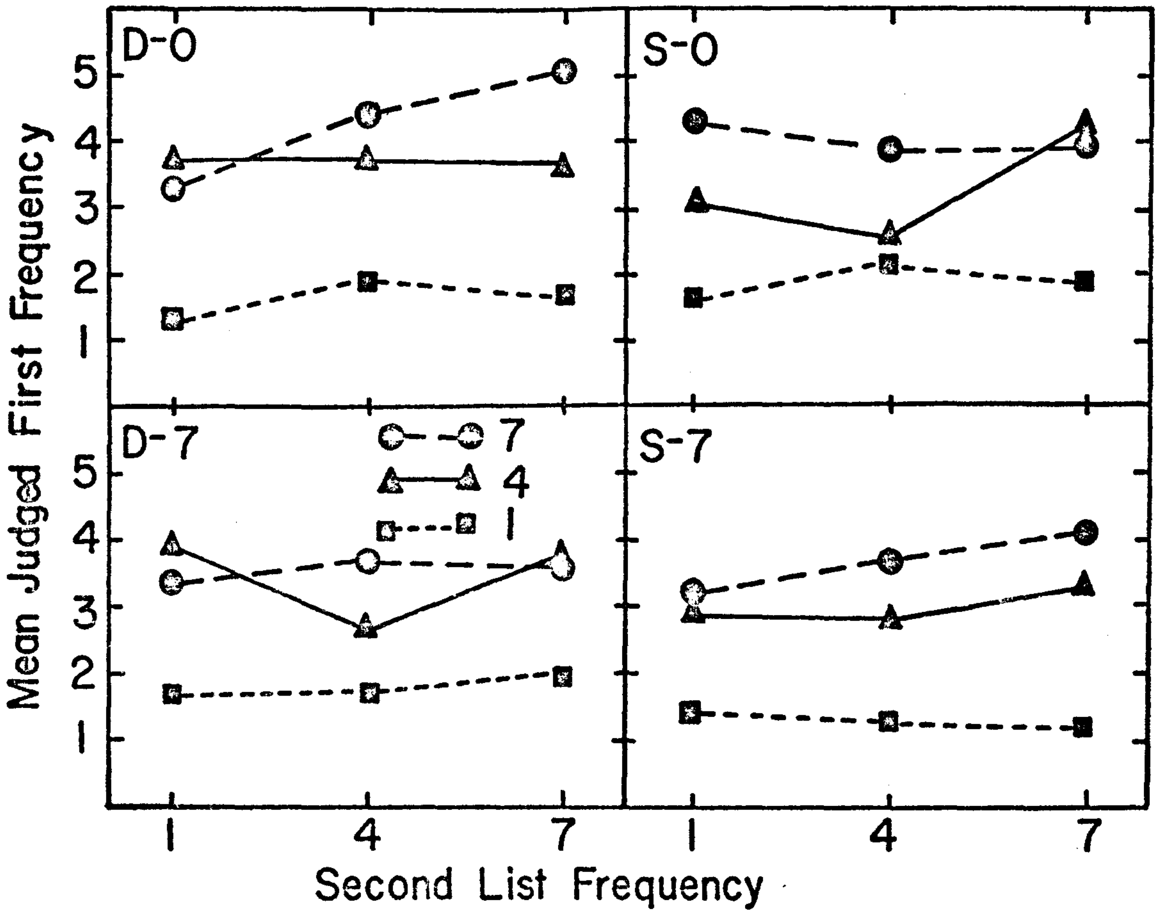

Figure 1

First-List Frequency Judgments for Items Presented in Both Lists as a Function of Item Frequency Within Each List, Modality, and Temporal Separation Between the Study Lists frequency on first-list judgments is somewhat weaker than the effect of first-list item frequency, the increase is reliable, $F\ (2, 144) = 7.14$, $p < .005$.

The interaction between first- and second-list item frequency was not significant, $F\ (4, 288) = 1.98$, $p > .05$. The effects of the covariation of first- and second-list item frequency, however, differed reliably between S-O, S-7, D-O, and D-7 conditions, $F\ (4, 288) = 3.17$, $p < .025$. This interaction seems to be attributable to items presented more than one time in the second list. More specifically, an inspection of Figure 1 reveals that there was a clear ordering of first-list judgments as a function of first-list item frequency over all levels of second-list item frequency only in the S-7 condition. Interestingly, it is this condition that most closely parallels the conditions employed by Hintzman and Block (1971).

Two other significant effects were obtained. First, there was a significant difference between the two sets of word lists employed, $F\ (1, 72) = 4.82$, $p < .05$. The reason for this difference is not entirely clear. Underwood and Freund (1970a), however, have noted that words equated in terms of background and situational frequency may differ in terms of apparent frequency due to individual word characteristics such as orthography, concreteness-abstractness, etc.

Second, the difference between the two sets of word lists interacted with first- and second-list item frequency, $F\ (4, 288) = 3.18$, $p < .025$. This interaction, which is represented in Table 1 by the appropriate treatment means, seems to be the result of the fact that word list differences were for the most part specific to items presented more than

Table 1

Treatment Means for Word Lists X Temporal Variable X Modality Change Interaction*

First-List Frequency	Second-List Frequency 1	4	7
1	2.06 (0.98)	1.76 (1.76)	1.77 (1.70)
4	3.81 (2.50)	3.45 (2.47)	3.97 (3.61)
7	3.51 (3.57)	4.46 (3.35)	4.51 (3.96)

*Treatment means for first set of word lists are outside parentheses. Treatment means for second set of word lists are inside parentheses.

once in the first list. This result is not surprising, however, since it would be expected that those word characteristics that affect apparent frequency should have an increasingly greater effect with increasing situational frequency. In particular, those attributes that serve to increase discriminability for an event would be expected to have an increasingly greater effect as the number of repetitions of that event increases. It should be noted that this interpretation is entirely consistent with the multiple-trace hypothesis (Hintzman, personal communication).

Finally, no other interactions or main effects were significant. The complete Analysis of Variance is summarized in Table A of Appendix I.

Second-list judgments. Mean second-list frequency judgments for items presented 1, 4, and 7 times in the second list are plotted as a function of first-list item frequency in Figure 2. Each data point is based on 40 observations.

The mean second-list frequency judgments for items presented 1, 4, and 7 times in the second list were 2.48, 3.36, and 4.01 respectively. This increase was significant, F (2, 144) = 60.28, $p < .001$. The mean judgments for items presented 1, 4, and 7 times in the first list were 2.81, 3.38, and 3.36 respectively. This increase was also reliable, F (2, 144) = 21.28, $p < .001$. The effects of the temporal variable were also significant, F (1, 72) = 14.23, $p < .001$. Graphically, this can be seen as higher overall frequency judgments for conditions D-O, and S-O relative to D-7 and S-7.

First-list item frequency interacted with second-list item frequency, F (4, 288) = 3.80. $p < .005$. Specifically, the mean second-list judgments

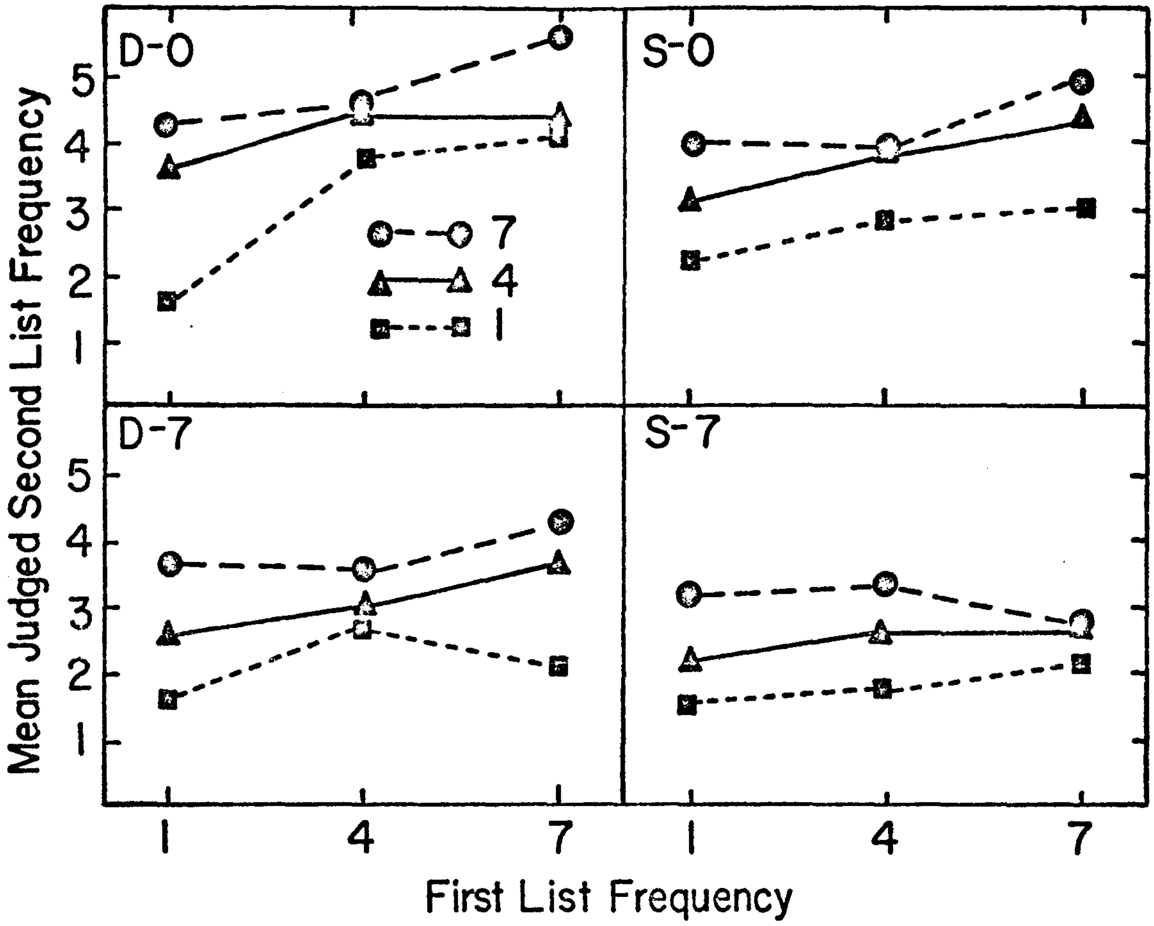

Figure 2

Second-List Frequency Judgments for Items Presented in Both Lists as a Function of Item Frequency within Each List, Modality and Temporal Separation Between the Study Lists for items presented one time in the second list and 1, 4, and 7 times in the first list were 1.76, 2.82, and 2.85 respectively. The corresponding values for items presented 4 times in the second list were 2.86, 3.51, and 3.71. The values for items presented 7 times in the second list were 3.81, 3.80, and 4.41. Thus, the difference between items presented 1 and 4 times in the first list varied inversely with second-list frequency, whereas the difference between items presented 4 and 7 times in the first list varied directly with second-list frequency.

It was mentioned earlier that the multiple-trace hypothesis predicts that second-list frequency discrimination should improve as the temporal interval separating presentation of the study lists increases. That is, it would be expected that first-list item frequency should have a lesser effect on second-list judgments in conditions S-7 and D-7 than in conditions S-0 and D-0. The present results are consistent with this prediction in that there was a reliable interaction between the temporal variable and first-list item frequency, $\underline{F}$ (2, 144) = 5.36, $\underline{p} < .01$. The treatment means for this interaction are given in Table 2. As predicted by the multiple-trace hypothesis, second-list judgments were less affected by first-list item frequency in the S-7 and D-7 conditions than in the S-0 and D-0 conditions.

It was also predicted earlier that when items are presented in different modalities in the two lists, there should be a subsequent decrease in the effect of first-list frequency on second-list judgments. This prediction was not upheld by the present data in that the main effect of modality change was not significant, $\underline{F}$ (1, 72) = 3.02, $\underline{p} > .05$. Also, none of the interactions involving modality change were significant. Hence, for both

Table 2

Treatment Means for Temporal Variable X

First-List Item Frequency Interaction

Temporal Separation	First-List Frequency 1	4	7
0 min.	3.14	3.92	4.41
7 min.	2.49	2.84	2.90

first- and second-list frequency judgments, the hypothesized effects of changed input modality were not obtained.

Similar to the results reported for the first-list judgments, there was a significant difference between the two sets of word lists employed, $\underline{F}$ (1, 72) = 12.45, $\underline{p} < .001$. This difference was also involved in a first order interaction with first-list item frequency, $\underline{F}$ (2, 144) = 3.32, $\underline{p} < .05$ and in a second order interaction with first- and second-list item frequency, $\underline{F}$ (4, 288) = 3.79, $\underline{p} < .005$. As pointed out previously, however, any word characteristics that influence subjective frequency estimates should also interact with situational frequency. It appears, then, that as frequency discrimination becomes more difficult, word characteristics that influence apparent frequency may play an increasingly greater role in the discriminative process itself.

Finally, no other interactions or main effects approached significance. The complete Analysis of Variance is summarized in Table B of Appendix I.

Items Presented in Only One List

The present analysis was concerned with those items that were presented in the first list but not the second, and in the second list but not the first. Since there is no danger of dependence among observations, the lists in which items were presented were also treated as a within-Ss variable. Also, the present analysis was confined to judgments for the appropriate list. Hence, the present analysis can be classified as a 2 (0 vs. 7 min.) X 2 (S vs. D) X 2 (First set of words vs. Second set of words) X 10 (Subjects) X a (Lists; first or second) X 3 (Item frequency; 1, 4, Or 7) design. The first three variables were between-Ss, and the latter two variables were within-Ss.

Mean frequency judgments as a function of item frequency are plotted in Figure 3. Each panel represents one list (First or Second), and, within each panel, the four sets of connected treatment means represent the S-7, D-7, S-0, and D-0 conditions. Each data point is based on 40 observations.

The mean judged frequencies for items presented 1, 4, and 7 times were 0.99, 2.56, and 3.54 respectively. The increase was reliable, F (2, 144) = 124.04, $p < .001$. The mean judged frequencies for items presented in the first and second lists were 2.16 and 2.57. The difference between these two values was significant, F (1, 72) = 7.05, $p < .025$. Somewhat surprisingly, there was also a significant effect of modality change, F (1, 72) = 7.41, $p < .01$. As can be seen in Figure 3, this difference is the result of higher frequency judgments being given to items in the D-7 and D-0 conditions. The reason for this difference is not clear. It may be the case, however, that the difference represents some general overall strategy difference employed by Ss in the D conditions relative to the S conditions. Such a hypothesis, however, would seemingly predict an interaction between the two lists and the effect of modality change since Ss were presented the first of the two lists in identical fashion across all conditions. This hypothesis is not supported in that the predicted interaction was not obtained ($F < 1.00$).

Finally, there was a significant interaction involving the temporal variable and item frequency, F (2, 144) = 5.54, $p < .005$. As can be seen in Figure 3, items presented 7 times were given lower frequency judgments under the 7 min. level of temporal separation than under the 0 min. level of temporal separation.

No other main effects or interactions were significant. The complete

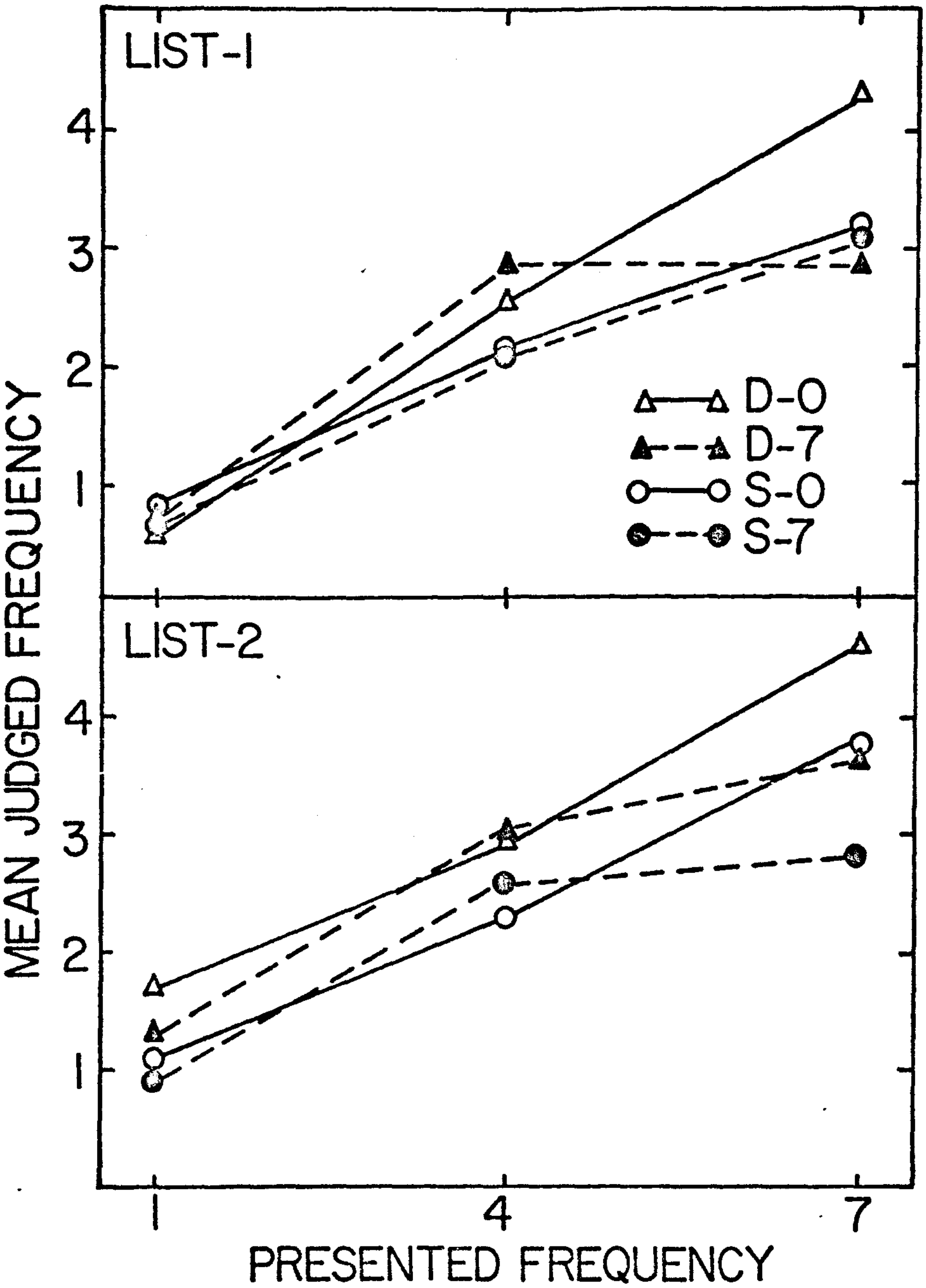

Figure 3

Mean Frequency Judgments for Items Presented in Either the First- or Second-List Only as a Function of Item Frequency, Modality, and Temporal Separation Between the Study Lists

Analysis of Variance is summarized in Table C of Appendix I.

False Identifications

Each S provided frequency judgments for six items that had not been presented in either list. The mean first-list and second-list frequency judgments for these items are presented in Table 3. There were no essential differences between conditions or between first-list and second-list judgments.

Modality Comparisons

The design of the present experiment permits evaluation of a number of secondary comparisons regarding apparent frequency as a function of situational frequency. In particular, there is a lack of empirical data comparing frequency judgments across sensory modalities using a within-Ss design. To this end, items that were presented 1, 4, and 7 times in one list only were compared with regard to auditory and visual presentations.

Since there was only one observation per S regarding the desired comparison, it was decided to collapse the data over the two lists presented to each S. Before proceeding with this analysis, however, auditory versus visual frequency judgments were compared between the two lists in order that the results from the comparison of interest would not be obviated due to list differences. For this analysis, each S's total frequency judgments were scored summing over the three levels of item frequency and over both list judgments. That is, since between-list frequency discrimination is not at issue in this comparison, each S's frequency judgments (collapsed over list judgments) for each item, and over the three items that comprised the different item frequencies were added to yield four measures: one for each list (first or second) and

Table 3

Mean Judged First-List and Second-List Frequencies for Items Not Presented in Either List by Conditions

List	Condition			
	S-O	D-O	S-7	D-7
1	0.15	0.09	0.11	0.13
2	0.07	0.14	0.09	0.16

modality (auditory or visual) combination. The results from this analysis indicated that although frequency judgments were higher for items presented in the first study list than for items presented in the second, F (1, 72) = 9.05, $p < .005$, there were no significant interactions involving the two lists Fs (1, 72) < 3.09, $ps > .05$. It should be noted once again that the purpose of this analysis was to determine if there were any interactions involving modality and the two lists that would preclude further observations regarding modalities and item frequencies.

The analysis of interest, therefore, was done in the following manner. Each S's frequency judgments for items presented 1, 4, and 7 times were obtained for each modality (A or V). Further, each S's frequency judgments were obtained without regard to list identification. That is, for a given item, both first-list and second-list judgments were added to yield the total frequency judgment for that item. Hence, six measures were obtained for each S, one for each level of item frequency (1, 4, and 7), and for both auditory and visual items.

The mean frequency judgments for items presented 1, 4, and 7 times in the auditory modality were 1.56, 4.40, and 4.85 respectively. The corresponding values for items presented in the visual modality were 1.56, 3.68, and 5.28. The effect of item frequency was significant, F (2, 144) = 136.04, $p < .001$. There was no reliable difference, however, between the auditory and visual items, $F < 1.00$. The Item Frequency X Modality interaction was also nonsignificant, F (2, 144) = 2.45, $p > .05$.

The effects of modality change, F (1, 72) = 8.32, $p < .01$, the interaction between item frequency and the two sets of word lists, F (2, 144) = 7.05, $p < .005$, and the interaction involving item frequency and the temporal separation variable, F (2, 144) = 3.56, $p < .05$, were all significant. Interestingly, the results from the present comparisons yielded results almost identical to those obtained when observations were collapsed over modalities but not over first- and second-list judgments (see Figure 3). The important fact to be realized from this analysis, then, is that auditory and visual presentations do not seem to affect apparent frequency in a differential fashion.

CHAPTER IV

Discussion

Tests of the Multiple-Trace Hypothesis

As was outlined earlier, the multiple-trace hypothesis asserts that with each presentation of a verbal item, a single unity "trace" for that item is established in memory. According to the hypothesis, apparent frequency, or S's subjective estimate of situational frequency, is dependent upon the extent to which the memory traces for an item can be differentiated on the basis of a temporal attribute or "time-tag." More specifically, an item will be remembered as having been presented at different points in time to the extent to which the occurrences of that item may be distinguished in terms of temporal cues. Hintzman and Block (1971) tested the multiple-trace hypothesis by presenting Ss with two word lists, with the words repeated within and between lists a varying number of times. The authors found that mean first- and second-list frequency judgments for a given item were ordered primarily by that item's frequency within the list being judged and secondarily by the frequency with which the item was presented in the list not judged. On the basis of these results, the authors suggested that the apparent frequency of an item in one experimental context may be independent of that item's presented frequency in another experimental context. The present results may now be discussed in terms of the multiple-trace hypothesis and in relation to the results obtained by Hintzman and Block.

The primary difficulty involved in any test of the multiple-trace hypothesis is the determination of when list judgments can be said to be independent. Hintzman and Block, for instance, found second-list item frequency to have a significant effect on first-list judgments and first-list item frequency had a similar effect on second-list judgments. These results not withstanding, the authors concluded that first- and second-list frequency judgments were independent. This conclusion was seemingly based on the fact that the greatest portion of the variance among means for both first- and second-list judgments was accounted for by first- and second-list item frequency respectively.

Similar analyses were conducted on the present data. Specifically, ω^2 (Hays, 1963) was computed for the effects of first- and second-list item frequency in regards to first- and second-list judgments. In this context, ω^2 can be said to be a measure of the strength of an association between the independent variable (item frequency) and the dependent measure (judged frequency). The results of this analysis indicated that the part of the total variance in first-list judgments that could be attributed to first-list item frequency was 17.82%, while the amount of variance attributable to second-list item frequency was 0.83%. The corresponding values for second-list judgments were 2.65% and 11.40% respectively. The important fact to be realized from this analysis is that list frequency judgments were primarily affected by the manipulation of item frequency within that same list, and only secondarily by the manipulation of item frequency in the remaining list. Since it is unlikely that between-list frequency discrimination might ever be perfect, the present results provide at least limited support for the multiple-trace hypothesis.

It is significant to note, however, that an asymmetry between the effects of first- and second-list item frequency on second- and first-list judgments were obtained. Specifically, both significance tests and the ω^2 values demonstrated that the effects of second-list item frequency on first-list judgments were not as strong as the effects of first-list item frequency on second-list judgments. These results do not stand in agreement with those obtained by Hintzman and Block (1971), who found an approximately symmetrical relationship between the two effects. In this regrad, the present results do not support the multiple-trace hypothesis.

The present results are consistent, however, with those obtained by Reichart, Shaughnessy, and Zimmerman (unpublished). In that study, a portion of the Ss were presented two lists where words were presented 1, 4, 7, or 10 times in each list. In contrast with the present experiment, frequency judgments were taken after the presentation of each list, rather than taking the list judgments concurrently. Following the test on the second list, Ss were retested on the first-list items. The authors' results indicated that first-list judgments were unaffected by second-list item frequency. Second-list judgments, on the other hand, were significantly affected by first-list item frequency. Thus, both the results of the present study and the experiment conducted by Reichart et al. contrast with the results obtained by Hintzman and Block (1971).

Reichart et al. proposed that the difference between their results and those obtained by Hintzman and Block may have been due to the number of item frequencies employed. That is, items in the Hintzman and Block experiment were presented either 0, 2, or 5 times. It might be the case, then, that Ss in the Hintzman and Block experiment were able to categorize the items according to whether they were high frequency items, low frequency items, or items that were not presented at all. Both the present study and the study conducted by Reichart et al., on the other hand, used a larger number of levels of item frequency. Hence, Ss in the present study may have employed an entirely different strategy during the testing phase of the experiment than did the Ss in the Hintzman and Block experiment. Thus, the degree to which situational frequencies for a given item may be distinguished between two experimental contexts may be a function of the number of levels of item frequency employed.

Another apparent limitation upon between-list frequency discrimination is the temporal interval separating presentation of the study lists. As can be seen in Figure 2, there was very little effect of first-list item frequency on second-list judgments in the S-7 and D-7 conditions relative to the S-0 and D-0 conditions. This result was reflected in a significant interaction involving the temporal variable with first-list item frequency. Once again, it should be noted that the S-7 and D-7 conditions most closely approximate the experiment reported by Hintzman and Block (1971).

The present results are also consistent with those obtained by Pasko and Zechmeister (in press). In that experiment, Ss participated in a verbal-discrimination transfer task where a reversal paradigm of the sort outlined in Chapter I was employed. It was mentioned earlier, that the multiple-trace hypothesis predicts that as the temporal interval between the learning of the two lists increases, there should be a subsequent decrease in the degree of negative transfer obtained. To test this hypothesis, one-half of the Ss in the Pasko and Zechmeister experiment were presented the second of the two lists immediately following presentation of the first list, while the remaining Ss participated in a 7 min. filler task between presentation of the two lists. Two levels of first-list learning were also employed. Specifically, Ss were given either 4 or 8 trials on the first list. The results of the experiment indicated that there was a marked decrease in negative transfer when there was a 7 min. interval separating presentation of the two lists, but that this effect occurred only when Ss were given 4 trials on the first list. It should be noted, however, that this might be expected since as the number of trials on the first list increases, the time interval between the beginning of the presentation of the two lists increases, and hence, the temporal context of the two lists may be sufficiently different such that increasing the temporal interval between the learning of the two lists would be of little use to Ss in discriminating experimental frequencies of the two lists. Hence, both the present results and those obtained by Pasko and Zechmeister support the predictions of the multiple-trace hypothesis insofar as the role of the temporal attribute is concerned.

Modality Information

It was predicted in Chapter I that when Ss are not able to discriminate between the two study lists on the basis of a temporal attribute, secondary attributes may serve as a mediating cue in between-list frequency discrimination. As a test of this hypothesis, one-half of the Ss in the present experiment were presented items in the same modality in both lists, and the remaining half of the Ss were presented lists in which the items were presented in different modalities in the two lists. The obtained results were inconsistent with the prediction. Specifically, there was no effect of modality change for items presented in both lists.

This result is somewhat surprising in light of an experiment recently conducted by Macey and Zechmeister (1973), who found that when two presentations of an item were in same or different modalities (auditory and visual) and presentations were massed, Ss were better able to identify an item as being presented in two modalities (and, hence, of having been presented twice) than they were of judging that an item had been presented twice in the same modality. On the basis of these results, it might be inferred that Ss were able to employ the modality information as an aid in determining the frequency with which items were presented when such judgments would not be possible on the basis of a temporal attribute.

One possible explanation for the apparent discrepancy between the present results and those obtained by Macey and Zechmeister (1973) might be that the effects of changed input modality may be apparent only in a within-Ss design. That is, the manipulation of modality change in the present experiment was between-Ss, whereas the manipulation of the modality change variable in the Macey and Zechmeister experiment was within-Ss. Thus, before S may employ the information available to him, it may be necessary to either identify to S that it may be useful in the task (via instructions), or S must feel that there is something intrinsically distinctive to the manipulation of the variable, as might be apparent in a within-Ss design.

Perhaps the most surprising result of the present experiment was the finding that the change in input modality resulted in an increase in Ss frequency judgment for items that were presented in one list only. The fact that manipulation of the modality change variable did not interact with the list within which an item was presented seems to rule out the possibility that the effect is due to some shift in rehearsal strategy during presentation of the second list, since such a hypothesis would predict an interaction between lists and the effects of modality change, a result which was not obtained. This same finding suggests that the obtained effect may be localized during the testing phase of the experiment. Since Ss' frequency judgments for each list were obtained concurrently, such a possibility should not be ignored in future research.

Summary and Conclusion

In summary, three points may be discussed regarding the results of the present experiment and the predictions outlined in Chapter I.

First, the present results support the multiple-trace hypothesis insofar as between-list frequency discrimination is concerned. In particular, first-list frequency judgments were influenced primarily by first-list item frequency and only secondarily by second-list item frequency. Similarly, second-list frequency judgments were influenced primarily by second-list item frequency and only secondarily by first-list item frequency.

Second, as predicted by the multiple-trace hypothesis, increasing the temporal interval between presentation of the study lists served to facilitate between-list frequency discrimination. The effect of the temporal variable, however, was significant only in regards to second-list judgments as affected by first-list item frequency. The failure to find a significant interaction involving the temporal variable and second-list item frequency in regards to first-list frequency judgments is probably the result of the fact that first-list frequency judgments were less dependent on second-list item frequency than were second-list judgments on first-list item frequency. As reported above, the ω^2 values support this conclusion. Thus, it appears that an effect of the temporal variable might be expected only in those situations where list judgments are not independent of apparent frequency established in prior experimental contexts.

Third, the failure to find an effect of modality change for items presented in both lists suggests that all discriminative attributes are not equally viable in aiding between-list frequency discrimination. That is, it may be the case that the efficacy of individual attributes may not be equally apparent to Ss, or more specifically, the utilization of such attributes may be dependent upon whether the manipulation of the appropriate variable is between-Ss or within Ss.

Alternatively, it may be the case that the effects of modality change are apparent only at the level of list discrimination. That is, if Ss remember that an item was presented in only one modality, such information may lead Ss to assign the total remembered frequency for that item to one of the two lists. If, on the other hand, Ss remember that an item was presented in two modalities, such information may be useless in assignment of list frequencies. The fact that there was a significant effect of modality change for items presented in one list only but not for items presented in both lists supports this conclusion.

While both of the alternatives outlined above seem promising, both are admittedly post hoc and at best tenative. Clearly, further research along the present lines is warranted.

REFERENCES

Brown, R., & McNeil, D. The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior*, 1966, 5, 325-337.

Cole, L., & Kanak, N. J. Transfer of implicit associative responses between free-recall learning and verbal discrimination tasks. *Journal of Experimental Psychology*, 1972, 95, 110-115.

Cooper, E. H., & Pantle, A. J. The total-time hypothesis in verbal learning. *Psychological Bulletin*, 1967, 68, 221-231.

Ekstrand, B. R., Wallace, W. P., & Underwood, B. J. A frequency theory of verbal discrimination learning. *Psychological Review*, 1966, 73, 566-578.

Hays, W. L. *Statistics*. New York: Holt, Rinehart and Winston, 1963.

Hinrichs, J. V. A two-process memory-strength theory for judgment of recency. *Psychological Review*, 1970, 77, 223-233.

Hintzman, D. L. Recognition time: Effects of recency, frequency, and the spacing of repetitions. *Journal of Experimental Psychology*, 1969, 79, 192-194. (a)

Hintzman, D. L. Apparent frequency as a function of frequency and the spacing of repetitions. *Journal of Experimental Psychology*, 1969, 80, 139-145. (b)

Hintzman, D. L. Effects of repetition and exposure duration on memory. *Journal of Experimental Psychology*, 1970, 83, 435-444.

Hintzman, D. L., & Block, R. A. Repetition and memory: Evidence for a multiple-trace hypothesis. *Journal of Experimental Psychology*, 1971, 88, 297-306.

Hopkins, R. H., Boylan, R. J., & Lincoln, G. L. Pronunciation and apparent frequency. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 105-113.

Jacoby, L. L. Context effects on frequency judgments of words and sentences. Journal of Experimental Psychology, 1972, 94, 255-260.

Kintsch, W. Recognition learning as a function of the length of retention interval and changes in the retention interval. Journal of Mathematical Psychology, 1966, 3, 412-433.

Kucera, H., & Francis, W. N. Computation analysis of present-day American English. Providence: Brown University Press, 1967.

Macey, W. H., & Zechmeister, E. B. Spacing effects in free recall following mixed modality presentation. Paper presented at the 45th Annual Meeting of the Midwestern Psychological Association, Chicago, May, 1973.

Madigan, S., & Doherty, L. Retention of item attributes in free recall. Psychonomic Science, 1972, 27, 233-235.

Pasko, S., & Zechmeister, E. B. Temporal separation in verbal discrimination transfer. Journal of Experimental Psychology, 1973, in press.

Postman, L., & Phillips, L. W. Short term temporal changes in free recall. Quarterly Journal of Experimental Psychology, 1955, 17, 132-138.

Raskin, D. C., Boice, C., Rubel, E. W., & Clark, D. Transfer tests of the frequency theory of verbal discrimination learning. Journal of Experimental Psychology, 1968, 76, 521-529.

Shapiro, B. H. The subjective estimate of relative sord frequency. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 248-251.

Thorndike, E. L., & Lorge, I. The teacher's word book of 30,000 words. Teachers College, Columbia University, Bureau of Publication, 1944.

Underwood, B. J. False recognition produced by implicit verbal responses. Journal of Experimental Psychology, 1965, 70, 122-129.

Underwood, B. J. Some correlates of item repetition in free-recall learning. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 83-94. (a)

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

Underwood, B. J. Word recognition memory and frequency information. Journal of Experimental Psychology, 1972, 94, 276-283.

Underwood, B. J., & Freund, J. S. Two tests of a theory of verbal-discrimination learning. Canadian Journal of Psychology, 1968, 22, 96-104.

Underwood, B. J., & Freund, J. S. Testing effects in the recongition of words. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 117-125. (a)

Underwood, B. J., & Freund, J. S. Relative frequency judgments and verbal discrimination learning. Journal of Experimental Psychology, 1970, 83, 279-285. (b)

Underwood, B. J., & Freund, J. S. Retention of a verbal discrimination. Journal of Experimental Psychology, 1970, 84, 1-14. (c)

Underwood, B. J., & Freund, J. S. Word frequency information and short-term recognition memory. American Journal of Psychology, 1970, 83, 343-351. (d)

Underwood, B. J., Zimmerman, J., & Freund, J. S. Retention of frequency information with observations on recognition and recall. Journal of Experimental Psychology, 1971, 87, 149-162.

Underwood, B. J., Shaughnessy, J. J., & Zimmerman, J. Learning-to-learn verbal discrimination lists. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 96-104. (a)

Underwood, B. J., Shaughnessy, J. J., & Zimmerman, J. List length and method of presentation in verbal discrimination learning with further evidence on retroaction. Journal of Experimental Psychology, 1972, 93, 181-187. (b)

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

Zechmeister, E. B., & McKillip, J. Recall of place on the page. Journal of Educational Psychology, 1972, 63, 446-453.

APPENDIX

TABLE A

Analysis of Variance Summary Table: First List Judged Frequency for Items Presented in Both Lists

	Source	df	MS	F
1	Temporal Variable (T)	1	25.33	1.88
2	Modality Change (M)	1	.94	0.07
3	Word Lists (W)	1	64.77	4.82*
4	First-List Frequency (F)	2	317.50	92.28***
5	Second-List Frequency (S)	2	17.09	7.71**
6	T x M	1	0.31	0.02
7	T x W	1	4.50	0.34
8	M x W	1	5.34	0.39
9	T x F	2	0.80	0.23
10	M x F	2	1.23	0.35
11	W x F	2	3.95	1.14
12	T x S	2	0.81	0.34
13	M x S	2	3.85	0.80
14	W x S	2	3.40	1.42
15	F x S	4	4.52	1.87
16	T x M x W	1	36.69	2.95
17	T x M x F	2	2.64	0.76
18	T x W x F	2	6.32	1.83
19	M x W x F	2	6.62	1.92
20	T x M x S	2	2.78	1.16
21	T x W x S	2	3.19	1.33

22	M x W x S	2	.26	0.10
23	T x F x S	4	1.06	0.43
24	M x F x S	4	2.20	0.91
25	W x F x S	4	7.67	3.18*
26	Subjects/Groups	72	13.43	
27	T x M x W x F	2	1.27	0.37
28	T x M x W x S	2	.36	0.15
29	T x M x F x S	4	7.64	3.16*
30	T x W x F x S	4	5.60	2.32
31	M x W x F x S	4	1.42	0.59
32	F x Subjects/Groups	144	3.44	
33	S x Subjects/Groups	144	2.39	
34	T x M x W x F x S	4	3.48	1.44
35	F x S x Subjects/Groups	288	2.41	

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE B

Analysis of Variance Summary Table: Second List Judged Frequency for Items Presented in Both Lists

	Source	df	MS	F
1	Temporal Variable (T)	1	209.08	14.23**
2	Modality Change (M)	1	44.50	3.02
3	Word Lists (W)	1	183.01	12.45**
4	First-List Frequency (F)	2	44.29	21.28***
5	Second-List Frequency (S)	2	141.43	60.47***
6	T x M	1	0.45	0.03
7	T x W	1	2.93	0.20
8	M x W	1	14.73	1.00
9	T x F	2	11.15	5.36**
10	M x F	2	4.98	2.39
11	W x F	2	6.91	3.32*
12	T x S	2	.35	0.15
13	M x S	2	1.64	0.70
14	W x S	2	0.012	0.01
15	F x S	4	5.84	3.80**
16	T x M x W	1	12.80	0.87
17	T x M x F	2	1.07	0.51
18	T x W x F	2	1.49	0.71
19	M x W x F	2	1.77	0.85
20	T x M x S	2	0.95	0.40
21	T x W x S	2	4.89	2.09

22	M x W x S	2	0.16	0.07
23	T x F x S	4	2.48	1.61
24	M x F x S	4	3.30	2.14
25	W x F x S	4	5.83	3.79**
26	Subjects/Groups	72	14.69	
27	T x M x W x F	2	5.64	2.71
28	T x M x W x S	2	0.38	0.16
29	T x M x F x S	4	2.91	1.89
30	T x W x F x S	4	1.09	0.71
31	M x W x F x S	4	3.63	2.36
32	F x Subjects/Groups	144	2.08	
33	S x Subjects/Groups	144	2.33	
34	T x M x W x F x S	4	3.88	2.00
35	F x S x Subjects/Groups	288	1.53	

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE C

Analysis of Variance Summary Table: Judged Frequency for Items Presented in One List Only

	Source	df	MS	F
1	Temporal Variable (T)	1	9.21	2.54
2	Modality Change (M)	1	26.83	7.41**
3	Word Lists (W)	1	3.76	1.03
4	List (L)	1	20.21	7.05*
5	F (Frequency)	2	264.80	124.04***
6	T x M	1	1.15	0.31
7	T x W	1	1.81	0.50
8	M x W	1	4.16	1.15
9	T x L	1	0.71	0.24
10	M x L	1	2.62	0.91
11	W x L	1	0.004	0.00
12	T x F	2	11.83	5.54**
13	M x F	2	1.90	0.89
14	W x F	2	5.42	2.54
15	L x F	2	0.76	0.42
16	T x M x W	1	2.77	0.76
17	T x M x L	1	0.0005	0.00
18	T x W x L	1	0.15	0.05
19	M x W x L	1	0.11	0.04
20	T x M x F	2	1.72	0.80
21	T x W x F	2	5.11	2.39

22	M x W x F	2	0.75	0.35
23	T x L x F	2	0.37	0.20
24	M x L x F	2	1.11	0.62
25	W x L x F	2	0.72	0.40
26	Subjects/Groups	72	3.62	
27	T x M x W x L	1	2.47	0.86
28	T x M x W x F	2	1.97	0.92
29	T x M x L x F	2	2.25	1.25
30	T x W x L x F	2	1.13	0.63
31	M x W x L x F	2	0.26	0.14
32	L x Subjects/Groups	72	2.86	
33	F x Subjects/Groups	144	2.13	
34	T x M x W x L x F	2	.061	0.03
35	L x F x Subjects/Groups	144	1.79	

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE D

Analysis of Variance Summary Table: Judged Frequency as a Function of Modality and Item Frequency

	Source	df	Ms	F
1	Temporal Variance (T)	1	23.85	3.76
2	Modality Change (C)	1	52.67	8.32**
3	Word Pool (W)	1	64.53	10.19**
4	Modality (M)	1	0.07	0.02
5	Frequency (F)	2	507.10	136.04***
6	T x C	1	3.85	0.60
7	T x W	1	10.20	1.61
8	C x W	1	0.83	0.13
9	T x M	1	0.53	0.14
10	C x M	1	3.67	0.97
11	W x M	1	4.60	1.22
12	T x F	2	13.29	3.56*
13	C x F	2	4.90	1.31
14	W x F	2	26.67	7.04**
15	M x F	2	6.22	2.45
16	T x C x W	1	1.63	0.25
17	T x C x M	1	4.41	1.17
18	T x W x M	1	3.17	0.84
19	C x W x M	1	4.21	1.12
20	T x C x F	2	2.62	0.70
21	T x W x F	2	3.05	0.81

22	C x W x F	2	0.41	0.11
23	T x M x F	2	1.66	0.65
24	C x M x F	2	0.07	0.03
25	W x M x F	2	1.46	0.58
26	Subjects/Groups	72	6.33	
27	T x C x W x M	1	0.75	0.20
28	T x C x W x F	2	4.93	1.32
29	T x C x M x F	2	0.09	0.03
30	T x W x M x F	2	4.85	1.91
31	C x W x M x F	2	3.97	1.57
32	M x Subjects/Groups	72	3.75	
33	F x Subjects/Groups	144	3.72	
34	T x C x W x M x F	2	1.18	0.46
35	M x F x Subjects/Groups	144	2.53	

* $p < .05$

** $p < .01$

*** $p < .001$

APPROVAL SHEET

The Thesis submitted by William H. Macey has been read and approved by members of the Department of Psychology.

The final copies have been examined by the director of the Thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the Thesis is now given final approval with reference to content and form.

The Thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

5/21/73
Date

Signature of Advisor