DECAY AND INTERFERENCE IN SHORT-TERM RECOGNITION MEMORY

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by

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Ph. D. ABSTRACT PSYCHOLOGY

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This study investigated the roles of decay and interference in short-term recognition memory for visual stimuli. Seven experiments, involving 520 Ss, were reported.

Experiments I, II and III showed that interference is significant in short-term recognition memory, while decay is not. But analysis of the recognition-errors suggests that the interference effect was an artifact of the recognition test. Experiment IV controlled for this artifact, and indicated that short-term recognition memory is subject to neither decay nor interference. Experiments V and VI confirmed the persistence of short-term recognition memory against interference and decay by increasing the amount of interference and the duration of delay. Experiment VII demonstrated that different rates of presentation for the stimulus and interference items did not consistently affect interference.

The results were interpreted as suggesting a persistence of the memory storage against decay or interference while the retrieval may be lost.

TABLE OF CONTENTS

INTRODUCTION	1
Decay and Interference in Short-term Memory	4
Decay	5
Rate of Presentation and Decay in STM	9
Delayed Recall and Decay in STM	12
Interference	18
Retroactive Interference	20
Proactive Interference	28
Comparison between Proactive and Retroactive Interference	31
Recognition Memory	33
Comparison between Recall and Recognition	33
Partial-learning Model of Recognition	37
Short-term Recognition Memory	40
The Present Investigation	45
THE EXPERIMENTS	47
Experiment I	47
Experiment II	59
Experiment III	67
Experiment IV	76
Experiment V	84
Experiment VI	91
Experiment VII	95
GENERAL DISCUSSION	100
SUMMARY	106
APPENDIX	109
REFERENCES	121

INTRODUCTION

Memory has been classified into two distinct categories: (1) long-term and (2) short-term. Long-term memory (LTM) is defined as firmly established storage consisting of associative connections involving repetition and practice (Corballis, 1965; Melton, 1963). Short-term memory (STM) is a one-trial learning phenomenon where the memory is formed after a single short presentation (Melton, 1963). Performance is perfect or near-perfect when the retention test is taken immediately after the presentation, but memory fails rapidly unless the materials are constantly rehearsed (Broadbent, 1957, 1958; Brown, 1958; Sperling, 1963).

Two major factors are suggested as the cause of forgetting both in LTM and STM. One is decay of memory traces through the passage of time, and the other is interference from interpolated materials. The relative importance of decay and interference in the explanation of forgetting has been a matter of debate in recent years (Melton, 1963). In the case of long-term memory, the literature suggests that interference by interpolated materials produces more retention loss than simple decay (Melton, 1963; Postman, 1961). But the role of decay as against interference in short-term memory is not clear (Broadbent, 1963; Corballis, 1965; Melton, 1963; Peterson, 1963).

STM and LTM are sometimes considered to be distinct processes involving separate non-overlapping mechanisms. But STM and LTM may also be placed on a continuum involving the same hypothetical mechanism. Theorists dichotomizing STM and LTM argue that there is no interference in STM; decay is the only factor responsible for loss of short-term retention (Broadbent, 1958, 1963; Brown, 1958; Conrad, 1957, 1958, 1960, 1964; Conrad and Hille, 1958; Hebb, 1949; Peterson and Peterson, 1959). Theorists favouring the continuum viewpoint claim that both interference and decay operate in STM (Melton, 1963; Keppel and Underwood, 1962; Peterson, 1966b, 1966c). The literature is not conclusive enough to resolve this controversy between decay and interference in STM (Broadbent, 1963; Corballis, 1965; Melton, 1963).

The experiments to be reported in this thesis were designed to compare the decay process with the interference process in short-term memory for visual stimuli under a recognition procedure. The loss of short-term retention produced by decay itself is compared with the loss brought about by decay and interference operating together. If there is any significant difference between the amounts of memory losses in these two conditions, a definite role may be assigned to interference in STM. But if the difference between decay and the combination of decay and interference is not significant, interference cannot be assigned any role in STM.

Most of the work on STM has used the method of recall. Recognition is a more sensitive measure of retention than recall. A subject might fail to recall some materials to which he has been exposed, but may be able to recognize the exposed materials from among other non-exposed materials. For recognition, a response need not be generated; it is already there. As a result, the retention score is usually higher with recognition than with recall. Thus recall does not tell the full story about retention. Some portion of retention, measurable by recognition, goes unmeasured by recall. This study uses recognition as a measure of short-term retention for visually presented stimuli.

Two form of interference: retroactive and proactive, are used in all memory tasks. Retroactive interference (RI) is produced by materials interpolated during the retention interval. This involves a corresponding decay effect. Proactive interference (PI) is produced by materials preceding the presentation of the test materials. This does not involve any decay, because there is no retention interval in this case. The present study uses both forms of interference.

Subjects often rehearse the items to be remembered during the stimulus presentation and retention interval. This rehearsal counter-acts decay and hence makes it difficult to isolate the decay effect. This study prevents rehearsal by having the subject say the items during presentation and by presenting some dissimilar non-interfering materials, apparently to be memorized, during the retention interval. There are two decay conditons: one with rehearsal allowed during the retention interval (nothing being presented), and the other with rehearsal prevented (dissimilar materials being presented). A comparison between pure decay and rehearsal, as isolated by the operation, is also made. The prevention of rehearsal by having the subject say the items during the stimulus presentation remains constant for all conditions.

The results of the present series of experiments indicate that there is no difference between effects of decay and interference in short-term recognition memory. Similarity of the interpolated materials to the test material does not make any difference in the recognition score. Time in store does not affect retention either. This does not support a decay interpretation of short-term recognition memory; nor does it confirm the interference interpretation. Rehearsal does not affect the recognition score. Short-term recognition memory appears to be rather resistant to both decay and interference. This suggests that the findings in most STM experiments with recall are applicable to retrieval process only, not to the storage as such.

Decay and Interference in Short-term Memory

The theoretical controversy between the continuity and dichotomy viewpoints of STM (Melton, 1963) is mainly due to the conflicting and confusing literature on decay and interference in short-term memory (Corballis, 1965). The dualistic theory of memory storage, responsible for the recent controversy between decay and interference in STM, was first proposed by Hebb (1949). He suggested that STM and LTM involve separate neural mechanisms. STM is mediated by a non-structural "activity trace"; and LTM by a relatively permanent "structural trace". The activity trace of STM consists of firing of neurons in reverberatory circuits. This reverberatory "activity trace" is subject to rapid decay over time. If the reverberation, however, is allowed to continue, the activity trace of STM may become the permanent structural trace of LTM. But the activity trace is disrupted and wiped out if something else is presented to the subject during the reverberatory process. Hebb (1961) revised his 1949 theory in the light of his 1961 experiment. In a memory span experiment, he repeated every third series of digits without the knowledge of the subject. The result was a significant cumulative learning effect in the repeated series, while the non-repeated series remained at a chance level. This shows a structural component in the so-called "activity trace" of short-term memory after a single presentation (Hebb, 1961).

Hebb's (1949) dualistic theory involves both decay and interference elements. The "activity trace" is subject to rapid decay, but it is also subject to disruption by the presentation of other materials. Hebb's revised theory (1961) seems, however, to incline to a monistic viewpoint of memory storage. Melton (1963) repeated Hebb's (1961) experiment and confirmed his conclusions.

Decay

Brown (1958) defines the decay theory as:

> ...when something is perceived, a memory trace is established which decays rapidly during the initial phase of its career. Some decay of the trace is assumed to be compatible with reliable recall--just as partial fading of print may be compatible with perfect legibility. But recall will cease to be reliable if decay of the trace proceeds beyond a critical level (Brown, 1958, p. 12).

More recently, Peterson (1963) gives another definition of the decay theory in terms of the operations carried out in memory experiments.

> When a series of digits, letters or words is presented and tested for recall without any appreciable lapse of time, it is only the last item in the series that has occurred immediately before the test. If the instructions specify that recall is to be attempted in order of presentation, then the test is not immediate even for that last item. This consideration has led to interpretation of memory span in terms of a trace decay theory. Stimulation sets up some kind of memory trace in the nervous system which decays rapidly over a short period of time. As the series of items presented is lengthened, the time interval between presentation and recall of the individual members becomes longer. As a result the trace becomes weaker, and probability of correct recall decreases (Peterson, 1963, p.336).

In discussing a decay factor in STM it is necessary to make a distinction between two kinds of short-term memories: (1) a rapidly decaying very short-term memory (lasting for a fraction of a second) for non-categorized items, and (2) a more slowly decaying STM trace receiving some categorized response (Aaronson, 1967; Broadbent, 1963). Evidence for decay of this kind of very short-term memory has come from the experiments of Sperling (1960), Averbach and Coriell (1961), and Averbach and Sperling (1961). Using a partial report technique for a display of letter-rows, Sperling (1960) and Averbach and Coriell (1961) found a rapid decay of the information available, with the greatest loss occurring within the first .25 second. Sperling (1960) also confirmed the earlier findings of Kay and Poulton (1951) and Poulton (1953) that retaining something in memory for later report interferes with the ability to recall earlier material. Averbach and Coriell (1961) found that recall varied as a function of delay between stimulus presentation and cue for recall from 70% at zero delay to 35% at .2 second delay. The interesting feature to note in this experiment is that the recall score neither reached 100% at zero delay nor did it approach zero at the final level. This means that some of the materials reached a more permanent store. These two experiments (Averbach and Coriell, 1961; Sperling, 1960) seem to indicate a rapidly decaying immediate memory system; although they show some interference effect too. Using a similar technique, Averbach and Sperling (1961) found that the decay time depends upon pre- and post-exposure conditions as well as on the exposure itself. The measured decays varied from 1/4 sec. to several seconds. They also found that new information erases previous information. Another series of studies on immediate memory (Broadbent, 1957, 1958; Brown, 1954) indicates a rapid-decay STM process. Broadbent (1957) presented six digits to one ear and two digits to the other ear, requiring Ss to recall the six digits first and then the two. Recall was higher if the two digits were presented at the very end of the six digits rather than a second earlier. Here the time difference seems to be the crucial factor and the results support a rapid-decay interpretation of immediate memory. Brown (1954) found a reciprocal relationship between the recall of some material and the retention of something else (while recalling) for later report. He presented arrows and numbers simultaneously. If S recalled the arrow list first, followed by the number list, recall of numbers was poorer than recall of numbers first. This shows a decay effect of the time taken by the recall of arrows. But the interference effect by the recall of arrows cannot be ruled out. If S recalled the numbers and then the arrows, number score was also worse than recall of numbers alone. Mere retention of the arrows while recalling the numbers affects the number-recall. This is rather hard to explain by the decay theory. The results confirm some earlier studies (Kay and Poulton, 1951; Poulton, 1953) and indicate that retention is an active process and the intervening activity (recall and retention of the arrows in this case) affects recall. Further support of the decay theory of STM has come from Conrad (1958). Using dial and keyset telephones he found that Ss make more mistakes in recalling a number by dialing than by pressing the buttons of the keyboard. The dial method of recall takes longer time and produces more forgetting (Conrad, 1958). This supports a rapid-decay interpretation of immediate memory.

Decay in the second category of STM is a function of time over a longer range of retention intervals (several seconds or minutes), irrespective of any material or activity occupying the interval (Broadbent, 1963; Peterson, 1963). The decay experiments of STM of this kind vary the time in store for materials either by varying the rate of presentation, as in traditional memory span experiments, or by delaying the recall for various intervals with or without interpolated materials. The inter-item rehearsal by S during presentation and recall in both kinds of experiments is not usually controlled except by requiring S to respond to the items. Most of the delayed recall experiments control rehearsal during the delay interval by presenting some dissimilar materials irrelevant to the memory task (Brown, 1958; Keppel and Underwood, 1962; Murdock, 1963 a, 1963 b; Peterson and Peterson, 1959); although a few delayed recall experiments left the interval unfilled and rehearsal uncontrolled (Anderson, 1960; Crawford et al., 1966; McLane and Hoag, 1943).

Rate of Presentation and Decay in STM

A decay theory would suggest that increasing the rate of presentation on an immediate recall task should decrease the time in store and improve recall. Decreasing the rate would accordingly increase time in store and should result in decreased recall. But rehearsal and organization of the stimuli by S confounds the decay prediction here (Corballis, 1965; Posner, 1963). Experiments with varying rate of presentation have yielded conflicting results; some are in favour of while others are against the decay prediction. Conrad (1957) tested the decay theory and found evidence to support it. Series of eight digits were presented and recalled either at a slow (30 digits/minute) or at a fast (90 digits/minute) rate. He found better recall with the faster rate. A similar study (Conrad and Hille, 1958) used paced or unpaced recall in addition to the slow and faster rates of presentation and recall. The results show a decline in recall with increasing mean time in store in paced recall. Unpaced recall was superior to paced recall at all rates. This seems to indicate that when rehearsal is controlled by pacing both stimuli and responses, recall is a function of mean delay between stimulus and response; this supports the decay theory. These results have been confirmed by Conrad (1958), Fraser

(1958), and Mackworth (1964a, 1964b).

But Bergstrom (1907) found a uniform decline in errors of immediate recall with increasing time intervals from .5 to 2 seconds. These results have been confirmed more recently by Guthrie (1933) and McReynolds and Acker (1959) using a different technique. Pollack (1952) presented mixtures of digits and consonants at intervals ranging from .31 to 4 seconds. He found a decrease in recall with reduction of interstimulus interval. The same general relationship was found in another study (Pollack, Johnson, and Knaff, 1959) with a different technique. In this experiment 25 to 40 digits were presented in a running memory span design at intervals of .25, .5, 1 and 2 seconds. The Ss were either informed or not informed of the series-length, but were required to recall as many successive adjacent digits as they could ending with the terminal point. The results show a higher recall at the slower speeds than at the faster speeds. Differences between groups informed and uninformed about the series-length were reduced as the rate of presentation increased. Mackworth (1962a) varied the rate of presentation (from 1/4 to 2 seconds) of 8-digit or 9-digit messages in a visual presentation and found an improvement in recall with slower presentations. The results do not support the decay theory. In another study (Mackworth, 1962b), she varied the duration and length of digit-lists in a simultaneous or successive visual presentation. Results show an increase in recall with the increase of message duration and length in the simultaneous presentation. This goes against the decay hypothesis. But the block display at 1/2-second/digit was significantly better than single digit display at 1-second/digit. This could, however, be interpreted as supporting the decay theory of immediate memory .

Mackworth (1964b) and Posner (1963, 1964) have attempted to account for these conflicting results. Mackworth suggests that presentation modality could be a crucial factor. Studies showing decreased recall with decreased rate have used aural presentation, while visual presentation has been used in most experiments showing opposite results. Posner (1963) suggests that slower rate allows S more time to perceive, organize, and rehearse the material, and it results in increased recall in many situations. However, when organizing ability is restricted by time factor and nature of the material, increasing the rate of presentation decreases the time in store and results in increased recall. Posner (1964) presented a series of eight digits aurally at two rates. He found that recall was more accurate at the fast than at the slow presentation when recall was ordered. If Ss were instructed to recall the last four digits before giving the first four digits, recall improved at the slow rate, but remained the same at the fast rate. Posner (1964) suggests that this higher recall at the slow rate might have resulted from more efficient rehearsal strategies and organizational factors.

Recent findings with varying rates and modality of presentation do not support the decay theory (Corballis, 1966a, 1966b). Corballis (1966a) varied both the between- and within-series speed in a digit span experiment. Recall was better with slower rather than with faster speeds. In another study (Corballis, 1966b) interdigit interval was either increased or decreased gradually both in visual and auditory presentations. Recall increased with increased inter-digit interval in visual presentation. This is again evidence against the decay theory. In the aural presentation, however, results did not show any consistent tendency with increase or decrease of inter-digit interval. This suggests that auditory short-term storage is more effective than visual storage, but there is little evidence within modalities to support the decay theory.

Delayed Recall and Decay in STM

Time in store is also varied by delaying the recall test after the presentation of the stimuli to be remembered. But the decay function of such a delay interval is confounded with a rehearsal factor counter-acting the decay process (Corballis, 1965; Posner, 1963, 1964). Most of the delayed recall experiments present some irrelevant materials and require S to respond to them in order to prevent rehearsal during the interval (Brown, 1958; Murdock, 1961; Peterson, 1963, 1966a; Peterson and Peterson, 1959; Pillsbury and Sylvester, 1940). Here also, the decay effect is confounded with the interference effect produced by the presentation of the irrelevant materials; and it is rather hard to isolate the decay factor as such from the interference factor in such situations (Corballis, 1965; Posner, 1963). Conflicting results are also reported in the delayed recall experiments: some are in favour of, others against the decay prediction of STM.

McLane and Hoag (1943) varied the delay from zero to 180 seconds after the presentation of six nonsense syllables. There was no interpolated task but Ss were asked not to rehearse the material during the delay interval. Recall was ordered. The results did not show any systematic decline in recall with time. Anderson (1960), however, found a decline of recall of 12 digits from 72 to 60% over a 30-second interval even when rehearsal was allowed. But a recent study (Crawford et al., 1966) confirms McLane and Hoag's (1943) results. Crawford et al. (1966) presented sequences of letters, either meaningless, or formed words, or formed sentences in content, at the rate of .7 second/letter. Retention interval varied from 1 to 10 seconds (1, 4, 7 or 10 sec.). There was no interpolated task during the retention interval. Recall did not decline with longer time intervals; rather it improved. Degree of meaningfulness affected the accuracy of recall, but there is no interaction between retention-interval effect and degree of meaningfulness. The findings are evidence against the decay theory of memory. Pillsbury and Sylvester (1940) found a decrement in recall produced by interpolated task. Ss were presented with series of six pictures, or nonsense syllables, or words. The results showed a decrement in recall scores from 24 to 43% as a function of the interpolated task. The results further show that the difficulty of the interpolated task, rather than its similarity, to the test material, is the crucial factor in producing the decrement. These results could be interpreted in support of the decay theory, since similarity of the interpolated materials does not count here. Decrement produced by the interpolated task could be due to effective control of rehearsal; the more difficult the interpolated task, the more effective is the control of rehearsal (Posner, 1963, 1964). Similar results have been found, more recently, by Brown (1958). In a test of the decay theory of immediate memory, he presented series of consonant diagrams. A number reading task was interpolated as the irrelevant stimuli. Further consonant combinations were presented as interference stimuli. The results show a poorer recall with time when rehearsal is controlled by the interpolated activity; similarity of the interpolated materials did not affect recall. Brown interprets these results as evidence for the decay factor in immediate memory. He further showed that proactive presentation of the irrelevant task makes only a slight difference, while retroactive presentation has the larger effect. Peterson and Peterson (1959) found a similar progressive decay effect with time in the recall of a single item. A single consonant trigram was presented and S counted backward in threes or fours from a specified number as the interpolated activity. Recall declined from 80% after 3 seconds to 10% after 18 seconds. The results are interpreted as a strong support of the decay theory of STM and the interpolated counting activity has been described as an effective rehearsal-preventive mechanism (Posner, 1963, 1964).

But the Peterson and Peterson experiment has also been cited in support of an interference theory of short-term memory (Keppel and Underwood, 1962; Melton, 1963). In an attempt to understand the relation between short-term and long-term memory, Peterson and Peterson required S to rehearse the trigram orally or silently before beginning the interpolated task. Recall improved as the time for oral rehearsal increased from zero to 3 seconds, but with silent rehearsal no significant improvement occurred. Similar results are reported by Conrad (1960). Seven- and eight-digit lists were used. During the 10-second period of silent rehearsal following the presentation of the list S was required to say the digit zero once for 1 second. This 1-second interruption could occur at any point during the 10-second silent rehearsal. The recall score drops down to a half due to this interruption. The silent rehearsal appears to be of no use as in the Petersons' results (1959). Thus the rehearsal explanation of Brown's (1958) and the Petersons' (1959) results does not seem to be very convincing and an interference effect by the interpolated task cannot be entirely ruled out.

Posner (1963) attempts to account for this discrepancy in terms of the amount of material to be recalled. Brown's (1958) two-letter items were better consolidated without overt rehearsal; but the Petersons' (1959) three unrelated letters needed much overt rehearsal to become significantly consolidated (Posner, 1963). A similar suggestion is also made by Murdock (1961) that the number of "chunks" (Miller, 1956) or units, rather than the number of items in the to-be-remembered materials, is the important factor in short-term retention. Murdock, (1961) repeated the Peterson and Peterson (1959) experiment with single words or three-words as the stimuli. He found results like the Petersons' (1959) experiment with three-words as the stimuli, but very little forgetting occurred in the single-word design. This supports the number-of-"chunks" hypothesis (Miller, 1956). Melton (1963) has confirmed Murdock's (1961) results with lists of consonants as stimuli, and found that the rate of forgetting was a direct function of the number of consonants (chunks) to be remembered. Melton (1963) interprets his results as a function of intra-unit interference between the chunks to be remembered. Melton's results have, however, been interpreted in terms of rehearsal during interpolated task as supporting a decay theory (Corballis, 1965). Corballis (1965) argues that "the major portion of variance (in Melton's results) is accounted for by the interaction between the number of chunks and time" (Corballis, 1965, p. 14). Further light is thrown on the rehearsal strategy in recall by Sanders (1961). He presented lists of eight digits and had his subjects group the digits into four chunks while rehearsing. The results show a significant effect of rehearsal.

Conrad (1964) presented letters visually and found acoustic confusions in recall as in auditory presentation under noisy conditions (Conrad and Hull, 1964; Conrad, Baddeley and Hull, 1966; Conrad, Freeman and Hull, 1965; Wickelgren, 1965a, 1965b, 1966a, 1966b). He checked that the errors were not perceptual. Conrad argues that the decay theory implies the existence of partially decayed memory traces yielding incorrect recalls (Brown, 1958) which are systematically, rather than randomly, related to the presented stimuli. The results are therefore consistent with the decay prediction of STM.

The difference between silent and vocal rehearsal has yet to be accounted for in interpreting the decrement in delayed recall tasks with interpolated activity (Brown, 1958; Peterson and Peterson, 1959) in terms of a decay factor in STM. Again, there is evidence against the view of rehearsal serving to prevent decay of the trace with time (Murdock, 1961; Peterson, 1963). Murdock (1961) varied the number of items in the list and the rate of presentation in a running memory task in which S had to report the first and last three words of a series of unknown length. Results show a decline in the recall of the first word with the number of interpolated items, but rate had no effect. The overall time in store did not affect the recall. This goes against the decay prediction and seems to support an interference interpretation.

Murdock (1963a) presented lists of A-B pairs, requiring S to recall the B member of a single pair, given the A member of the pair. Recall varied with the number of interpolated pairs rather than the length of time. In another study (Murdock, 1963b) lists of 6 paired-associates were presented, and either 3 pairs or all the 6 pairs were tested for recall. Recall score declined as the number of interpolated recalls increased. These results seem to support an interference rather than a decay theory of short-term memory. Peterson (1963) presented a nonsense syllable twice, at an interval varying from 1 to 11 seconds filled with counting activity. Recall was taken after a 6-second interval of counting backward following the two presentations. Results show a significant improvement in recall with increasing time between the two presentations. This is just the opposite of the decay expectation and hard to explain by a simple decay notion.

Recently, Peterson (1966a) found another phenomenon difficult to explain by the decay theory. He presented lists of five paired-associates sequentially. Recall of the items from last positions in the list decreased at first as the interpolated activity (reading numbers) lengthened, but then it increased. Earlier items tended to be recalled with greater frequency as the interval lengthened. The initial drop in recall could be interpreted as supporting the decay theory; but the reminiscence phenomenon counts as more evidence against the decay theory of STM.

In all these conflicting results, however, some ambiguity is unavoidable since there is as yet no independent criterion for determining how effectively the interpolated task prevents rehearsal, or what other detrimental effects the interpolated materials might have on recall (Corballis, 1965; Keppel, 1965). We have to wait for some clear-cut results showing all these factors properly isolated before drawing any conclusion about the role of decay in short-term memory.

Interference

The interference theory as an explanation of forgetting has its origin in McGeoch's (1932) classical attack on the Law of Disuse, although such a concept was known to Ebbinghaus (1885). More recently, according to Postman (1961) "Interference theory occupies an unchallenged position as the major significant analysis of the process of forgetting. ...the recent years have seen little debate about the basic assumptions of the interference theory" (Postman, 1961, p. 152). This statement refers mainly to long-term memory (LTM); but the theory has implication for short-term memory (STM) as well. In its refined form (Melton, 1961; Postman, 1961), the interference theory implies that even the traces resulting from single repetition are "structural" (Hebb, 1949, 1961) and permanent "except as overlaid by either the recovery of temporarily extinguished stronger competing traces or by new traces; and ...all persistent and progressive losses in the retrievability of traces are to be attributed to such associative interference factors, and not to decay or to combination of nonassociative disruption plus decay" (Melton, 1963, p. 8). In testing the decay hypothesis in STM, rehearsal is controlled by presenting some tasks during the retention interval. But such presentation of rehearsal-preventing tasks might also interfere with the normal formation of the traces. "According to decay theory such interferences should, however, be independent of the degree of similarity between the original task and the interpolated activity" (Postman, 1964, p. 158). Similarity between the original and interpolated tasks, according to the interference theory, is a crucial variable in producing forgetting both in LTM and STM (Postman, 1961).

In testing the interference theory in STM (LTM as well) similarity of the interfering materials is systematically varied; dissimilar materials are presented as a control preventing rehearsal by the subject. Experiments on interference in STM present the interfering materials sometimes before (proactive interference) and sometimes after (retroactive interference) the presentation of the test materials. Studies dealing with the interference factor in STM will accordingly by discussed under two headings: (1) retroactive interference and (2) proactive interference.

Retroactive Interference

The similarity factor in retroactive interference (RI) studies has been the most controversial issue in the debate between the decay and interference theories in short-term memory in recent years (Broadbent, 1963; Corballis, 1965; Peterson, 1963; Postman, 1964). Decrement of recall resulting from presentation of some rehearsal-preventing dissimilar materials is consistent with both decay and interference theory. Additional loss of retention due to the presentation of materials similar to the test materials is the prediction made by the interference, but denied by the decay theory. Results from the crucial tests of this prediction of the interference theory in STM are ambiguous: evidence is sometimes in favor of the interference claim, sometimes against it.

An early study (Pillsbury and Sylvester, 1940) did not find similarity of the interpolated task to reduce recall; rather the difficulty of the interpolated task reduced recall. Brown (1958) varied the similarity of the interpolated task, but did not find any similarity effect of RI in STM. More recently, Pollack (1963), using a memory span design for digits, reports a significant interference effect by interpolated digits. He found that recall significantly decreased with increasing number of interpolated items, the rate of presentation being constant; while increasing the rate, keeping the amount of materials constant, affected recall less. In fact, recall improved with slower presentation of the interpolated digits. This was interpreted by Pollack as supporting the interference theory in short-term memory. But his results do not necessarily indicate a similarity function of the interpolated task as there was no dissimilarity-control; and Ss were encouraged to rehearse whenever possible. The greater decrement of recall with increasing number of interpolated digits (rate being constant) might have been due to effective prevention of rehearsal, rather than interference. More clear-cut results showing a RI similarity effect in short-term memory are now available. Mackworth (1964a) presented digits, colors, shapes or letters for immediate recall. She found recall to be inversely related to the duration of a different kind of interpolated materials rather than the amount. But in the homogeneous messages (same kind of interpolated material), recall decreased with the length of the interpolated message. This indicates that similarity of the interpolated materials plays a signficant role in the RI effect in STM.

More positive evidence for the effect of similarity is provided by Neimark et al. (1965). Short-term retention of single high- or low-association value CVC trigrams was tested after 0, 3, 9 or 18 seconds of interpolated presentation of 3-digit numbers or high-, medium- or low-association value CVC items. High-association value CVCs were well recalled under all conditions. For low-association value items, recall declined with increasing similarity of the interpolated items. The results support the similarity prediction of the RI paradigm in STM. These results have been confirmed by Schwartz (1966). Digits, CVC trigrams, monosyllabic words, colors and forms were presented in blocks. Each added block lowered recall of the preceding block. Retroactive loss was greatest when similar materials were presented in two adjacent blocks. Similarity of the interpolated materials plays a significant role here, and the results support the interference theory in short-term memory. The similarity factor is also found to impair recall in paired-associates studies. Bruning and Schappe (1965a) individually presented single CVC paired-associates and tested after 0, 4, 8 or 16 seconds of presentation of numbers, consonants,or CVC pairs. Recall varied inversely with the similarity of test and interpolated items. A replication of the study with some modification yielded similar results (Bruning and Schappe, 1965b). These results are confirmed by Brelsford et al. (1966). Sequences of 4, 6 or 8 paired-associates were presented. Recall declined with increasing number of interpolated pairs. The results furnish evidence for significant RI effect in STM. A similarity effect on RI is found in retarded subjects (Metzger et al., 1965). In this study, retarded Ss were presented with single words and tested for recall after 16 seconds of presentation of similar words, instructed rehearsal, listening to music, or simple rest. Recall was significantly poorer in case of presentation of similar words than other conditions. The results indicate that similarity of the interpolated task decreases recall in retardates as in normals.

Somewhat different results are obtained with letter-sequences as the stimuli. Murray (1966) presented sequences of letters and varied the similarity of the interpolated materials, rate of presentation and length of stimulus lists. Results show a poorer recall with more similar interference items (rhyming letters), longer list length, and with less time available for rehearsal. But there was also significantly more decrement in recall with active calculation of the interpolated digits than when merely calling them out. The results pose problems both for decay and interference theory. The greater loss of recall under active calculation of the interpolated digits is consistent with decay theory: the active calculation prevents rehearsal more effectively. But the greater decrement of recall with more similarity of the interpolated materials is not accountable by the decay theory; interference (RI) is probably the only explanation. But the greater decrement with active calculation is inconsistent with the interference theory, unless greater task-involvement is assumed to be an interfering situation. Similar decrement of recall with greater involvement with the interpolated task is reported by Loess and McBurney (1965). They presented word triads and consonant trigrams individually and tested after 9 seconds of interpolated task, either active (subtraction) or passive (saying digits). Recall was best without the interpolated task; but poorest recall was found in the active interpolated condition. The results, while consistent with the decay theory, do not support the interference theory, unless task-involvement is considered as interfering. But the study found some evidence for interference by similarity of the interpolated materials. Recall was worse in a letter-interpolated condition than digit-interpolated conditions. This supports the interference theory (RI). The relation between task-involvement and recall in the results of Murray and Loess and McBurney has been confirmed by Bruning et al. (1966) with a paired-associate method. Low-association value CVC paired-associates were presented and tested after 7.5 seconds of different kinds of interpolated tasks (active or passive). The interpolated task was multiplication of 2-digit numbers by 1-digit numbers. In the active condition Ss worked out the solutions, and in the passive condition the solutions were given; Ss merely recited them. Recall was poorer when the interpolated task was active. The degree of involvement in the interpolated activity seems to be an interfering conditon, unless it is explained as a decay situation with effective prevention of rehearsal. Probably along the same line, an interference effect of a mere expectancy of a brief interpolated task (without any apparent interpolated activity) is reported by Polyshyn (1965). Retention test of a 8-letter display was taken after 15.5 seconds. A brief interpolated event (choice reaction time for 1 second) occurred at different points (0.5, 1.5, 4.5 or 13.5 seconds) of the retention interval. In the control condition (without interpolated event) an expectancy for the interpolated task was maintained. There was not much difference in recall between the interpolated and noninterpolated conditions. This indicates that expectancy has an interference effect. Among the interpolated conditions, the drop in recall was the largest when the interpolated event occurred immediately after the presentation of the stimulus display. This suggests that consolidation of STM trace is an important factor to be taken into account. It also implies that retention is not a mere function of time; rather the events taking place between the stimulus presentation and recall are important variables determining the retention score. The results are inconsistent with both decay and interference theories in their present forms. The largest drop in recall following the immediate occurrence of the interpolated event is not quite consistent with the rehearsal prevention hypothesis of the decay theory, because the subjects can very well rehearse during the rest of the interval. Likewise, the similarity hypothesis of the retroactive interference theory is not consistent with the results of this study, since interpolation of a dissimilar task (or mere expectancy of it) impairs recall. But the overall decrement in recall was not very large in comparison to Conrad's (1960) results; and Polyshyn explains this as due to dissimilarity of the interpolated materials.

The acoustic and semantic similarity of the interpolated materials are also found to produce a RI effect in STM. Wickelgren (1965b) auditorily presented sequences of 4 letters and tested after interpolation of 8 acoustically similar or dissimilar letters. Ss copied both the stimulus and interpolated letters. Recall was poorer with acoustically similar than dissimilar letters interpolated. Results indicate that acoustic similarity of the interpolated materials is more interfering than acoustic dissimilarity. The similarity hypothesis of the RI theory of STM (as in LTM) is supported by the results. But the similarity factor carried to a high degree actually facilitates recall, rather than hindering it. Wickegren found that when identical letters are presented (in a different order) in the interpolated situation, RI is less in the recall of items but more in the recall of serial positions. These results have been confirmed by later studies with single consonants and consonant sequences as stimuli (Conrad, Baddeley and Hull, 1966; Wickelgren, 1966b). Baddeley (1966) compared the acoustic and semantic similarity of the interpolated materials in the RI effect in STM. He presented sequences of five words, acoustically similar or dissimilar, or semantically similar or dissimilar (adjectives with similar or different meanings). Both acoustic and semantic similarity significantly decreased recall; but acoustic similarity has the larger effect. The acoustic similarity effect was confirmed in a visual presentation, but the semantic similarity was not. The results lend support to the similarity hypothesis of RI effect in STM in its acoustic sense, and, to some extent, in its semantic sense also.

A different kind of interference effect (input and output interference) is reported by Tulving and Arbuckle (1966). They presented a single paired-associate item in a fixed position in a series of similar pairs, and tested for recall after various interpolated pairs (inputs) or recalls (outputs). Recall of the critical item was higher following the interpolated recall of two items than following interpolated presentation of two pairs. The results confirm an earlier study (Tulving and Arbuckle, 1963) and indicate that input interference is greater than output interference in STM. These results do not readily fit in the interference or decay models in their present forms. The time interval for both the interpolated presentation and recall is the same, and rehearsal is equally prevented in both the situations (perhaps more effectively under interpolated recall); the difference in recall of the critical item cannot be attributed to decay. The interference theory with its similarity hypothesis also cannot account for the difference, since the similarity variable in both the situations is more or less constant. Greater interference by interpolated information processing than retrieving previously stored information is perhaps the explanation for the results; and in that sense it could probably fit in the RI model of STM.

The evidence so far seems to be stronger in support of the similarity hypothesis in the retroactive interference theory of short-term memory. But there is evidence that the similarity variable, in its semantic sense at least, is not a crucial factor in the RI effect in STM. Baddeley and Dale (1966) compared the semantic similarity effect on retroactive interference in LTM and STM with paired-associates tests. In a classical RI experiment on LTM with paired-associates, recall was found to be a decreasing function of semantic similarity of the interpolated pairs; but semantic similarity did not affect recall in the STM test. In the STM test, sequences of three pairs of adjectives were presented and the first two pairs were tested immediately after the presentation, the third being the interpolated pair. Similarity or dissimilarity of the interpolated pair did not affect recall. In another experiment of the series, increasing list-length (2, 4 or 6 pairs) was used, but no evidence for RI effect in STM was found. The results show that semantic similarity has no RI effect in STM, although it has significant RI in LTM. The continuum hypothesis of LTM and STM is questioned by the results and a dichotomy is favored. Posner and Konick (1966) varied the intraseries and interseries item-similarity and the difficulty of the interpolated task. Within-series item-similarity and time in store were found to impair retention more than similarity and difficulty of the interpolated tasks. The results indicate that inter-item interference of the stored materials is greater than interference of the interpolated task. Similarity affects recall; but not the similarity of the interpolated task, rather similarity between the stored items produces the decrement. The results question the role of similarity in the RI effect in STM.

This negative evidence (Baddeley and Dale, 1966; Brown, 1958; Posner and Konick, 1966) cannot be neglected and has to be accounted for before drawing any conclusion regarding the similarity hypothesis of retroactive interference in short-term memory.

Proactive Interference

In the proactive situation, the interfering materials are presented before the presentation of the test materials, and recall is usually taken without any further interpolated task, although some interpolated tasks are occasionally used. The similarity variable is stressed in proactive interference (PI) effect as well, and similarity of the proactively presented interfering items is systematically varied in PI studies. Experiments with positive PI effect are quite numerous; but negative evidence is not lacking.

Keppel and Underwood (1962) demonstrated the PI effect of the number of previous trials with similar items in an essentially RI study of STM. Single consonant trigrams were individually presented and tested for recall after 3, 9 and 18 seconds of interpolated task of counting backward by threes. Recall declined with increasing number of previous trials. Keppel and Underwood varied the degree of initial learning and the number of prior items in a single list, and found that forgetting increased as a function of the number of previous items presented. The results are interpreted in terms of PI effect in STM as in LTM. Proactive inhibition mounts up as practice with similar materials continues.

Wickens et al. (1963) presented single consonant trigrams or 3-digit numbers after various amounts of prior practice with similar or different kinds of materials. Test of the critical item was taken after 11 seconds of interpolated color-naming task. Recall of the critical item decreased with increasing prior practice with similar materials; prior practice with dissimilar materials did not affect recall. The results show a significant similarity-function in the PI effect in STM, and confirm the Keppel and Underwood results. These results (Wickens et al., 1963) have been recently confirmed by Hofer (1965) with similar techniques using both consonant trigrams and word-triads. Loess (1964) reported similar PI effect in STM with increasing prior practice with similar materials. Twelve consonant trigrams were individually presented and tested after 9, 18 and 27 seconds of interpolated counting backward by threes. Recall declined with increasing number of prior items. The results indicate PI effect in STM, and confirm the Keppel and Underwood study. In another experiment, Loess presented consonant trigrams individually and tested after 3, 9 or 18 seconds of counting activity. Ss took two more sessions (each three weeks apart) with additional materials. The results show a significant

PI effect as a function of the number of prior trials with similar materials. Loess concludes that PI operates both in LTM and STM in the same fashion. He further suggests that much of the forgetting resulting from the Peterson and Peterson (1959) method is probably due to proactive inhibition from prior trials.

Although most of the PI studies reported positive evidence for PI effect in STM, some experiments reported negative results. Murdock (1964) presented lists of six paired-associates (common English words) and tested at 1-3 serial positions at 6-10 seconds of retention interval. The results do not show any significant decrement in recall as a function of stage of practice, and there is no evidence for PI effect in STM. Conrad and Hull (1966) sequentially presented series of 4 letters (consonants) and tested for ordered recall after slow or fast presentation of a fixed number of interpolated digits. Although recall errors decreased significantly with slower presentation of interpolated digits (greater rehearsal), the results do not show any significant PI effect from previous trials (serial position intrusion). In fact, the serial position intrusion decreased with increase of retention interval: just the opposite of Keppel and Underwood PI prediction of increasing recovery of previous associations (more PI) with time. Similar negative results are reported by Peterson and Gentile (1965) with CVC items. Individual CVC trigrams were presented in 6 blocks of 6 tests each with 5 or 16 seconds of within-block (between tests) and 91 seconds of between-block intervals. Recall was taken (in each test) after 0, 3 or 9 seconds of counting backward by threes. Recall was better with longer (16 seconds) intertest interval; intrusions were smaller. This lack of proactive intrusions implies forgetting of the previous items probably due to RI by later items. But the same RI effect should work as PI for the subsequent lists. The results suggest that RI effect is the stronger of the two interference situations (RI and PI). However, the lack of intrusions,and hence of PI, questions the PI hypothesis in STM and raises doubt about the results of Keppel and Underwood (1962) and Loess (1964); and this challenge has to be answered before drawing any conclusion about the PI effect in short-term memory.

Comparison between Proactive and Retroactive Interference

Before concluding the discussion on retroactive and proactive interference in short-term memory, some comparions between PI and RI effects in STM is in order. Tulving and Thornton (1959) presented lists of 16 dissyllabic English words. The learning of each list was preceded and followed by learning of other comparable lists. Ss recalled as many words as they could after 10 minutes of interpolated activity (Shipley-Hartford Abstraction Test). The results show that the number of prior lists (PI) did not affect recall, while the increasing number of subsequent lists significantly decreased recall (RI). This indicates that RI is significant in STM, PI is not. But a recent comparison between RI and PI yields opposite results (Goggin, 1966). Two lists of paired-associates, each of 2 pairs of CVC trigrams and words, were serially presented and tested after 6, 22 or 40 seconds of number-reading task. While there was neither PI nor RI with positive transfer, PI was greater than RI with negative transfer. However, more light is shed on the relative strength of PI and RI in STM by Wickelgren (1966b), using single consonants as stimuli. Acoustically similar consonants were aurally presented. Subjects copied a list of PI letters, then copied a single critical letter, and then copied a RI list of letters; and recall of the critical item followed. The length and phonemic similarity of the PI and RI lists were varied. Both PI and RI effects were significant and increased with increasing phonemic similarity. RI increased with increasing list-length, but PI did not increase beyond 4 letters. This could be explained by assuming that decay is confounded with RI, but PI is a pure associative interference situation. This contention is supported by the fact that both PI and RI increase with phonemic similarity. This demonstrates significant proactive and retroactive interference in short-term memory. The results are interpreted by Wickelgren to be consistent with parallel PI and RI effects in LTM.

To summarize, the positive evidence for the similarity effect in both PI and RI in short-term recall is greater. But the negative results have to be adequately accounted for before drawing any conclusion about the role of interference in short-term memory and in resolving the controversy between the decay and interference theories in short-term memory.

Recognition Memory

Comparison between Recall and Recognition

Recognition has consistently been found to yield higher scores than all forms of recall (Brown, 1965; Hollingworth, 1913; Luh, 1922; Postman, Jenkins and Postman, 1948; Postman and Rau, 1957). The superiority of recognition over recall has recently been challenged by Davis, Sutherland and Judd (1961). They argue that this apparent superiority of recognition over recall is because of a smaller number of alternatives to choose from in the conventional recognition task (multiple-choice) than in recall. If the number of possible alternatives is made equal in both recall and recognition, much of the difference between them would disappear. In a test of this hypothesis, they presented lists of 15 two-digit numbers and 15 two-letter syllables once, and then asked the Ss to recall or recognize the items presented. Recognition was taken out of a list of 30, 60 or 90 alternatives; recall was from an ensemble of 90 possible alternatives. The results show that the amount of information transmitted in the recognition conditions tended to increase as the number of alternatives increased. Performance scores, transformed into information measures, show that as much information was transmitted in recall as in recognition. Davis et al. concluded that the superiority of recognition over recall, normally found, is mainly due to larger number of alternatives to choose from in recall than in recognition. When the number of alternatives is equal, recognition is no better than recall. The recognition score depends not only on the number, but also on the nature of the alternatives used. Dale and Baddeley (1962) presented 15 two-digit numbers between 10 and 100 to 100 Ss at the rate of 5 seconds per item. Ss wrote down as many numbers as they remembered. Two sets of 15 two-digit numbers were then constructed from the errors of intrusions; one set consisted of the most frequent, and the other of the least frequent intrusions. These two sets of numbers were then used as incorrect alternatives in two recognition tests. The original 15 test-items were presented to two groups of fresh subjects. One group took the recognition test with frequent intrusions and the other group with infrequent intrusions as the incorrect alternatives. The recognition score for the rare intrusion group was significantly higher than the frequent intrusion group. The difference between the original recall score and the recognition score with frequent intrusions was very small. Dale and Baddeley conclude that recognition memory largely depends on the identification of certain characteristics of the items. When the incorrect alternatives possess similar characteristics (frequent intrusions), recognition ability declines; and much of the difference between recall and recognition disappears.

Scores on recall and recognition depend also on the memorizing strategy used by the subject. Eagle and Leiter (1964) compared recall and recognition of 36 words presented in three different ways. One group was instructed to remember the words (intentional); a second group was only required to respond to each word by indicating whether it was a noun, or verb, or adjective (incidental); and the third group had to both remember the words and perform the orienting task. Recall was better in the first group (intentional), but recognition was better in the other two groups. The superior recall of the intentional group is mainly due to use of a memorizing strategy (e.g., grouping, rehearsing etc.). The results indicate that recall and recognition require somewhat different learning operations. Recall requires organization and rehearsal, while recognition requires responding to the features and characteristics of the items.

Lachman and Field (1965) show that recognition is superior to recall only at the early stage of learning; with increasing degree of training much of the difference disappears. Independent groups of Ss received 1, 2, 4, 8, 16, 32, and 128 presentations of a 50-word sequential list with close approximation to English prose. The recall group wrote down as many words as they remembered. In the recognition test, the test-items were randomly mixed up with another 50 new words of the same order of approximation. The results show that recognition is superior to recall only at the initial stage of learning. Following trial 8, recall is uniformly superior to recognition. Recognition errors decline rapidly after the first trial. The authors take this to indicate that recognition consists in eliminating the incorrect alternatives in a multiple-choice test. Lachman and Field assume this as the cause of the apparent superiority of recognition over recall. It may be noted here that recognition of incorrect alternatives implies a corresponding recognition of the correct alternatives. However, somewhat different results are reported by Lachman, Laughery and Field (1966) had to both remember the words and perform the orienting task. Recall was better in the first group (intentional), but recognition was better in the other two groups. The superior recall of the intentional group is mainly due to use of a memorizing strategy (e.g., grouping, rehearsing etc.). The results indicate that recall and recognition require somewhat different learning operations. Recall requires organization and rehearsal, while recognition requires responding to the features and characteristics of the items.

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A depressing effect of recall on recognition was reported by Postman, Jenkins and Postman (1948). In a nonsense syllable experiment, recognition was found to be poorer after recall than before recall. Recall after recognition, however, was found to be superior to recall before recognition. Recently, Hanawalt and Tarr (1961) show that recall has no depressing effect on recognition; rather it facilitates recognition. Lists of statements ending in adjective-words were presented for a true-false test in an incidental learning situation. The terminal adjectives were tested for recall and multiple-choice recognition. Recognition was taken immediately following recall and 48 or 52 hours after recall. The recall groups produced higher mean-recognition scores than the nonrecall groups. There is no evidence of a depressing effect of recall upon recognition in the results. In the delayed recognition groups there was of ` urse a facilitation effect of recall upon recognition. These results are confirmed by Brown (1965), In a "missing scan" experiment recognition was found to improve after several attempts at recall. The results show an overall superiority of recognition over recall, either before or after recall.

Partial-learning Model of Recognition

McNulty (1965a) compared different measures of retention (serial anticipation, reconstruction, unaided recall and recognition) and found recognition to yield the highest score. He explained this apparent superiority of recognition as an artifact of the learning operation. He argued that recognition does not require learning of the complete items or their serial order. Only some partial characteristics or features of the items are to be learned for correct identification in a recognition test. But all forms of recall require a complete learning of the whole items to be correctly recalled. Comparison of recall and recognition is therefore pointless. Such a partial-learning characteristic of recognition memory was also indicated by Dale and Baddeley (1962) and Lachman and Field (1965). This partial-learning nature of recognition process has been further analyzed and confirmed by restricting the opportunities for partial-learning in the recognition test (McNulty, 1965b). Lists of items of there different orders of approximation to English (first, third and text order) were presented. Retention was tested after each presentation either by recall, or standard recognition, or restricted recognition. An equal number of new items from the same order of approximation was mixed up with the old items in the standard recognition test. In order to limit the effectiveness of partial-learning, the restricted recognition test contained incorrect alternatives differing from the original items in only one letter (structural partial-learning). The difference in retention score between restricted recognition and recall was much smaller than between recall and standard recognition. The results show that when opportunities for partial learning to be used in recognition were restricted, much of the difference between recall and recognition disappeared. The results support a partial-learning model of recognition memory.

The remaining difference between recall and recognition after elimination of partial learning probability (McNulty, 1965b) was further suggested by McNulty (1966) to be due to a mediational association aroused by the stimulus items. In spite of the structural similarity between correct and incorrect alternatives, the correct items may be recognized if their mediational associations differ from that of the incorrect alternatives. This associative-type of partial-learning was found to account for some of the difference between recall and recognition. In one experiment the restricted recognition test contained incorrect alternatives similar in meaning to the original words. The assumption was that the incorrect alternatives with similar meaning would tend to arouse the same associations, and it would be hard to identify the correct item on the basis of the associative-type of partial-learning. Some of the difference between recall and recognition again disappeared; but the difference between standard and restricted recognition was small. This could be due to greater effectiveness of structural-type of partial-learning than associative-type; and the structural type of partial-learning was not varied in this experiment. Accordinly, another experiment of the study was designed to vary both structural- and associative-type of partial-learning simultaneously. Eight-letter sequences of first order of approximation to English were used as stimuli. The structural similarity between correct and incorrect alternatives was obtained by having them differ only in one letter. To provide common mediational association to the correct and incorrect alternatives, paired-associate training was given to all the alternatives with the same meaningful words. Stimulus items of the paired-associate lists were tested for recognition in four different ways: (1) standard recognition (alternatives differ both in structure and association), (2) restricted recognition--structure (correct and incorrect alternatives differ in only one letter), (3) restricted recognition--association (alternatives have common mediational association), and (4) restricted recognition--structure and association (alternatives have both similar structure and common mediational association). A control group was given the recall test. The results show that the difference between recall and recognition was less when structural-type of patial-learning was controlled than associative-type. But when both the structural- and associative-type of partial learning were restricted simultaneously, the difference between recall and recognition was insignificant. These results were interpreted by McNulty as supporting a partial-learning model of recognition memory. A similar suggestion of partial learning in recognition memory was made by Postman, Jenkins and Postman (1948). Postman et al. analyzed the recognition errors (false positives) and found that items with one or two common letters were more often chosen than items with completely different letters. They concluded that some partial features are still remembered even when the whole item is not recognized.

Whatever the nature of recognition memory, we might wonder whether this trend of superiority of recognition over recall is applicable to short-term memory as well. And the same controversy between decay and interference theories could be raised for short-term recognition memory also. Short-term recognition memory (STRM) has not been so extensively studied; nevertheless, some data are available.

Short-term Recognition Memory

Korn and Jahnke (1962) made a comparison between recall and recognition in short-term memory for digits, consonants and nonsense syllables of high and low association values. Immediate memory of these materials was measured first by recall, and then by recognition for half of the Ss. This procedure was reversed for the other half of the Ss. Recognition scores were higher than recall scores. Recognition span and recall span were most similar for digits and progressively less similar for consonants, high- and low-association value nonsense syllables. The results indicate that a similar relationship holds between recall and recognition in short-term memory as in long-term memory.

The decay characteristic of short-term recognition memory for 3-digit numbers was studied by Wickelgren and Norman (1966). Lists of two to seven items were presented at the rate of one item per second. Every serial position was tested. A single 3-digit number was presented in the recognition test. The Ss had to say "yes" or "no" indicating whether the item was included in the stimulus list. Ss rated their confidence in the decision on a 5-point scale. The results show that STRM decays exponentially with the number of subsequently presented items. Similar results are reported by Wickelgren (1967) in a study of short-term recognition memory for serial order. A series of 12 digits was presented in each trial. A pair of digits was presented in the recognition test in which S made a "yes--no" decision regarding whether the response item of the test pair was an immediate successor of the stimulus item in the list just presented. The Ss made a confidence judgment of their decision on a 4-point scale. The results show a significant decay in STRM for serial order. Wickelgren interprets this decay to be exponential in nature. The rate of decay in STRM for serial order is found to be quite similar to that obtained in STRM for items (Wickelgren and Norman, 1966). This suggests that both item memory and serial-order memory are performed by the same memory system: inter- or intra-item association.

Retroactive interference in short-term recognition memory operates in the same way as it does in short-term recall memory. Wickelgren (1966a) found that phonemic similarity of the interpolated materials produces the RI effect in STRM as in STM. A single letter was presented, followed by twelve acoustically similar or dissimilar letters (sequential presentation). Then a single letter was presented for recognition test. The subjects responded "yes" or "no" to the test item indicating whether it was identical with or different from the original stimulus item. Ss rated their confidence in the judgment on a 5-point scale. Recognition was poorer when interpolated letters were acoustically similar to the stimulus item. The results support the similarity function of the RI hypothesis in short-term recognition memory. This suggests that RI operates in recall and recognition memory in the same way. An analysis of the recognition errors further confirms this suggestion. False recognitions are analogous to intrusions in recall studies, viz., they tend to be acoustically similar to the correct items (Conrad, 1964; Wickelgren, 1965a, 1965b). A similar RI effect is observed in STRM for pitch (Wickelgren, 1966c). Ss listened to a standard tone, followed by an interference tone. Then a comparison tone was presented for 2 seconds, following which Ss decided whether the standard and comparison tones were same or different. Ss rated their confidence on a 5-point scale. The results show that recognition of the standard tone becomes poorer when the interval between the standard and comparison tones is filled with an interference tone, and the duration of the interference tone is inversely related to the recognition score. This supports an RI interpretation of short-term recognition memory.

As in short-term recall memory, the controversy between decay and interference in short-term recognition memory also has to be left unresolved. The evidence for retroactive interference in STRM is greater; but the decay effect is also observed (Wickelgren, 1967; Wickelgren and Norman, 1966). Further evidence is required before drawing any conclusion about the controversy.

On the other hand, persistence of short-term recognition memory after long delay and considerable amount of intervening materials is another phenomenon to be explained by a memory theory. Shephard and Teghtsoonian (1961) found recognition to be above-chance after as many as 60 interpolated presentations. A large sequence of 3-digit numbers was presented. Each number occurred twice in the sequence after varying intervening numbers. Subjects responded to each number as "old" or "new" indicating whether or not they saw the number before. Ss proceeded at their own speed (but were not allowed to look back on any item), and the delay between presentation and test of each item was operationally defined in terms of the number of intervening items. The percentage of correct responses dropped from 100% at zero delay to 56% after 60 intervening presentations. But even after such long delays correct recognition was well above false recognition (recognition errors). This indicates a resistence of recognition memory to decay or interference. Similar results are reported by Shephard and Chang (1963). A sequence of 3-digit numbers was presented. Two 3-digit numbers, one old and one new, were paired on each of the recognition-tests trials. Subjects were to indiiate which of the two numbers they saw before. The results show that the number of correct choices decreased with increasing delay since the earlier presentation of the old number. Similarity between the two numbers of the test pairs impaired recognition score. This interference effect was smaller than the corresponding decay effect. But the accuracy of recognition was well above chance-level even after 50 intervening choices. This again suggests a persistence of recognition memory after massive interference (RI and PI) and long delay. These results pose a problem for both decay and interference theories of short-term memory.

Persistence of recognition memory is also reported by Schwartz and Perkins (1966). They presented a series of twenty-five 3-digit numbers or random combinations of typewriter symbols (3 at a time) for recognition test. Two items, one new and one old, were presented in the test sequence. Subjects indicated the old item in each pair and studied the new item for a subsequent test. While recognition was better at shorter intervals, both numbers and symbols were recognized with above-chance accuracy after as many as 50 intervening responses, although chance-accuracy on the symbols after a few intervening items was expected. This persistence of recognition memory cannot be explained by either of the theories, decay or interference. But another experiment of the series shows that introduction of two common elements in 50% of the items (symbols) reduces recognition to a chance-level. This supports an interference hypothesis in short-term recognition memory. On the other hand, common elements in a fraction of the new items (less interference) facilitates recognition of the old items. This is probably due to a sharp contrast between the old and new items. Schwartz and Perkins conclude that interference is the stronger factor than decay in short-term recognition memory as in short-term recall.

However, the persistence of short-term recognition memory after long delay and considerable interference demonstrated by Shephard and Teghtsoonian (1961), Shephard and Chang (1963), and Schwartz and Perkins

(1966) is still a problem for both decay and interference theory of short-term memory. This has to be adequately explained before offering a good theory of memory, short- or long-term.

The Present Investigation

This investigation was designed to compare the decay and interference processes in short-term recognition memory for visually presented stimuli. A decay situation was arranged by introducing a delay between presentation and test without any interpolated task. The interference condition used interpolated tasks of a similar nature between presentation and test. Dissimilar materials were interpolated as a control for decay in order to prevent rehearsal during the intervening period between presentation and test.

Seven experiments are reported. Presentation of the stimuli was sequential in all the experiments. The recognition test in the first two experiments was a binary-choice type: the correct and incorrect alternatives being sequentially presented in a random order. A multiple-choice type of recognition test was used in Experiment III. The correct and incorrect alternatives were presented together in a random arrangement. Experiments IV to VII used a 3-alternative forced-choice test for each stimulus item sequentially presented.

The experimental paradigm was to test 6 independent groups of subjects in each experiment (except Exps. VI and VII). Group I was tested immediately after the presentation of the stimuli in order to assess the extent of short-term recognition memory without any decay or interference (decay resulting from the time taken by the presentation and test and the interitem interference were assumed to be common in all cases). This group also served as a control for both decay and interference. Group 2 took the recognition test after an unfilled delay interval following the stimulus presentation (a decay situation with rehearsal allowed). Group 3 was presented with a series of dissimilar items (apparently to be tested) in order to prevent rehearsal during the intervening period between presentation and test. This group also served as "dissimilarity control" for "similarity-interference" group (Group 4). Group 4 received two series of similar items but was tested for the first series only. Ss were given the impression that all the materials would be tested. This group was assumed to be the retroactive interference (RI) group. Group 5 was the opposite of Group 4: a proactive interference (PI) situation; recognition test was taken for the second series of items. Group 6 was the "dissimilarity control" group for PI; the first series was the dissimilar items, the second series being the test stimuli. It was hoped that the relative importance of decay and interference processes as cause of forgetting in short-term recognition memory could be determined by a cross-comparison of the performance of these different groups.

The different experiments varied the nature of the recognition test, the rate of presentation, the duration of the delay interval, and the amount of interpolated materials. The mean-recognition scores (corrected for guessing wherever appropriate) were used as measures of short-term retention in different conditions.

THE EXPERIMENTS

Experiment I

This was an exploratory experiment designed to develop a technique to study the operation of decay and interference processes in short-term recognition memory.

Method

Subjects

Sixty paid subjects (27 male and 33 female) participated in the experiment. They were divided into 6 groups of 10 Ss each. The Ss were college or high school students between 16 and 22 years old.

Apparatus and Materials

Ten low-association value (0 to 20%) nonsense syllables (Hilgard, 1951) constituted the stimulus items. Another set of similar (common initial letter) low-association value (0 to 20%) nonsense syllables was used as the interference items. Ten 3-digit numbers, selected from a table of random numbers, were the dissimilar rehearsal-preventing items. Thirty new (0 to 20%) nonsense syllables were randomly mixed up with the stimulus and interference items to form a sequence of fifty alternatives in the binary-choice recognition test. All items were sequentially presented by a slide projector onto a white screen. Each item occurred on a separate slide (black on white). The rate of presentation was controlled by a Lafayette electronic timer connected with the projector. The distance between S and the screen was 10 feet; and the projected size of the letters or digits was 2 1/2 X 2 1/2 inches.

Procedure

The test consisted of two parts, a presentation part and a recognition part. All Ss were individually tested. They were told that the experiment was a recognition-memory test. Ss were instructed to say the letters or digits of the items in the presentation part. The recognition part required them to respond "yes" or "no" to each of the alternatives indicating whether they saw the item in the presentation series. Subjects were instructed not to count the number of yeses or noes, and nothing was said about guessing. As a result, the number of yeses or noes for any subject was unrestricted (within the limit of fifty). E recorded S's responses on a sheet containing the alternatives arranged in the same order. Any missed item was considered as an error. The rate of presentation for all items was 3 seconds/item with an interval of 1 second between items.

Six groups of subjects received six different treatment conditions as outlined below.

Group 1: This group took the recognition test immediately after the presentation of the stimuli. The termination of the stimuli was marked by a blank flash on the screen. A question mark (?) appeared on the screen to signal the beginning of the recognition test.

Group 2: The recognition test was taken after a delay of 40 seconds following the presentation of the stimuli. The projector was turned off during the delay interval and Ss rested. There was no specific instruction about the rest interval. S's rehearsal was therefore uncontrolled. After the delay, S was given a ready signal and the projector was turned on. The test signal (?) appeared and the recognition test followed in the same way.

Group 3: Two sequences of stimuli were presented; the nonsense syllables were followed by a number series. The two series were separated by a blank flash on the screen. Ss were told that either the nonsense syllables or the numbers would be tested, depending on whether they saw the symbol ?L or ?D before the recognition test. The test was of course always on the nonsense syllable series.

Group 4: Two series of similar nonsense syllables were presented with the instruction that either first or second series would be tested, depending on whether the test symbol ?I or ?II appeared. The test was always on the first series.

The duration of the interpolated task in both Group 3 and Group 4 was 40 seconds.

Group 5: This group was just the opposite of Group 4. Subjects received the same instruction as in Group 4, but the test stimuli occurred in the second series; and the second series was always tested.

Group 6: The number series was presented first followed by the nonsense syllable series. Ss were told that either of the series would be tested; but the test was always on the second series (nonsense syllables).

Results

The number correct (out of ten) was taken to be the recognition score. Since the "yes-no" choice was out of 50 alternatives, individual differences in recognition-error was quite large. The following formula was derived for the correction for guessing in the recognition scores.

Assume that S actually recognizes x items and randomly guesses another y items.

He guesses then from a pool of $50 - x$

Expected number of <u>correct</u> guesses $= \dfrac{10 - x}{50 - x} \cdot y$

Expected number of <u>incorrect</u> guesses $= \dfrac{40}{50 - x} \cdot y$

$$\therefore \quad x + \frac{10 - x}{50 - x} \cdot y = R \text{ (number right)}$$

$$\frac{40}{50 - x} \cdot y = W \text{ (number wrong)}$$

Solving for x:

$$x + \frac{10 - x}{50 - x} \times \frac{50 - x}{40} \cdot W = R$$

$$\therefore \quad x + \frac{10 - x}{40} \cdot W = R$$

$$\therefore \quad x - \frac{Wx}{40} = R - \frac{W}{4}$$

$$\therefore \quad x = \frac{4R - W}{4} \times \frac{40}{40 - W}$$

$$\text{or} \quad x = \frac{40R - 10W}{40 - W} \quad \text{(formula used)}$$

The mean and standard deviation of the corrected scores for the different groups are presented in Table I (a). A one-way analysis of variance was carried out on the corrected scores. The F ratio (7.05; df: 5, 54) is highly significant ($p<.001$). A summary of the analysis of variance appears in Table A of the Appendix. Following the analysis of variance, Duncan's New Multiple Range Test (Edwards, 1960) was used for individual comparison of the group-means. Table I (b) summarizes the comparison. The comparison shows that performance in the similarity PI group (Group 5) is significantly poorer than all other groups, except similarity RI (Group 4). Recognition in the similarity RI group (Group 4) is significantly poorer than its "dissimilarity control" group (Group 3) and the delay group (Group 2). The difference between the dissimilarity PI group (Group 6) and the delay group (Group 2) also turns out to be significant. This shows a PI effect even with dissimilar items. The difference between the immediate-test and delayed-test groups was not significant; nor was the delayed (rehearsal allowed) group significantly different from the dissimilar interpolation (rehearsal prevented) group. This indicates that neither decay nor rehearsal seems to have any significant effect on short-term recognition memory. Only the similarity-interference (retroactive and proactive) factor seems to significantly decrease STRM.

As the items of the interference series were included among the recognition alternatives, a discrimination of the list-membership of each

Table I (a)

Group Means and Standard Deviations of the Recognition Scores (Corrected for Guessing): Experiment I

Group	Mean	Standard Deviation
1: Immediate	6.26	1.94
2: Delay	7.10	1.62
3: Dissimilar RI	7.72	1.51
4: Similar RI	4.82	2.21
5: Similar PI	3.10	1.89
6: Dissimilar PI	5.56	2.06

Table I (b)

Multiple Comparison of Group Means by Duncan's

New Multiple Range Test: Experiment I

Group	1	2	3	4	5	6
1: Immediate						
2: Delay						$p<.05$
3: Dissimilar RI						$p<.05$
4: Similar RI		$p<.05$	$p<.01$			
5: Similar PI	$p<.01$	$p<.01$	$p<.01$			$p<.05$
6: Dissimilar PI						

Table I (c)

Mean Errors of Recognition from the Interference and New Items of the Recognition Alternatives: Experiment I

Group	Interference Items	New Items
1: Immediate	6.30	6.30
2: Delay	3.30	3.80
3: Dissimilar RI	5.70	6.10
4: Similar RI	11.10	5.50
5: Similar PI	11.10	6.10
6: Dissimilar PI	5.70	5.90

item was required for its correct recognition. An analysis of the recognition errors was therefore carried out in order to determine whether the interference items were more frequently chosen than the new items. The mean number of items chosen from the interference and new series by different groups is presented in Table I (c). As the number of new items among the recognition alternatives was three times larger than the interference items, the error-scores from the interference items were multiplied by three to equate the probability of choice of items from both categories (interference and new) of incorrect alternatives. A two-way analysis of variance for repeated measures (interference items and new items) was carried out on the error-scores. The main effect as well as the interaction between the groups and repeated measures (interference items and new items) is highly significant ($p<.001$). A summary of the analysis of variance appears in Table B of the Appendix. Following the analysis of variance, the t-test was applied for the individual comparison of the repeated measures in each group. The difference between the interference and new items chosen was highly significant ($p<.01$) in the two similarity-interference groups (Groups 4 and 5). The difference between the interference and new items in all other groups was insignificant.

Discussion

The results do not show any decay effect of the delay interval used. The recognition performance in the delayed-test group is better than in the immediate-test group. This might have been due to a rehearsal factor counteracting the decay effect. But the recognition score for the rehearsal-prevented group (dissimilar interpolation) turns out to be still higher. Although the difference is not significant, this does not support the rehearsal-strategy hypothesis. The better performance in the delayed-test groups (blank or dissimilar interpolation) is perhaps due to consolidation operating during the delay interval while no similar interfering material is presented. This consolidation factor counteracts both decay by the delay interval and interference by the dissimilar materials.

The results, however, show a significant interference effect by similar materials (retroactive and proactive). Groups 4 and 5 (similar interference, RI and PI) yielded the lowest scores. But proactive interference seems to be stronger than retroactive. The similarity PI group yielded consistently poorer recognition scores than all other groups. The RI effect is not consistent: the similarity RI group (Group 4) is not significantly different from other non-interference groups except its dissimilarity control (Group 3). This inconsistency in the RI effect might have been due to associational factors resulting from the long exposure duration per item (3 seconds/item) used in this experiment. On the other hand, the PI effect even with dissimilar materials is significant. Performance in the dissimilar PI group (Group 6) is significantly poorer than all other non-interference groups except Group I (immediate).

The immediate-test group, for some reason, has a very low performance score. This is perhaps because of the absence of consolidation in this group. In the three test-conditions which prevent consolidation

(Groups 1, 5 and 6), performance is poor, the similar PI group being the poorest of all. Among the three groups permitting consolidation (Groups 2, 3 and 4), the similar RI group (Group 4) has the lowest score. The poorest performance in the similar RI group is due to similarity-interference counter-acting consolidation. But poorer performance in Group 2 (delayed-test, rehearsal allowed) than in Group 3 (dissimilar interpolation, rehearsal prevented) cannot be explained by the consolidation hypothesis. It indicates that rehearsal impairs STRM rather than facilitating it. Thus in Group 2 rehearsal counteracts consolidation, and performance is poor. The dissimilar RI group (Group 3) has the most uninterrupted consolidation as neither rehearsal not similarity-interference is counter-acting it. Consequently, this group yields the highest recognition score.

The poor performance in the two similarity-interference groups (RI and PI) supports the interference hypothesis in STRM; and the results are consistent with STM findings using recall.

On the other hand, the analysis of errors shows that interference items were significantly ($p<.001$) more often chosen than new items by the groups exposed to the interference items (similarity RI and PI), while other grups not exposed to the interference items chose both the interference nad new items on a chance level. This means that recognition as such was not affected by the similarity-interference; instead, the discrimination of list-membership of the recognized items was impaired. The appearance of the interference items among the recognition alternatives requires a discrimination of the list-membership of each individual item in addition to judging its familiarity (recognition in the absolute sense). Thus the interference effect measured by the number of items correctly recognized appears to be an artifact of the recognition test used. Similarity interference may not decrease recognition performance in its absolute sense. This impairment of the discrimination of list-membership is similar to interlist intrusions observed in short-term recall studies.

But how much of the interference effect showed by the recognition scores could be explained away as an artifact could not be determined from the results. A simpler recognition task without discrimination of list-membership is necessary to determine the extent of interference effect produced by similar interference items in STRM; and this was provided in later experiments (Experiments IV to VII).

Experiment II

Experiment I was mainly exploratory; and the exposure duration per item was perhaps too long for a short-term memory test. The decay effect (with or without rehearsal) was not significant. The interference effect, however, was significant, but the trend was not consistent enough to warrant any conclusion. Besides, long-term memory components were found to be prominent as Ss indicated that they were forming associations for the items. Accordingly, Experiment I was replicated as Experiment II with a faster rate of presentation.

Method

Subjects

Another six groups of 10 Ss each were drawn from the same source (23 male and 37 female).

Apparatus and Materials

The apparatus and materials used were the same as in Experiment I.

Procedure

The same procedure was followed as in Experiment I except that the rate of presentation was 1 second/item; and the delay interval as well as the duration of the interpolated task was 20 seconds.

Results

The same formula was used for the guessing correction of the recognition scores as in Experiment I. The mean number correct and the standard deviation of the recognition scores (corrected for guessing) for different groups are presented in Table II (a). Examination of Table II (a) shows that Groups 4 and 5 (similar RI and PI) have the lowest recognition scores. All other groups look more or less alike in their mean recognition scores. A one-way analysis of variance was carried out on the corrected scores. The F ratio ($F = 9.35$; $df = 5, 54$) is highly significant ($p < .001$). A summary of the analysis of variance appears in Table C of the Appendix. Duncan's New Multiple Range Test for the comparison of means following the analysis of variance shows that Groups 4 and 5 (similarity RI and PI) are significantly poorer ($p < .01$) than all other groups. There is no significant difference between the similarity RI and PI groups (Groups 4 and 5), however; although the recognition scores in the similarity RI group is slightly higher than in the similarity PI group. No other groups are significantly different from one another. The comparison of different groups appears in Table II (b).

While the results apparently indicate a significant interference effect (RI and PI) by the similar materials, analysis of the recognition errors reveals a different picture. Table II (c) shows the mean error-scores from the interference and new items. As the number of new items among the recognition alternatives was three times larger than the inter-feremce items, the error-scores from the interference items were multiplied by three to equate the probability of choice of items from both categories

Table II (a)

Group Means and Standard Deviations of the Recognition Scores (Corrected for Guessing): Experiment II

Group	Mean	Standard Deviation
1: Immediate	6.65	1.74
2: Delay	5.88	2.40
3: Dissimilar RI	6.68	1.79
4: Similar RI	2.81	2.20
5: Similar PI	2.58	1.52
6: Dissimilar PI	6.28	1.51

Table II (b)

Multiple Comparison of Group Means by Duncan's New Multiple Range Test: Experiment II

Group	1	2	3	4	5	6
1: Immediate						
2: Delay						
3: Dissimilar RI						
4: Similar RI	p<.01	p<.01	p<.01			p<.01
5: Similar PI	p<.01	p<.01	p<.01			p<.01
6: Dissimilar PI						

Table II (c)

Mean Errors of Recognition from the Interference and New Items of the Recognition Alternatives: Experiment II

Group	Interference Items	New Items
1: Immediate	4.50	5.20
2: Delay	5.70	5.60
3: Dissimilar RI	7.80	6.20
4: Similar RI	10.50	5.30
5: Similar PI	12.60	6.00
6: Dissimilar PI	7.20	5.40

(interference and new) of incorrect alternatives. A two-way analysis of variance for repeated measures was carried out on the error-scores to determine whether the interference items were significantly more often chosen than the new items. The summary of the analysis of variance is presented in Table D of the Appendix. The main effect as well as the interaction between groups and repeated measures (interference items and new items) was highly significant ($p<.001$). The t-test following the analysis of variance shows that the two similarity-interference groups (Groups 4 and 5) chose the interference items (among the errors) significantly more often than the other groups ($p<.001$). The choice from either categories of incorrect alternatives (interference items and new items) in all other groups was on a chance level. The analysis of errors raises doubt about the interference interpretation of the results, and suggests that much of the interference effect could probably be attributed to the discrimination of list- membership of items rather than to the decreasing function of the similarity-interference (RI and PI) effect.

Discussion

As in Experiment I, the results do not show any decay effect by the delay interval used. Only the interference effect due to the presentation of similar materials (RI and PI) seems to produce significant decrement in the recognition scores. Both similarity RI and PI consistently show up in the results. Although there is no significant difference between the two similarity-interference groups, PI effect seems to be stronger than RI as in Experiment I. The STRM loss in the similarity PI group is greater than in the similarity RI group. This difference might have been due to lack of consolidation in the PI group, while consolidation facilitates performance in the RI group. But the consolidation hypothesis as such does not seem to be tenable as there is little difference between the non-interference groups enjoying consolidation (Groups 2 and 3) and the ones lacking consolidation (Groups I and 6).

The poorer performance in Group 2 (delayed-test, rehearsal allowed) than in Group I (immediate-test)--although the difference is not significant--might indicate a decay effect of the delay interval in spite of rehearsal counteracting decay; and this suggests that if rehearsal were prevented, the decay effect would probably be significant. But the better performance by Group 3 which prevents rehearsal by interpolating dissimilar materials rules out the decay suggestion. The poorer performance by Group 2 (delayed-test, rehearsal allowed) than by Group 3 (dissimilar interpolation, rehearsal prevented) indicates, as in Experiment I, that rehearsal probably impairs rather than facilitates short-term recognition memory.

While the recognition scores show a significant similarity-interference effect (RI and PI), the analysis of recognition errors suggests that the apparent decreasing function of both RI and PI by similarity might be an artifact of the recognition test. As in Experiment I, the discrimination of list-membership rather than absolute recognition seems to be impaired by similarity-interference. Thus, while both similarity RI and PI effect became consistent after elimination of the associational factors by using faster rate of presentation (1 sec./item), the similarity-interference interpretation does not seem convincing because the groups exposed to interference chose the interference items (among the errors) significantly more often than new items, but the error-scores from both categories of incorrect alternatives (interference and new items) in all other groups not exposed to interference remained at a chance level. This shows, as in Experiment I, that much of the similarity RI and PI effect obtained could be attributed to impairment of the discrimination of list-membership rather than loss of absolute recognition. Although it could not be determined from the results that how far of the similarity-interference effect is atrributable to the discrimination of list-membership, the results seem to question both the decay and interference theory of short-term memory so far as short-term recognition memory is concerned.

Experiment III

The number of recognition responses was unrestricted and guessing was high in the first two experiments. The variance was quite large as a result. The task was difficult because Ss had to decide first whether they had seen a particular alternative before, and then, in the similar interference condition, whether the syllable had been seen in the test or in the interference list. Thus guessing probability was high, and consequently, recognition-error was large. Experiment III was designed to use a multiple-choise recognition test with all the alternatives presented together. Guessing would be reduced because the maximus number of choices was limited by the number of correct responses.

Method

Subjects

The subjects were 71 males and 49 females (between 17 and 20 years old) volunteering from an introductory psychology course. They were divided into 6 groups of 20 Ss each.

Apparatus and Materials

The apparatus and materials used were the same as in Experiments I and II, but all the alternatives of the recognition test were arranged together in a random order on a single slide. The distance between S and the screen was 15 feet; and the projected size of the letters or digits was 3/4 x 3/4 in.

Procedure

The procedure was same as in Experiment II except in the recognition-test part. The correct and incorrect alternatives appeared together for comparison in the recognition test. Ss were required to identify the "correct" items from the list and write them down in any order. They were instructed to write down as many items as they could recognize (not exceeding ten) within a 2-minutes' time limit.

Results

As the number of recognition responses for different subjects was still unequal, the same formula was used for guessing correction as in Experiments I and II. The mean and standard deviation of the corrected scores for all the groups are presented in Table III (a). An analysis of variance (one-way classification) was carried out on the recognition scores. The F ratio ($F = 6.99$; $df = 5, 114$) is highly significant ($p<.001$). A summary of the analysis of variance appears in Table E of the Appendix. Following the analysis of variance, Duncan's New Multiple Range Test was used for individual comparison of the different groups. The multiple comparison of the group means appears in Table III (b). Both the similarity-interference groups (RI and PI) are significantly poorer in recognition performance than all other groups ($p<.01$). The difference between all other groups is insignificant. There is of course no significant difference between the two similarity-interference groups (RI and PI), although the similarity PI group (Group 5) has slightly

Table III (a)

Group Means and Standard Deviations of the Recognition Scores (Corrected for Guessing): Experiment III

Group	Mean	Standard Deviation
1: Immediate	3.96	2.34
2: Delay	4.61	1.56
3: Dissimilar RI	3.89	1.81
4: Similar RI	2.02	1.80
5: Similar PI	2.10	1.59
6: Dissimilar PI	4.39	2.11

Table III (b)

Multiple Comparison of Group Means by Duncan's New
Multiple Range Test: Experiment III

Group	1	2	3	4	5	6
1: Immediate						
2: Delay						
3: Dissimilar RI						
4: Similar RI	p<.01	p<.01	p<.01			p<.01
5: Similar PI	p<.01	p<.01	p<.01			p<.01
6: Dissimilar PI						

Table III (c)

Mean Errors of Recognition from the Interference and New Items of the Recognition Alternatives: Experiment III

Group	Interference Items	New Items
1: Immediate	3.45	3.50
2: Delay	1.95	2.45
3: Dissimilar RI	4.20	2.00
4: Similar RI	6.75	3.05
5: Similar PI	7.20	3.30
6: Dissimilar PI	4.05	2.65

higher score than similarity RI group (Group 4). Unlike the previous two experiments, the delayed-test group (Group 2) has the highest, and the dissimilar PI group (Group 6) the next highest scores. Among the non-interference groups, the immediate-test group (Group 1) is the poorest in performance.

Since the interference items were also included among the recognition alternatives, an analysis of the recognition-errors was made to determine whether the interference items were more often chosen (among the errors) than new items by the interference groups than by the non-interference groups. The mean error-scores from both categories of incorrect alternatives (interference items and new items) are presented in Table III (c). As the number of new items among the recognition alternatives was three times larger than the interference items, the error-scores from the interference items were multiplied by three to equate the probability of choice of items from both categories (interference and new) of incorrect alternatives. A two-way analysis of variance for repeated measures (interference items and new items) was carried out on the error-scores. Both the main effect and the interaction between the treatment groups and repeated measures are highly significant ($p<.001$). A summary of the analysis of variance is presented in Table F of the Appendix. The t-test following the analysis of variance shows that the two similarity-interference groups (Groups 4 and 5) chose the interference items (among the errors) significantly ($p<.001$) more often than the new items. The non-interference groups, except Group 3 (dissimilar-interpolation), chose items from both categories (interference and new) on a chance level.

The dissimilar interpolation group (Group 3), however, chose the interference items significantly ($p<.01$) more often than new items.

Discussion

The results do not show any decay effect of the delay interval on short-term recognition memory. The similarity-interference effect (RI and PI), on the other hand, is highly significant as the performance in both similarity RI (Group 4) and similarity PI (Group 5) groups is significantly poorer than all other groups (including their respective "dissimilarity-controls"). This suggests that interference may play a significant role in STRM, while decay does not.

But the similarity-interference interpretation is questioned by the analysis of the recognition errors as in Experiments I and II. The groups exposed to similarity-interference chose the interference items among the errors significantly ($p<.001$) more often than the new items, while the non-interference groups chose items from both categories (interference and new) on a chance level. This shows that discrimination of list-membership of the recognized items, as required by the presence of both stimulus and interference items among the recognition alternatives, was impaired by the similarity-interference rather than absolute recognition being affected. But this impairment of the discrimination of list-membership, in spite of all the items being available for comparison at the same time, could perhaps be interpreted as a similarity-interference effect, and the results would support the interference theory of short-term memory in that sense.

Group 3 (dissimilar interpolation) also chose the interference items among the errors significantly ($p<.01$) more often than new items. As this group was not exposed to the interference items, the preference for interference items to new items cannot be explained by the discrimination-of-list-membership hypothesis. The only explanation that could be offered for the greater frequency of interference items (among errors) than new items in this group is the greater similarity of the interference items to the stimulus items. But this explanation even does not seem convincing because no other non-interference group shows this tendency. The explanation is rather unknown and further investigation is necessary to provide the explanation.

Unlike the previous two experiments, rehearsal seems to facilitate performance as the recognition score in Group 2 (delayed-test, rehearsal allowed) is higher than any other group, though the difference is significant only in case of the two similarity-interference groups (Groups 4 and 5). Performance becomes poorer when rehearsal is controlled by interpolating dissimilar materials (Group 3), although the difference is not significant. This tendency of rehearsal to facilitate performance, while consistent with STM results using recall, seems to rule out the suggestion made by the first two experiments that rehearsal might impair rather than facilitate STRM. Those conflicting results about the effect of rehearsal on short-term recognition memory might have been due to the difference in the recognition procedure used in this experiment.

Another insignificant but interesting difference is between Group I (immediate-test) and Group 6 (dissimilar PI). The recognition test in both the groups is taken immediately after the presentation of the stimulus items. In spite of the dissimilarity-interference of the proactively presented numbers, the performance in Group 6 is higher than in Group I (immediate-test) which has no interference whatsoever (RI or PI). This difference might have been due to a contrast effect between the numbers and nonsense syllables, or due to a "novelty reaction" to the nonsense syllables after receiving the numbers. On this assumption, however, a similar facilitating effect would be expected in Group 3 (dissimilar-interpolation) even after eliminating the facilitating effect of rehearsal, and in the corresponding conditions of the previous two experiments. This is not the case; and the "contrast-effect" or "novelty-reaction" hypothesis, peculiar to this experiment, would seem convincing if it is assumed that numbers and nonsense syllables have differential facilitating effect on each other due to contrast effect or novelty reaction.

The consolidation effect does not show up in the results as there is little difference between the non-interference groups enjoying consolidation (Groups 2 and 3) and the ones lacking consolidation (Groups I and 6) when the facilitating effect of rehearsal and "novelty reaction" is eliminated.

Experiment IV

In experiment III, there were too many alternatives to be compared within the available time; and subjects could not be forced to make equal numbers of responses. Besides, the test-time (2 minutes) was too long for a short-term memory test. The between-item interval (1 second) favoring inter-item rehearsal in the first three experiments could not be reduced because of limitations of the equipment used. In order to overcome all these difficulties, Experiment IV used different equipment to provide a forced-choice recognition task. The test-time as well as the inter-item interval was reduced considerably.

Because the similar-interference items were included among the incorrect alternatives in the first three experiments, a discrimination of list-membership was required for correct identification of an item. The analyses of the recognition-errors made in the first three experiments show that the interference items were more often chosen (among the errors) than new items. In order to eliminate this additional factor in the recognition process, Experiment IV used only new items (not previously exposed) as the incorrect alternatives in the recognition test.

Method

Subjects

The subjects were 120 college or high school students (71 male and 49 female) between 16 and 25 years old. They were divided into 6 equal groups of 20 Ss each. All Ss were paid for their participation.

Apparatus and Materials

The stimulus items were the same ten nonsense syllables used in the first three experiments. The interpolated numbers also were the same as before. A new set of 0 to 47% association-value nonsense syllables (Hilgard, 1951) more similar to the stimulus items (the initial and last letters are common with that in the corresponding stimulus item) was used as the interference materials. The recognition test consisted of presenting three alternatives for each stimulus item. One of the alternatives was the correct item, the other two being similar (0 to 47%, terminal letters common) new items (not exposed before). Each set of the three alternatives appeared in a vertical column; and the position (top, bottom, or middle) of the correct item in the set varied in a random order. Six different films were prepared as the stimuli. Each film contained the entire sequence of items (stimuli, interpolated items if any, and the recognition alternatives) appropriate for the experimental group used. The films were projected on the screen by a filmstrip projector controlled by a timer. S's responses were recorded by a tape recorder. S sat at a distance of 10 feet from the screen; and the projected size of the letters or digits was 3 X 3 inches.

Procedure

All subjects were individually tested. Each S participated in one condition only. S was given the appropriate instructions for the condition being tested. Then E started the sequence. The stimulus and the interpolated items were not separated by any signal. Ss were told that all the items would be tested. The recognition test was signalled by a question mark (?). Subject was required to pronounce the nonsense syllables and call out the numbers in the presentation part (stimulus and interpolated items). The recognition part required S to indicate the position (top, or middle, or bottom) of the "correct" item on each set of the three alternatives. The items of the stimulus as well as of the interpolated series were presented in a random order. The test series of set of alternatives appeared in the same order as the stimulus series. The presentation rates were .75 second/item for the stimulus series, 1.5 seconds/item for the interpolated series, and 3 seconds/set for the recognition series of set of alternatives. The inter-item interval was .05 second. In the proactive situation, the rate for interpolated items was used for the proactively presented items. The subjects were asked to make a recognition choice for each of the items tested ("forced-choice"); and the number of recognition-responses for each S was accordingly uniform. Ss were instructed to guess if they were not sure.

Six groups of Ss were tested according to the experimental paradigm used before except that Group 2 (delayed-test, rehearsal allowed) looked at blank flashes on the screen during the delay interval. The duration of the delay interval as well as the interpolated task was 15 seconds. Group 3 (numbers interpolated) and Group 6 (numbers proactively presented) were told that the test would be on both numbers and nonsense syllables; either the syllable- or the number-set would come first in the recognition test. The test was always on the nonsense syllables as before. Beside tape-recording S's voice, E recorded S's recognition responses on a prepared data sheet.

Results

The number of items correctly recognized by each subject was taken as the recognition score for that particular subject. There was no necessity for guessing correction as the number of recognition-responses was equal for all subjects ("forced-choice"). The mean and standard deviation of the recognition scores for all the groups are presented in Table IV. The analysis of variance (one-way classification) did not yield a significant F ratio ($F = 2.01$; $df = 5, 114$). A summary of the analysis of variance appears in Table G of the Appendix.

The performance in Group 5 (similar PI), however, is poorer than any other group. All other groups look more or less alike; Group 2 (delayed-test, rehearsal allowed) and Group 3(dissimilar RI) are slightly poorer than other groups.

Discussion

The results do not show any decay effect (rehearsal allowed or prevented); nor there is a significant interference effect with

Table IV

Group Means and Standard Deviations of the

Recognition Scores: Experiment IV

Group	Mean	Standard Deviation
1: Immediate	7.05	1.24
2: Delay	6.85	1.20
3: Dissimilar RI	6.90	0.31
4: Similar RI	7.05	1.47
5: Similar PI	5.90	1.45
6: Dissimilar PI	7.00	1.73

similar or dissimilar materials. But the poorer performance in similar PI group (Group 5) suggests that proactive interference by similarity may be a cause of forgetting in short-term recognition memory, while decay or similarity RI are not. This tendency was also noticed in Experiment I and II. It may be assumed here that the similarity PI effect would probably be significant if the amount of interference is increased. This probability is investigated in the next experiment (Experiment V).

The poorer performance in the similarity PI group (Group 5) might have been due to a "primacy" factor facilitating the recognition of the earlier over the later items. The traces for the first series of items are perhaps more strongly formed and interfere with the trace-formation for the items of the second series. Consequently, the performance on the second series is expected to be poorer than on the first series. Thus the poorer performance in the similarity PI group (Group 5) which takes the test on the second series of items as well as the better performance in the similarity RI group (Group 4) which takes the test on the first series becomes quite convincing on the primacy assumption. But on this assumption a poorer performance would be expected in Group 6 (dissimilarity PI) which also takes the test on the second series. In Group 6, perhaps the "contrast-effect" or "novelty-reaction" factor, assumed earlier, compensates the primacy effect, and the performance is consequently better.

Curiously enough, the recognition score in the similarity RI group (Group 4) is the highest among the delayed-test groups (Groups

2, 3 and 4). The RI similarity effect seems to rather facilitate short-term recognition performance than hinder it. Performance in Group 2 (delayed-test, rehearsal allowed) and Group 3 (delayed-test, dissimilar interpolation) is poorer than all other groups except similarity PI (Group 5). This indicates that rehearsal might impair rather than facilitate STRM as was suggested by the first two experiments. Thus performance improves as rehearsal is controlled more effectively. Accordingly, performance is the highest in the similarity RI group (Group 4) which controls rehearsal most effectively, and lowest in Group 2 which does not control rehearsal at all. The dissimilar RI group (Group 3) being the mid-way in controlling rehearsal, comes in-between the rehearsal-allowed (Group 2) and rehearsal-prevented (Group 4) groups among the three delayed-test groups.

The analysis of recognition errors in the first three experiments suggested that there may not be any similarity-interference effect in STRM. The results of this experiment seem to confirm that suggestion and indicate that STRM is rather resistant to both decay and interference. Rehearsal does not facilitate STRM, rather it seems to impair it to some extent. The results, however, suggest two probabilities to be explored in order to determine the extent of persistence of STRM against interference or decay. First, the interference effect in this experiment might not have been intense enough to produce any significant decrement in STRM; if the amount of interference is increased considerably, there might be a significant interference effect due to similarity. Second, the delay interval might not have been long enough to produce any significant decrement in STRM; there might be a significant decay effect of the delay interval if the duration of the delay is increased considerably. These probabilities are explored in the next two experiments (Experiment V and VI).

Experiment V

Experiment IV did not show any decay effect of the delay interval; nor did it show any interference effect due to the interpolated materials (similar or dissimilar). Two alternative hypotheses were postulated to explain the results. First, perhaps the interference was not intense enough to produce any significant decrement in the recognition score. Second, the delay interval was probably not long enough to produce any decay effect. Besides, short-term recognition memory might be resistant to both decay and interference even after long delay and considerable interference, as was suggested by the results of Schwarts and Perkins (1966), Shephard and Chang (1963), and Shephard and Teghtsoonian (1961).

Experiments V and VI tested these two alternative hypotheses. Experiment V tested the first hypothesis (interference) by increasing the number of interference items keeping the delay interval (and the total duration of interference items)constant. The purpose was to determine whether interference affects short-term recognition memory at all when the amount of interference is increased to a great extent.

Method

Subjects

There were 5 groups of 20 Ss each participating in this experiment. The Ss (61 male and 39 female between 16 and 25 years old) were either college students volunteering from an introductory psychology course, or paid high school students.

Apparatus and Materials

The stimulus materials (test items) were the same as in the previous experiments. Thirty interpolated numbers (including the previous ten) were used as rehearsal-preventing and dissimilarity-control materials; and thirty similar (0 to 47%, terminal or two adjacent letters common) nonsense syllables (Hilgard, 1951) including the previous ten, were used as the interference materials. Everything else was the same as in Experiment IV.

Procedure

The procedure was the same as in Experiment IV except that the rate of presentation for the interpolated materials (numbers and nonsense syllables) was .5 second/item.

Results

Table V (a) shows the means and standard deviations of the recognition scores for different groups. The analysis of variance (one-way classification) yields a significant ($p<.05$) F ratio ($F = 2.99$; $df = 5, 114$). A summary of the analysis of variance appears in Table H of the Appendix. Following the analysis of variance, Duncan's New Multiple Range Test was carried out to determine the extent of difference between the groups. The comparison between the groups is pre-

Table V (a)

Group Means and Standard Deviations of the Recognition Scores: Experiment V

Group	Mean	Standard Deviation
1: Immediate	7.05*	1.24*
2: Delay	6.85*	1.20*
3: Dissimilar RI	7.10	1.79
4: Similar RI	6.80	1.81
5: Similar PI	5.50	1.83
6: Dissimilar PI	6.90	0.30

* Data from Experiment IV

Table V (b)

Multiple Comparison of Group Means by Duncan's New Multiple Range Test: Experiment V

Group	1	2	3	4	5	6
1: Immediate						
2: Delay						
3: Dissimilar RI						
4: Similar RI						
5: Similar PI	p<.05	p<.05	p<.05	p<.05		p<.05
6: Dissimilar PI						

sented in Table V (b). Group 5 (similarity PI) is significantly ($p<.05$) poorer than any other group (including the similarity RI group: Group 4). No other group is significantly different from any other. It is interesting to note that the difference between Group 4 (similarity RI) and Group 5 (similarity PI) becomes significant in contrast to all the previous experiments. But the score in the similarity RI group (Group 4) is the next lowest. Group 3 (dissimilar interpolation) has the highest score as in the first two experiments.

Discussion

The results show neither any decay effect with the delay interval, nor retroactive interference due to interpolation of the similar materials. Short-term recognition memory appears to be resistant to retroactive similarity-interference. Performance is only slightly poorer in the similarity RI group (Group 4) than in its "dissimilarity-control" (Group 3) even after being subjected to 30 similar interference items. This shows a strong persistence of STRM against a massive retroactive interference with similar materials.

The proactive similarity-interference effect, however, is significant at the .05 level. This confirms the suggestion made by the earlier experiments (Experiments I, II and IV) that the PI effect is stronger than the RI effect. The results also confirm the assumption that similarity-interference was not probably intense enough to produce a significant decrement in STRM in Experiment IV, so far as the PI similarity effect is concerned. This seems to suggest that similarity PI effect plays a significant role in STRM, while decay and similarity RI do not. The results are not consistent with the general STM findings using recall; and this suggests that short-term recognition memory is perhaps quite different from short-term recall in nature. However, the extent of persistence of STRM against decay after long delay remains to be investigated before drawing any conclusion about this.

The difference between the similarity RI and PI effect in short-term recognition memory is perhaps due to a "primacy" factor (assumed earlier) facilitating the recognition of earlier items over the later items. In the retroactive situation, the traces for the first series (stimulus items) are stronger than the second series (interference items) which, being weaker in trace-strength, cannot produce any significant decrement in the first series. Consequently there is little or no decrement of STRM in the similarity RI group (Group 4). In the proactive situation, on the other hand, the traces for the first series (interference items) are strongly formed and interfere with the trace-formation for the second series (stimulus items). As a result, the performance on the second series is poorer; and this shows a similarity PI effect. The poorer performance in the similarity-PI groups in most of the experiments (Experiments I, II, IV and V) becomes quite convincing if the "primacy" assumption is true.

On the basis of the results of this experiment, it may, however, be concluded that PI similarity effect becomes significant, though not very strong, when the amount of interference is increased considerably; but the RI similarity effect does not play a significant role in STRM.

Short-term recognition memory seems to be resistant to retroactive similarity-interference (RI). The extent of resistence of STRM to decay is explored in the next experiment (Experiment VI).

Experiment VI

Experiment V did not show a significant retroactive interference effect in short-term recognition memory even after increasing the interference materials by three times. Short-term recognition memory appears to be resistant to retroactive interference with similar materials; the similarity PI effect, however, is significant in STRM. Experiment VI was designed to test the decay hypothesis. The delay interval (the total duration of the interpolated task as well) was increased considerably in order to determine whether STRM is subject to decay at a longer delay interval.

Method

Subjects

Sixty subjects divided into 3 equal groups participated in this experiment. The Ss (27 male and 33 female between 17 and 25 years old) were either college students volunteering from an introductory psychology course, or paid high school students.

Apparatus and Materials

The apparatus and materials were the same as in Experiment V except that the last two films (5 and 6) were not used.

Procedure

The procedure was the same as in Experiment V except that a slower rate was used for the presentation of the interpolated materials, and the proactive groups were left out. The presentation rate for the interpolated items was 1.5 seconds/item; and the delay interval was 45 seconds. It may be noted here that the immediate-test conditions (Group 1) for Experiments IV, V and VI were identical; and the same data were used for Group 1 of all the three experiments (IV, V and VI). Group 2 (delayed-test, rehearsal allowed) of Experiment IV was identical to that of Experiment V; and the same data were therefore used for Group 2 of both the experiments (IV and V).

Results

The mean number correct and standard deviation for different groups are presented in Table VI. Although Group 4 (similarity RI) has the highest recognition score as in Experiment V, the difference between the groups is very small. A one-way analysis of variance was carried out, and the F ratio ($F = 0.49$; df = 3, 76) is far from being significant. A summary of the analysis of variance appears in Table I of the Appendix.

Since the experiment was essentially an investigation of the decay factor, the two proactive conditions (Groups 5 and 6) which do not involve any decay effect were not run.

Discussion

The results do not show any decay effect even after increasing

Table VI

Group Means and Standard Deviations of

the Recognition Scores: Experiment VI

Group	Mean	Standard Deviation
1: Immediate	7.05*	1.24*
2: Delay	7.25	1.51
3: Dissimilar RI	7.10	1.64
4: Similar RI	7.60	1.71

* Data from Experiment IV.

the delay interval by three times. The performance in the delayed-test conditions (with or without rehearsal) is even higher than in the immediate-test condition (Group 1). Short-term recognition memory seems to be resistant to decay even after quite a long delay (45 seconds). But how long STRM might persist could not be determined from the results, and was beyond the scope of the present study.

Interestingly enough, the similarity RI group (Group 4) has the highest score and the immediate-test group (Group 1) the lowest; while just the opposite would be expected according to both decay and interference theory. The RI similarity effect seems to rather facilitate short-term recognition memory as was observed in Experiment IV. The facilitation might have been due to the "primacy" effect of the first series of items (as was assumed in Experiments IV and V), which renders the similarity RI effect in STRM ineffective.

Rehearsal seems to facilitate performance as the score in Group 2 which allows rehearsal is higher than the score in Group 3 which prevents rehearsal by presenting the dissimilar materials during the delay interval. But no conclusion is warranted as the difference is insignificant and very small. Besides, the highest score in the similarity RI group (Group 4) which prevents rehearsal most effectively and presents interference in addition, precludes any conclusion about rehearsal independent of interference.

Experiment VII

The results of Experiments V and VI suggest that short-term recognition memory is resistant to both decay and retroactive interference. The proactive interference with similar materials, however, was significant at the .05 level in Experiment V. It was concluded that STRM does not decay with a longer delay interval (within the range studied), although how long it might persist was not determined in the present study. But the interference conclusion is ambiguous. Different rates were used for presentation of stimulus and interpolated items in the previous experiments (Experiments IV, V and VI). Perhaps the different degrees of learning of stimulus and interpolated materials resulting from different rates of presentation obscured an interference effect. As a control for this possibility, Experiment VII used the same rate of presentation for both stimulus and interference materials.

Method

Subjects

Two groups of subjects (20 Ss each) were tested in this experiment. Ss were college students (15 male and 25 female) volunteering from an introductory psychology course.

Apparatus and Materials

The two interference films (retroactive and proactive) from

Experiment V were used in this experiment. Everything else was the same as in Experiments V and VI.

Procedure

Only the two similarity-interference groups (Group 4: RI and Group 5: PI) were tested. The rate of presentation was .75 second/item in both stimulus and interference sequences. The duration of the interference sequence (RI and PI) was 22.5 seconds. Everything else was the same as in Experiments V and VI.

Results

Experiment VII was a control study designed to determine whether an interference effect in the two similarity-interference conditions (Groups 4 and 5) was obscured by the different rates of presentation used for the stimulus and interference series in Experiments IV, V and VI. A comparison of the group means and standard deviations for the two similarity-interference groups of Experiments IV to VII is presented in Table VII. A one-way analysis of variance was carried out on the scores of both the similarity RI and similarity PI groups of the different experiments. The F ratio ($F = 1.72$; $df = 3, 76$) for the similarity RI group (Group 4) is not significant. A summary of the analysis of variance for this group appears in Table J of the Appendix. The F ratio ($F = 4.22$; $df = 2, 57$) for the similarity PI group (Group 5), however, is significant at the .05 level. The summary of the analysis of variance for Group 5 (similarity PI) appears in Table K of the Appendix.

Table VII

Comparison of the Means and Standard Deviations of the Similarity RI and Similarity PI Groups (Groups 4 and 5) over Experiments Using Different Rates of Presentation for the Stimulus and Interference Items

Experiment	Group 4 Similar RI		Group 5 Similar PI	
	Mean	SD	Mean	SD
IV: Interference Slower	7.05	1.47	5.90	1.45
V: Interference Faster	6.80	1.81	5.50	1.83
VI: Interference Slower	7.60	1.71		
VII: Equal Rate	7.80	1.12	7.00	1.64

Following the analysis of variance in the similarity PI group (Group 5), Duncan's New Multiple Range Test was used for the individual comparison of means in different experiments. The comparison shows that the performance in the PI similarity group (Group 5) in Experiment VII is significantly better ($p<.05$) than in Experiment V; and the difference between Experiments IV and VII (higher score in Experiment VII) is just short of significance at the .05 level. There is no comparison with Experiment VI as the proactive groups were left out in Experiment VI. The results seem to indicate that equal rate of presentation in the stimulus and the interference series in the proactive situation facilitates performance, and eliminates the similarity PI effect observed in Experiment V (and in Experiment IV to some extent).

Discussion

The different rates of presentation in the stimulus and interference series used in different experiments (and hence the resulting differential degrees of learning as assumed) do not seem to have played any role in the operation of interference process, so far as the similarity RI effect is concerned. The performance is more or less equal under the same or different rates of presentation for the stimulus and interference series across all the experiments. The equal rate of presentation for both the series, however, seems to facilitate performance in the RI similarity situation, as the performance in Experiment VII, which uses equal rate for both the stimulus and interference series, is higher than in all other experiments using different rates for the two series. Experiment V which uses a faster rate for the interference series has the lowest score. But the two experiments (IV and VI) which use a slower rate in the interference series score mid-way between the faster (Experiment V) and equal (Experiment VII) rate of presentation.

The PI similarity effect, on the other hand, seems to have been affected by the different rates of presentation for the stimulus and interference items; but the trend is not consistent enough to warrant any conclusion about the effect of rate of presentation in the stimulus and interference series of items on the similarity PI effect. When a slower rate (1.5 seconds/item) is used for the interference series (Experiment IV), the similarity PI effect is close to significance; the PI similarity effect becomes significant ($p<.05$) when a faster rate (.5 second/item) is used for the interference items (Experiment V). But when an equal rate (.75 second/item) is used for both the stimulus and interference items (Experiment VII), the similarity PI effect is cancelled out and the performance is rather better.

GENERAL DISCUSSION

The results of the present series of experiments do not support the decay theory of short-term recognition memory. The extent of persistence of STRM against decay was not determined in the present study. But within the range of intervals studied (up to 45 seconds), it may be concluded that short-term recognition memory is not subject to decay. On the contrary, short-term recall is often found to be subject to decay with much shorter intervals (See Introduction, Pp. 12-15). Short-term recognition memory seems to be quite different from short-term recall.

The effect of interference is ambiguous. In the first three experiments, similarity-interference (RI and PI) seems to have produced a significant decrement in short-term recognition. But analysis of the recognition-errors showed that this apparent interference effect was an artifact caused by the presence of the interference items among the recognition alternatives. This conclusion is confirmed by the later experiments (Experiments IV - VII) which do not show any significant retroactive interference when there was no discrimination of recognition alternatives required. Thus short-term recognition memory seems to be resistant to retroactive interference. But in a paired-associate STM study by Garskof and Sandak (1964) the A-B pairings are actually unlearned due to the interpolated A-C pairings in the RI paradigm with recognition.

The proactive interference effect is somewhat confusing. The similarity PI effect was significant in Experiment V, and was close to significance in Experiment IV. But in Experiment VII, which was identical with Experiment V except that an equal rate was used for the presentation of both the stimulus and interference items, the similarity PI effect disappears and the overall performance improves. This inconsistency prevents a firm conclusion about the similarity PI effect; but it suggests that STRM may also be resistant to proactive interference.

The persistence of short-term recognition memory against both decay and interference suggests that the memory storage (short- or long-term), once formed, becomes relatively permanent, and is little subject to decay or interference. The results suggest that only retrieval is subject to decay or interference, while storage is not. Retrieval is an essential part of recall; and the loss of STM due to decay or interference usually reported by experiments using recall is perhaps caused by the loss of the retrieval process. Memory storage is more than mere retrieval. The storage may persist even when retrieval is lost and recall has failed. A recognition test which does not require retrieval might show the memory storage even after loss is reported by recall. The present results confirm earlier findings (see Introduction, Pp. 43-45) of Schwartz and Perkins (1966), Shephard and Chang (1963), and Shephard and Teghtsoonian (1961) and indicate that both short- and long-term recognition memory persists against decay or interference.

All memory (short- or long-term) has two aspects: retrieval and storage. Retrieval is temporary and short-lived after a single presentation, and is subject to decay or interference (e.g., Brown, 1958; Keppel and Underwood, 1962; Melton, 1963; Peterson and Peterson, 1959). But retrieval may be enhanced by repetition and rehearsal. The memory storage, on the other hand, is relatively permanent after one trial as suggested by the present results. Any particular item may be both in short-term and long-term storage at the same time (Waugh and Norman, 1965). After a single presentation an item is in the short-term store so far as its retrieval is concerned, and in terms of the memory storage it is in the long-term store. This seems to bridge the gap between short-term and long-term memories. The same processes: retrieval and storage occur in both short- and long-term memory. When retrieval is lost after one trial due to decay or interference, and recall has failed, we call this short-term memory; persistence of retrieval after repetition and rehearsal is called long-term memory. The memory storage, once formed, seems to persist and may be revealed by recognition tests which do not require retrieval, although loss may be reported by recall tests which pre-suppose retrieval. Thus the difference between short- and long-term memory appears to depend upon the tests used.

The persistence of STRM may also be due to a partial learning and retention of some characteristics or aspects of the items (McNulty, 1966). These partial characteristics may be enough for the correct recognition of the items even when retrieval of the items is lost. But the persistence of these partial characteristics themselves against decay and interference cannot be explained by the partial learning model of recognition memory (McNulty, 1966). Perhaps the same "retrieval and storage" explanation should also be appropriate here. The persistence of the memory storage (complete or partial) seems to be the most convincing explanation. Further investigation is necessary to determine the nature of retrieval and storage processes as such, and their relationships.

The results of the first three experiments could be interpreted as supporting an interference theory if the discrimination of list-membership of the stimulus and interference items is taken as the criterion of performance. Exposure to the similar interference items impairs the discrimination, and intrusions from the interference series are numerous. Wickelgren (1965c) found a similar tendency of intrusions in recall. Intrusions tend to be similar to the presented items, and their frequency increases with the degree of similarity with the presented items. The same kind of intrusions are also reported with acoustic similarity of the interference items (Wickelgren, 1965d).

If, on the other hand, the absolute recognition performance (identification of the previously exposed items: both stimulus and interference) is taken as the criterion, interference has no effect on short-term recognition memory. When the recognition alternatives include the interference items (Experiments I - III), the performance is impaired; but when the interference items do not occur among the recognition alternatives (Experiments IV - VII), the performance is unaffected. If the interference items were included among the recognition alternatives in the forced-choice recognition test of the later experiments (Experiments IV - VII), results similar to the first three experiments might have been obtained.

The significant PI similarity effect in Experiment V and the close-to-significant PI effect in Experiment IV, together with the lack of a significant RI similarity effect, is consistent with Postman's (1963) notion about RI and PI: "...proactive inhibition is an established fact, retroactive inhibition is rarely complete,..." (p. 298). This suggestion is also confirmed by the stronger PI than RI in the similarity-interference conditions of Experiments I and II. But the similarity PI effect itself is not very consistent. In Experiment IV which uses a slower presentation rate for the interference than for the stimulus items, the PI effect is close to significant; the PI effect becomes significant when the rate in the interference series is faster (Experiment V), but disappears when an equal rate of presentation is used for both the stimulus and interference series (Experiment VII).

It may be concluded from the results that short-term recognition and short-term recall measure different aspects of the memory process. Recall measures retrieval, or ability to reproduce an item retained, while recognition measures the memory storage independent of retrieval. This is quite consistent with Murdock's (1963c) suggestion that "...recognition and recall are not necessarily equivalent methods of measuring retention." (Murdock, 1963c, p.20). The results indicate that retrieval is subject to decay or interference as reported by most STM experiments using recall (e.g., Brown, 1958; Keppel and Underwood, 1962; Mackworth, 1964a; Melton, 1963; Peterson, and Peterson, 1959), but that storage is persistent against decay or interference as reported by Schwartz and Perkins (1966), Shephard and Chang (1963) and Shephard and Teghtsoonian (1961).

SUMMARY

This study was designed to investigate the decay and interference processes in short-term recognition memory for visually presented nonsense syllables. Seven experiments, involving a total of 520 subjects, are reported. The experimental paradigm was to test 6 independent groups of Ss in each experiment (except Experiments VI and VII). The six experimental groups were: (1) Immediate-test, (2) Delayed-test, (3) Dissimilar-interpolation (numbers) before the test, (4) Similar-interpolation (similar nonsense syllables) before the test, (5) Similar-proactive presentation before the stimulus items (test follows), and (6) Dissimilar-proactive presentation before the stimulus items. All presentation was sequential.

Experiment I was a preliminary study designed to develop a technique to study short-term recognition memory. Ten low-association value nonsense syllables were used as the stimulus items; ten 3-digit numbers and 10 similar nonsense syllables were used as the "dissimilarity-control" and interference materials respectively. The recognition test was a 50-alternative (including the 10 stimulus and 10 interference items) "yes-no" choice for all the alternatives sequentially presented. The results do not show any decay effect but the similarity-interference (RI and PI) was highly significant.

Experiment II was a replication of Experiment I with a faster rate of presentation in order to eliminate the associational factors observed in Experiment I. The results of Experiment II more strongly support the interference theory in short-term recognition memory.

Experiment III used a 50-alternative multiple-choice recognition test with all the alternatives presented together. Ss were required to pick out the "correct" (stimulus) items within a time-limit. In all other respects Experiment III was similar to Experiments I and II. The results confirmed the first two experiments: no decay but significant interference.

The analyses of the recognition-errors in the first three experiments indicate that the observed interference effect might have been an artifact of the recognition test which required a discrimination of the list-membership of the recognized items due to the appearance of the interference items among the recognition alternatives.

Experiment IV was a 3-alternative forced-choice recognition test for each of the stimulus items. The interference items did not occur among the recognition alternatives. There was neither decay nor interference shown by the results.

Experiment V increased the interference materials by three times in order to determine the extent of persistence of short-term recognition memory against interference. The results did not show any RI effect; the PI effect was significant at the .05 level.

Experiment VI increased the delay interval by three times to determine whether short-term recognition memory is subject to decay at a longer delay. The results do not show any decay effect; nor is there significant RI effect. The PI groups were left out in this experiment.

Experiment IV, V and VI used different rates for the presentation of the stimulus and interference items. The differential learning of the stimulus and interference items resulting from their different rates of presentation might have obscured an interference effect in Experiments IV, V and VI. Accordingly, Experiment VII used an equal rate of presentation for both the stimulus and interference items. The rate of presentation does not seem to have affected the RI effect; but the PI effect observed in Experiment V does not occur in Experiment VII with equal rate of presentation for the stimulus and interference items.

The overall results do not support the decay theory of short-term recognition memory. Although the PI effect was significant in one experiment (Experiment V), the results do not support an interference theory of short-term recognition memory. Short-term recognition memory seems to persist against both decay and interference. The results are interpreted by assuming that the memory storage may persist even after retrieval is lost and recall has failed. The storage is revealed by a recognition test which does not require retrieval; and the recognition memory persists against decay or interference, as was observed in the present study.

APPENDIX

Tables of Analyses of Variance

Table A

Analysis of Variance for Recognition Scores

(Corrected for Guessing): Experiment I

Source	SS	df	MS	F
Between Groups	139.20	5	27.84	7.05**
Within Groups	213.34	54	3.95	
Total	352.54	59		

** $p<.01$

Table B

Analysis of Variance (Repeated Measures) for Recognition-

Errors from the Interference and New Items: Experiment I

Source	SS	df	MS	F
Between Subjects	1073.49	59		
Groups (G)	343.84	5	68.77	5.09***
Error b	729.65	54	13.51	
Within Subjects	727.50	60		
Repeated Measures (R)	75.21	1	75.21	9.16**
R X G	208.84	5	41.77	5.09***
Error w	443.45	54	8.21	

** $p<.01$

*** $p<.001$

Table C

Analysis of Variance for Recognition Scores

(Corrected for Guessing): Experiment II

Source	SS	df	MS	F
Between Groups	184.66	5	36.93	9.35***
Within Groups	<u>213.23</u>	<u>54</u>	3.95	
Total	397.89	59		

*** $p<.001$

Table D

Analysis of Variance (Repeated Measures) for Recognition-Errors from the Interference and New Items: Experiment II

Source	SS	df	MS	F
Between Subjects	791.67	59		
Groups (G)	257.37	5	51.47	5.20***
Error b	534.30	54	9.89	
Within Subjects	815.00	60		
Repeated Measures (R)	177.63	1	177.63	22.28***
R X G	206.87	5	41.37	5.19***
Error w	430.50	54	7.97	

*** $p<.001$

Table E

Analysis of Variance for Recognition Scores

(Corrected for Guessing): Experiment III

Source	SS	df	MS	F
Between Groups	131.07	5	26.21	6.99***
Within Groups	427.59	114	3.75	
Total	558.66	119		

*** $p < .001$

Table F

Analysis of Variance (Repeated Measures) for Recognition-

Errors from the Interference and New Items: Experiment III

Source	SS	df	MS	F
Between Subjects	887.66	119		
Groups (G)	264.99	5	53.00	9.70***
Error b	622.68	114	5.46	
Within Subjects	967.50	120		
Repeated Measures (R)	189.04	1	189.04	35.45***
R X G	170.49	5	34.10	6.39***
Error w	607.98	114	5.33	

*** $p<.001$

Table G

Analysis of Variance for Number Correct: Experiment IV

Source	SS	df	MS	F
Between Groups	19.74	5	3.95	2.01
Within Groups	224.05	114	1.97	
Total	243.79	119		

Table H

Analysis of Variance for Number Correct: Experiment V

Source	SS	df	MS	F
Between Groups	35.90	5	7.18	2.99*
Within Groups	273.30	114	2.40	
Total	309.20	119		

* $p<.05$

Table I

Analysis of Variance for Number Correct: Experiment VI

Source	SS	df	MS	F
Between Groups	3.70	3	1.23	0.49
Within Groups	189.30	76	2.49	
Total	193.00	79		

Table J

Analysis of Variance for the Similarity RI Group (Group 4) over Experiments Using Different Rates of Presentation for the Stimulus and Interference Items

Source	SS	df	MS	F
Between Experiments	13.04	3	4.35	1.72
Within Experiments	192.15	76	2.53	
Total	205.19	79		

Table K

Analysis of Variance for the Similarity PI Group (Group 5) over Experiments Using Different Rates of Presentation for the Stimulus and Interference Items

Source	SS	df	MS	F
Between Experiments	24.13	2	12.07	4.22*
Within Experiments	162.80	57	2.86	
Total	186.93	59		

* $p<.05$

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