WORDS AND PICTURES IN A SHORT-TERM MEMORY TASK

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ABSTRACT

The following series of experiments was designed to investigate verbal and visual coding differences for visually presented words and their corresponding pictures in a STM task. Results show that verbal and visual short-term coding depends on task requirements. In a free recall situation, words and pictures have to be labelled for the response task, and subsequent recall scores reflect verbal coding in both conditions. If verbal coding of pictures can be reduced, as in a recognition task, evidence for verbal and visual short-term coding processes can be obtained in conjunction with verbal interference and rehearsal activities during the retention interval. The damaging effects of verbal interference and the facilitative effects of verbal rehearsal for the verbal short-term store have been reconfirmed in this experiment. The same interpolated activities, in contrast, have been shown to exert an undifferentiated effect on the visual short-term store. The data are interpreted as supporting previous findings of the verbal short-term store characteristics. In contrast, the picture recognition data seem indicative of a visual short-term store. In contrast to the verbal store, however, the visual store shows a lack of, or at least an ineffective rehearsal mechanism in the given experimental situation.

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GENERAL INTRODUCTION

Memory research within the last decade has provided sufficient evidence in favour of a trichotomous human memory system persuading even the more traditional theorists to abandon the previously accepted unitary memory concept. While there is less than unanimous agreement on the nature of and necessity to include particular subsystems, several of these seem to reappear consistently in various models, though in slightly altered forms. In general, these basic memory subsystems include a sensory memory, and a short term memory system as well as the more familiar long term memory.

Ample support for the concept of a sensory memory, at least in the visual modality, has accumulated since Sperling's work with tachistoscopic stimulus presentations (Sperling, 1960; Neisser, 1967). This line of research has established that after the termination of a visual stimulus, some information continues to be available to S for further processing for a brief period of time. In general, the findings suggest that the visual stimulus leaves a brief sensory trace which rapidly decays during a period of several hundred milliseconds, which is subject to masking and replacement by immediately succeeding stimuli. A similar case has also been made for the auditory modality in Neisser's (1967) echoic memory system, and Crowder's (1970) precategorical acoustic storage.

While sensory traces of this kind almost border the realm of perception, and subsequently can be easily identified as a distinct memory system, the dichotomy between short-term memory (STM) and long-term memory (LTM) underwent a more controversial development. The need to distinguish between a primary and secondary memory system had already been realized by William James (1890). Yet, it was not until Peterson and Peterson (1959) set the groundwork for an operational distinction between the two systems that theoretical models emerged which utilized this dichotomy (Waugh & Norman, 1965; Neisser, 1967; Atkinson & Shiffrin, 1968).

The distinction between STM and LTM is based largely on two criteria: first, the operational definition describing the experimental situation; second, characteristics ascribed to memory structures and processes operating within the two experimental paradigms. Short-term memory experiments are usually defined as investigating memory after single, brief stimulus presentations and short retention intervals. In contrast, LTM experiments make use of repeated trials and relatively longer retention intervals. Basic characteristics proposed for STM include a limited storage capacity, a rehearsal mechanism, and a coding mechanism which relies predominantly on verbal-acoustic features of the stimulus material. In contrast, LTM characteristics include, among others, an unlimited storage capacity, indefinite retention of stored information, and elaborate coding mechanisms.

Probably the most fruitful current memory model utilizing these subsystems has been developed by Atkinson & Shiffrin (1968). Subdivided into the sensory memory (SM), short-term store (STS), and long-term store (LTS), the model introduces several innovative features with potentially far reaching implications for memory research and theory. For instance, a clear distinction is made between STM and STS - similarly between LTM and LTS - which is generally based on the previously discussed defining criteria of each subsystem. Hence, STM refers to the operational definition of the experimental situation and STS to the memory mechanism underlying the previously discussed characteristics which may obtain in a STM task. In addition, there is a strong attempt to differentiate between structural features and control processes, as well as their interaction, within each subsystem. This particular aspect of the model is, however, still at a highly tentative stage due to the lack and difficulty of experimental validation. Yet, the model at least takes these necessary refinements of a theory into consideration. Similarly, though the model is largely based on research with verbal stimulus material, it provides ample room for additions of non-verbal memory processes, thereby encouraging research in other memory modalities not yet adequately investigated. Apart from presenting a comprehensive, workable model for current memory research, Atkinson & Shiffrin succeed in providing a theoretical framework designed to stimulate and incorporate a vast amount of future memory research.

Evidence supporting the trichotomy of human memory is by no means unambiguous, yet does point towards the general validity of the concept with regard to STS characteristics, for instance, it sometimes becomes necessary to rely on inferences from widely divergent research in order to arrive at acceptable postulates. For example, short-term memory capacity had long been investigated (Miller, 1956), though in a different context. Whether employing digits, letters or words, Miller found the immediate memory span to be fairly constant if measured in terms of number of items, i.e. seven items plus or minus two. But, in terms of information content, this finding does not hold across types of stimulus material. Miller overcomes this paradox by expressing the basic unit of memory storage in "bits of information." That is, one letter and one word with several letters constitute each one bit of information. Atkinson & Shiffrin interpret the limited storage capacity of STS in terms of rehearsal processes. They propose a rehearsal buffer of fixed size which is determined by input and reorganisation factors of the experimental situation.

More critical than the specific size of the rehearsal buffer, i.e., STS capacity, is its important function as a regenerating mechanism of STS traces[1] (Atkinson & Shiffrin, 1968). Evidence of the functional significance of the rehearsal mechanism derives from two divergent experimental operations, i.e. introducing rehearsal or interference during the retention interval in a STM task. In the typical interference paradigm, initiated by Peterson and Peterson (1959), S is presented with the stimulus, which is followed by a three digit number from which S has to count backwards by threes until cued for the response task. Murdock (1963) found recall of triads and trigrams to decrease to a probability of .08 after 15 to 18 seconds of counting backwards. In contrast, if rehearsal is allowed during the retention interval, recall for letters, words, and sentences has been shown to increase over a 10 second delay (Crawford, Hunt & Grahame, 1966). Combining the two operations, recall can effectively be manipulated by introducing repetitions (Hellyer, 1962) or rehearsal (Stonner & Muenzinger, 1969) before the onset of the interference task.

In terms of the Atkinson and Shiffrin model the following events are assumed to occur in these experimental situations. When the stimulus is presented it enters the sensory memory and is at once transferred to the STS, where an attempt is made to rehearse the stimulus material. Such attempts are terminated when attention is given to the interference task. The decreasing response strength with longer interference intervals subsequently reflects the continuous loss of information from STS if the material is not rehearsed. Almost complete loss of information in STS is postulated to appear after 15 to 30 seconds. The observation that recall probability is not zero after 15 seconds (Murdock, 1963) is attributed to an initial build-up of memory traces in LTS. This initial build-up of the LTS trace can be regulated by introducing repetition or rehearsal before the interference task. On the other hand, in an experimental situation without an interference task there will be no loss of information from STS, given optimal experimental conditions, since the rehearsal mechanism serves to regenerate short-term traces as well as to transfer information to the more permanent LTS. Hence, response scores in this situation will be facilitated by STS and LTS. In effect, the functional importance of the STS rehearsal mechanism appears to be threefold: it prevents loss of information in STS, builds up short-term traces by continuous regeneration, and is instrumental in the transfer of information to LTS.

The third important feature of STS is the predominantly verbal-acoustic effects in STM experiments. Sperling (1960, 1963) postulated an "auditory information storage" in immediate memory as a result of observing a large number of auditory confusion errors with tachistoscopically presented stimuli. Further support for verbal-acoustic effects in STM derived from a paradigm which investigates error scores after presenting strings of either acoustically similar or dissimilar items. The generally consistent findings in this experimental situation are: 1) substitution errors tend to be acoustically confusing items; and 2) there is a higher error score with acoustically similar than dissimilar lists. These results hold for strings of consonants, whether auditorily presented and embedded in noise (Conrad, 1964) or visually presented (Wickelgren, 1965), and are also consistent for words, (i.e. homophones), in a recall (Kintch & Buschke, 1969), or recognition task (Wickelgren, 1966).

The latter findings are quite in contrast to LTM research where performance is shown to be impaired by semantic but not acoustic similarity (Baddely, 1966). The implications of this line of research, therefore, strongly suggest that STS relies largely on acoustic coding and is relatively unaffected by the semantic content of the message to be stored. However, semantic factors may be important under given experimental manipulations in a STM experiment (Wickens & Eckler, 1968).

Thus, STM experiments employing a variety of tasks and stimuli tend to present consistent evidence in favour of STS as a distinct memory system. Storage capacity seems certainly the least disputable distinctive feature, simply because of the experimental requirements of the respective memory tasks. The significance of the rehearsal mechanism in preventing loss of information from STS and in implementing the transfer process to LTS has also been adequately displayed with help of rehearsal and interference activities in STM experiments. Furthermore, acoustic versus semantic similarity effects on STS and LTS suggest distinctively different coding mechanisms for the two subsystems.

At the same time, however, it is not certain that STS is an exclusively verbal-auditory memory system. Evidence suggesting non-verbal short-term processes has been obtained in a variety of experimental situations. In an experiment correlating the ability to reproduce briefly exposed figures with the ability to describe them, Cohen and Granström (1969) found a higher positive correlation between performance on the two tasks for complex than for simple figures. Cohen and Granström suggest that the difference is due to visual memory which plays a greater role in memorizing simple figures. However, their evidence for a visual STS has to be evaluated in light of two critical factors in the experiment: visual and verbal aspects of the experimental task are not experimentally separated, and, the correlations are based on two different paradigms, i.e. a Peterson and Peterson (1959) task for reproduction versus a 90-sec. stimulus exposure during description. More convincing evidence for a visual STS is presented by Posner's (Posner, 1967; Posner & Konick, 1966) visual location task, in which S has to reproduce the angle of a previously presented line segment in a typical Peterson and Peterson paradigm. Results show that a rest period, i.e. time for verbal rehearsal, does not facilitate performance, while a written interpolated task lowers the accuracy of the location response. In addition a more accurate response level can be obtained by giving S visual rather than exact verbal information of the stimulus angle. In this situation the stimulus material apparently cannot be readily encoded verbally. Therefore, verbal rehearsal and verbal stimulus information do not lead to response facilitation. On the other hand, during the written interpolated task, attention is diverted from the STS of the stimulus pattern, leading to a decrement in performance. The implications here are still ambiguous. The decreasing response level after interference seems typical of verbal storage. Yet, the superior performance with a visually presented stimulus angle over exact verbal information of the stimulus angle, as well as the ineffectiveness of verbal rehearsal, strongly suggest that other than verbal short-term processes are involved in an experiment of this type. It seems difficult, however, to determine empirically to what extent kinesthetic or visual short-term processes are underlying these results.

Up to this point, non-verbal short-term processes have been discussed with respect to visually presented stimulus information which can not be readily verbalized. The question then arises as to what happens, when a given stimulus configuration, presented visually, can be equally well encoded verbally or non-verbally, i.e., in a visual, physical form. Words and digits, for instance can be labelled, as well as recognized, as physical configurations. Will the visually presented letter, therefore, be encoded in verbal-acoustic properties or physical-visual properties of the stimulus? The previously discussed research points strongly towards verbal-acoustic coding of letters in STM experiments. However, under different experimental manipulations, as in a visual search task, Gibson and Jonas (1966) demonstrated that visually confusing letters lead to lower performance than do acoustically confusing lists of letters. Since the task requirements in this experiment involve a visual scanning of an array of letters, visual storage of the target letter seems a more efficient working modality for this task. Whether this visual storage is in STS or LTS, however, is unclear.

Other research suggests that there are also modality-specific interference effects. Margrain (1967) found a stronger interference effect for recall of visually presented words following written than verbal interpolated activity. On the other hand, in an auditory shadowing experiment recall suffered more for auditorily than for visually presented letters, but only after a 25-second retention interval (Kroll, Parks, Parkinson, Bieber & Johnson, 1970). Interesting as these data are in their implications with respect to verbal and non-verbal short-term coding mechanisms, possible conclusions from this type of evidence have to remain tentative until supported by future research.

Further evidence suggesting that non-verbal encoding processes can be found in a variety of "same-different" recognition experiments. In a letter matching task, reaction time is faster in a physical than a name match, if the letters are separated by up to one second (Posner, Boies, Eichelman & Taylor, 1969). The superiority of a physical match, however, disappears with an interstimulus interval of two or more seconds. If sensory memory involvement can be considered in this task, the following interpretation will emerge. When the test letter is presented before verbal encoding is completed, the matching response is mediated by the sensory trace of the SM, resulting in superior physical matching in the shorter presentation intervals. Since the memory trace of the SM decays rapidly, the matching response after a 2-sec. interval is mediated by equally efficient auditory and visual short-term traces. In effect, there seems to be a similarly efficient information transfer process from the sensory memory to STS in the verbal and non-verbal short-term system.

The evidence reviewed to this point is, however, still ambiguous. While the results are suggestive of non-verbal STS, the data can also be explained by other mechanisms. Probably the most convincing attempt to separate verbal and visual coding mechanisms in a STM task has been presented by Tversky (1969). In a manner similar to Posner et al. (1969) Tversky used a "same-different" recognition task with a 1-sec. interstimulus interval. The stimuli consisted of visually presented schematic faces and their well-learned names. In each block of trials Ss were presented with either word or picture stimuli. The first stage was always followed by either a word or a picture. Stimuli in the second stage were always arranged in an eight to two ratio. Results showed that reaction time was always faster for the more frequently presented type of second stimuli, regardless of whether the first stimuli were words or pictures. Thus, the evidence from this experiment suggests that verbal material can be encoded pictorially, and pictorial material can be encoded verbally. Furthermore, the particular coding strategies could be effectively manipulated by S's anticipation of the response requirements.

A completely different approach to delineate verbal and visual coding processes has been taken by Paivio and Czapo (1969). Words and pictures of familiar objects were presented at 5.3 or 2 items per second and tested on four response tasks. At the fast presentation rate no modality difference appeared, regardless of response task. There was a general increase in performance for all groups at the slower rate, with an additional picture over word superiority for recall and recognition scores. Since the fast presentation rate was designed to prevent crossmodality encoding, i.e. pictures encoded verbally and vice versa, results provide further support that under given experimental conditions equal auditory-verbal and visual coding abilities can be demonstrated. Recall and recognition scores at the slow rate are, however, quite in contrast to previous modality effects in STM research. In light of the response requirements, i.e. the recognition task lasting 108 seconds, and since modality effects are in line with LTM characteristics (Shepard, 1967) these data, however, present little argument against previous STM findings, and should probably be evaluated within a LTM framework.

To summarize, verbal-acoustic variables have been extensively used in STM research, initially in conjunction with semantic variables to isolate STM effects, and later in conjunction with visual-pictorial variables in order to investigate verbal and non-verbal coding mechanisms in STS. The differential effect of semantic and acoustic similarity in LTM and STM experiments has been one of the more convincing arguments for postulating two memory systems. The data strongly suggest that STS relies heavily on the acoustic characteristics of the input information, regardless of visual or auditory presentation, which is quite in contrast to LTS characteristics. However, alternate coding mechanisms in STM experiments also have been postulated. For instance, if the visual information cannot be readily verbalized or if the task requirements of the experiment are not facilitated by a verbal code, short-term processes in other modalities may be available to S. But, in contrast to evidence supporting the verbal

STS, corresponding non-verbal processes seem still at a highly tentative stage. The major purpose of the present research was to explore further ways of contrasting verbal and non-verbal coding mechanisms in STM tasks.

At the same time, there is no memory model available at this stage which claims to account for all these data collected in STM experiments. While the Atkinson and Shiffrin model (1968) presents an adequate framework for verbal-auditory STS processes, it is only the lack of consistent empirical evidence which hastens them to postulate similar non-verbal short-term structures and processes. It is probably worth noting at this time that most of the support for a visual STS has been provided since their model was published. In any case, non-verbal STM systems can be readily incorporated in the present structure of their model, and it becomes, therefore, important to investigate these systematically to determine the nature of non-verbal STM effects.

The present research is, therefore, designed to investigate short-term memory processes with respect to visually presented words and pictures. Since pictorial information in the sensory store can be encoded and stored verbally, given the appropriate experimental situation, the following question emerges. If the pictorial information is prevented from being encoded verbally, does a visual short-term mechanism exist which will store and rehearse the pictorial information over STM retention intervals? In other words, can similar structures and processes of the verbal-auditory STS be found in the visual STS? By presenting a matrix of familiar objects as either words or pictures, and testing recognition at various intervals, it is expected that rehearsal and interference effects of previous STM studies can be replicated with verbal material. The important findings in this research, however, will center around rehearsal and interference effects in picture conditions. Since the results can be influenced by differential acquisition rates in the learning stage, definite predictions can not be made at this time, but the implications arising from the results will under any circumstances be valuable. A comparison of the interpolated activity effects across word and picture presentations should reveal possible differences or similarities of the two coding mechanisms, while a comparison of rehearsal and interference effects in the picture groups should throw some light on the usefulness of the concept of a visual rehearsal mechanism.

However, before it is assumed that a given experiment has exposed verbal-pictorial coding differences of short-term processes, several critical aspects of the design will have to be carefully considered. One major problem in a word-picture comparison is the uncertainty as to what extent the two coding processes might be confounded within each operationally defined condition. That is, how readily and how fast are pictures encoded verbally, and words coded pictorially, thereby reflecting results within a given condition, which might in fact be mediated by processes in both modalities. Reaction time measures, for instance, show visual encoding of words to be slower than verbal encoding of pictures. Also, words can be read faster than objects can be named (Paivio & Czapo, 1969). But, evidence of this kind can only be considered as a rough correlation of motor and sensory-motor responses with their underlying psychological processes, without revealing direct evidence about the availability of these memory processes. It becomes necessary, therefore, to consider carefully encoding, storage, and retrieval factors in the design of the experimental task, in order to reduce, if not eliminate confounding effects of cross-modality encoding.

EXPERIMENT I

Introduction

The first experiment was designed to determine to what extent words and pictures can be differentially encoded in their respective verbal and visual STS, how effective the two codes are in a recognition sequence, and how damaging verbal interference is on the short-term storage in both coding systems. A series of pilot studies, ranging from presenting one item, to presenting nine items in a Peterson and Peterson task, led to the choice of using six items, presented for 1.2 seconds, as an optimal learning task. The test phase of the experiment consisted of six item recognition sequences after 0, 15 and 30 seconds of verbal interference which could be analysed with respect to recognition and latency scores.

The choice of particular temporal and task variables was largely based on previous research findings and results from pilot studies. Hence, the combination of input capacity and temporal presentation seemed sufficiently difficult to allow for errors reflecting changes due to the interpolated activity, while also remaining within the immediate memory span capacity (Miller, 1956). Although there was no experimental control over the time S would spend with each item in the matrix, it was expected that the requirements of the response task would force S to scan over each item in the matrix at an equally rapid rate, i.e. on the average 200 milliseconds, to reduce, if not to eliminate cross-modality encoding (Paivio & Czapo, 1969; Neisser, 1967). The choice of a six-item recognition sequence was partly an arbitrary decision. This task has the advantage of testing a larger part of the memory store, while possibly introducing additional delay effects for most recognition responses. In any case, a recognition task will minimize retrieval problems and, therefore, reflect response scores which are more sensitive to memory storage. It also has the advantage of avoiding the necessity of verbal responding to pictorial material.

Differential coding mechanisms for visually presented words and pictures can then be assessed by recognition and latency scores in a factorial design using words and pictures in the learning and recognition stage. This design generates two same-presentation groups, i.e. Word-Word (WW) and Picture-Picture (PP), and two mixed presentation groups, i.e. Word-Picture (WP) and Picture-Word (PW). Predictions as well as results of this experiment will have to be evaluated with respect to two questions: 1) is the learning rate the same for pictures and words?; 2) how strong, if any, are the effects of cross-modality encoding? The first question was tentatively resolved in pilot work where recall and recognition scores, as well as subjective reports of scanning rates seemed to suggest similar learning rates for words and pictures. The second problem can be more satisfactorily assessed by a comparison of WW-WP and PP-PW groups. If the mixed-presentation groups reveal a similar interference effect as their respective same-presentation groups it can be safely inferred that the information was stored in the form of the learning phase, i.e. no cross-modality encoding. This analysis, of course, precludes a differential interference effect in WW and PP groups.

Given these two assumptions, the following assessment of differential storage for word and picture material can be made. Zero delay responses for WW and PP groups should reflect the most accurate storage differences due to verbal and visual coding effects. Comparisons among WW-WP and PP-PW should reveal no differences in recognition scores unless the stimulus materials are poorly designed. Latency scores in these comparisons should, however, differ because of increased retrieval problems in mixed-presentation groups. Interference effects on verbal storage should lead to lower recognition scores with longer delays, while responses in the picture groups should show to what extent the visual store is affected by verbal interference. A comparison of WW-WP and PP-PW groups should in turn indicate the degree of cross-modality encoding under these experimental conditions.

If these two assumptions do not hold, different results will have to be expected. Differential learning rates will, of course, render the analysis of verbal versus visual storage mechanisms worthless. Similarly, cross-modality encoding, if it occurs in both directions will reduce word-picture differences within each delay condition. In effect then, while it might be impossible to separate completely verbal and visual memory processes in a given experimental design and, in the end, be able to postulate purely verbal and purely visual components of STS, it can be expected that at least the results of the design will indicate to what extent this aim has been achieved.

METHOD

Subjects and Design

Students from introductory psychology courses were contacted by phone and asked to volunteer for the experiment. Forty males and forty females, ranging in age from 17 to 23 years, participated in EXP. 1. Twenty Ss were assigned to each group, i.e. WW, WP, PW, PP. Each group was further subdivided into sub-groups of five Ss each receiving a different learning list.

Delay was added as a within-subject variable. The three delay periods, 0, 15 and 30 sec., were randomly assigned to the nine trials in blocks of threes. Since complete latinization of delay, trials, and sets of lists seemed unfeasable, two randomly determined delay sequences were used for 10 Ss in each group. No claim can be made about complete randomization of the delay variable. However, similar to the probe position variable within the lists, the complexity of the task left no choice about these possible confounding effects.

Material

A basic pool of 81 items was obtained from stimulus material used by Paivio and Czapo (1969). The items consisted of pictorial representations of familiar objects in the form of simple line drawings. Consistency of labelling data had been obtained on these drawings (Paivio & Czapo, 1969) to ensure unambiguity of the stimuli. In their verbal form the items consisted of concrete words with high frequency and meaningfulness ratings. For the verbal condition each word was printed on a 4" x 6" card in 1-in. block letters. For the picture condition each item appeared as a simple line drawing. Special care had been taken to keep size and complexity of the drawings equal for all objects.

Two sets of items were constructed for each trial. Six items per trial appeared in the learning phase as a 3 x 2 matrix, three items high and two across. Three items from the learning stage (OLD items) and three NEW items were then randomly arranged for the recognition sequence. The matrices as well as the single recognition items were then photographed in their verbal and pictorial form. The negatives were mounted as slides in which the items appeared as white outlines on a dark background.

There were two problems which had to be considered in constructing the lists: (a) the positions of the probe items in the matrix as well as in the recognition sequence; (b) high associations of items, semantic and acoustic similarities of words as well as similarities of their pictorial representations had to be avoided within each list.

Since it seemed unfeasable to latinize completely probe positions and list content, four sets of nine lists each were constructed. The number of lists used was largely limited by the number of available items which could meet the criteria of stimulus selection. Two sets of list content and two sets of probe positions were factorially combined to generate four different sets of learning lists. Set Ia differed from set Ib only with respect to the positions of the probes. Set IIa and IIb contained a new arrangement of list content, but had the same probe positions as Ia and Ib respectively. The recognition sequences I and II, following learning lists Ia, Ib and IIa, IIb respectively, differed in list content, but not in probe positions. In effect then, each probe item in the learning stage was presented at two different positions in the matrix, and each probe position in the learning stage was tested with two different probe items.

The probe positions in the matrices and the recognition sequence were, of course, randomly determined, and every position was equally often probed. However, since there are six possible positions and nine trials, with three probes in each trial, half of the positions were assigned four, the other half five probes over all nine trials.

The selection of list content for the two sets, in contrast, was only partly determined by random selection, since other factors seemed of greater importance. For instance, acoustically similar items had to be separated, e.g. tower-flower, associations like flower-boy had to be avoided, and categories, e.g. fruits, animals etc. had to be evenly divided over the nine trials. At the same time it was critical not to include items with pictorial similarity in the same list, e.g. pencil-arrow-cigar. In addition, two practice lists were constructed to familiarize S with the procedure. Since words and pictures were used in the test phase, letters of the alphabet were chosen as fairly neutral items for the practice session.

Apparatus

A Carousel 850 projector was connected to an automatic timer for the presentation of the matrix. Recognition slides were presented manually by pressing a button on E's panel. This button also activated a stop timer. The S's panel had two buttons, labeled OLD, NEW. When one of these was activated, it stopped the timer and lit up one of two lights on E's panel, indicating the response choice. E was then able to recycle both panels for the next operation. In addition, E had a separate timer to indicate delay periods as well as presentation rate of the recognition sequence.

Procedure

Ss were individually tested and randomly assigned to the four groups. The male-female ratio was constant across groups. Upon entering the lab, S was seated in front of the response panel eight feet from a 3 x 2 foot screen. E read out a standard set of instructions (Appendix), differing for the four groups only with respect to the particular word-picture presentation involved. S was told he would be presented with a matrix of six items for one second, followed by a sequence of six recognition slides. Some of the recognition slides were from the previous matrix, and some were new items. As a recognition slide appeared on the screen, he was to press, as fast as possible, one of the response buttons, i.e. OLD, for items from the previous matrix, NEW, for items he had not seen before. Since the matrix was presented for a relatively brief exposure, it was twice emphasized that S would have to scan over the six items as fast as possible in order to maximize his recognition score. In addition, if a three-digit number appeared on the screen after the matrix display, S was instructed to count backwards by threes from that number, till the first recognition slide was presented. S did not know how many delay trials or when delay trials occurred, nor was S aware of the OLD-NEW item ratio in the recognition sequence. Instructions were followed by two practice trials, one with delay the other with immediate recognition, to familiarize S with the general procedure.

The following temporal sequence was maintained throughout the experiment. Each test trial started with a 1.2 second presentation of the matrix, followed within one second by either the first recognition slide or a number, in case of delay trials. The presentation rate during the recognition sequence was 7.5 seconds per slide, which included one second for the slide change, for a total of 45 seconds per recognition sequence. Since the occasional S did not respond every time within the 6.5 second presentation of the recognition item, and no provisions had been made to continue the recognition sequence unless S had responded, E was not able to adhere strictly to the 7.5 second presentation rate in all cases. Yet the time for the whole recognition sequence, i.e. maximum 45 seconds, was consistent across all Ss. There was a 20 second interval between the end of the recognition sequence, i.e. 45 seconds after the presentation of the first recognition slide, and the onset of the next trial. During the recognition sequence E scored the response choice as well as latency for each OLD and NEW item.

RESULTS & DISCUSSION

Latency and choice responses were collapsed over the four sets of material. Reaction time measures were almost constant across all four groups and delay conditions (Table 4), which is quite contrary to expected results. While these results could initially be interpreted in terms of undifferentiated coding mechanisms across stimulus material and interference conditions, an inspection of the choice data invalidates this claim. In light of other research investigating reaction time in an STM task, (Posner et al., 1969; Tversky, 1969) it becomes apparent that the underlying causes for the undifferentiated latency scores can be attributed to the particular experimental task at hand. For instance, Posner et al.

and Tversky used repeated daily sessions and highly overlearned test and recognition material in order to obtain latency differences, in contrast to new material, and one session of nine recognition trials in this experiment. Furthermore, since S in this experiment was given 6.5 seconds to respond it seems questionable whether S's emphasis was on fast responding or correct responding. Since the choice data presented consistent recognition differences across conditions and latency scores were fairly constant, they were excluded from further analyses in light of the above mentioned limitations of the experimental situation.

The choice data were analysed with respect to three response measures: (1) correct probe responses; (2) d' scores for all three recognition sequences in each delay condition; (3) percent correct responding to probe items with respect to their position in the recognition sequence. The d' scores include a correction for guessing. It is, for instance, possible for S to respond OLD to every recognition item, thereby obtaining an errorless score on the probe analysis which does not reflect his true recognition level. The d' score was developed to correct the data for guessing errors of this type (Kintsch, 1970) by transforming the number of OLD responses to OLD items and number of OLD responses to NEW items to standard scores on the normal curve. This does not mean, however, that the probe analysis should be completely ignored, since discrepancies between the two measures will point out experimental conditions which are susceptible to guessing.

Initially, the total correct and incorrect responses for OLD and NEW items were computed for each S. The mean correct responses for OLD and incorrect responses for NEW items can be seen in Tables 1 and 3. False alarm scores were subsequently analysed only in conjunction with d' scores. A 2 x 2 x 3 analysis of variance was performed on data from the correct probe responses. The factors are: study-presentation (word vs. picture); test-presentation (word vs. picture), and three delay conditions as a repeated measure (Appendix, Table 1). Presentation effects are small and not significant in the study or recognition phase. There is no main effect for delay. However, the study-presentation x delay interaction is significant ($F=11.99$; $df=2, 152$; $p<.01$). An analysis of simple effects (Appendix, Table 2) points out that study-presentation effects appear only at zero delay ($F=26.26$; $df=2, 152$; $p<.01$). A Newman-Keuls test (Appendix, Table 3) further clarified the nature of this interaction. After 15 seconds of delay, presentation differences disappear due to a significant decrease for verbal and significant increase for picture study groups. In effect, there are only random differences between the four groups at 15- and 30-sec. delay conditions.

A 2 x 2 x 3 analysis of variance for d' scores (Appendix, Table 4) presents some changes in the response pattern (Fig. 1 & 2). There is a significant study x test presentation interaction ($F=10.89$; $df=1,76$; $p<.01$). Recognition scores in both mixed-presentation and PP groups are significantly lower than for the WW group, as indicated by an analysis of simple effects (Appendix, Table 5). The previous study-presentation x delay interaction is, however, also replicated with d' scores ($F=8.42$; $df=2, 152$; $p<.01$). A Newman-Keuls test (Appendix, Table 7) reveals only minor discrepancies between the two analyses at 30 seconds delay. Yet

TABLE 1

Mean Number of Correct Probe Responses with Verbal Interference (Experiment I)

	Delay in Seconds		
	0	15	30
WW	7.75	6.70	7.60
WP	7.50	6.85	6.95
PW	6.60	6.95	7.20
PP	5.90	7.40	7.45

TABLE 2

Mean d' Scores for Experiment I

	Delay in Seconds		
	0	15	30
WW	3.97	3.37	3.17
WP	3.17	2.37	2.30
PW	2.42	2.79	2.95
PP	2.64	3.59	2.95

TABLE 3

Mean False Alarm Rate for Experiment I

	Delay in Seconds		
	0	15	30
WW	.1	.1	.9
WP	.7	1.2	2.00
PW	1.2	.9	1.3
PP	.6	.6	1.1

TABLE 4

Mean Latency Scores for Experiment I

Note: Reaction Time measures include a constant of one second for slide change.

	Delay in Seconds		
	0	15	30
WW	2.35	2.66	2.49
WP	2.54	2.66	2.82
PW	2.51	2.66	2.48
PP	2.48	2.34	2.35

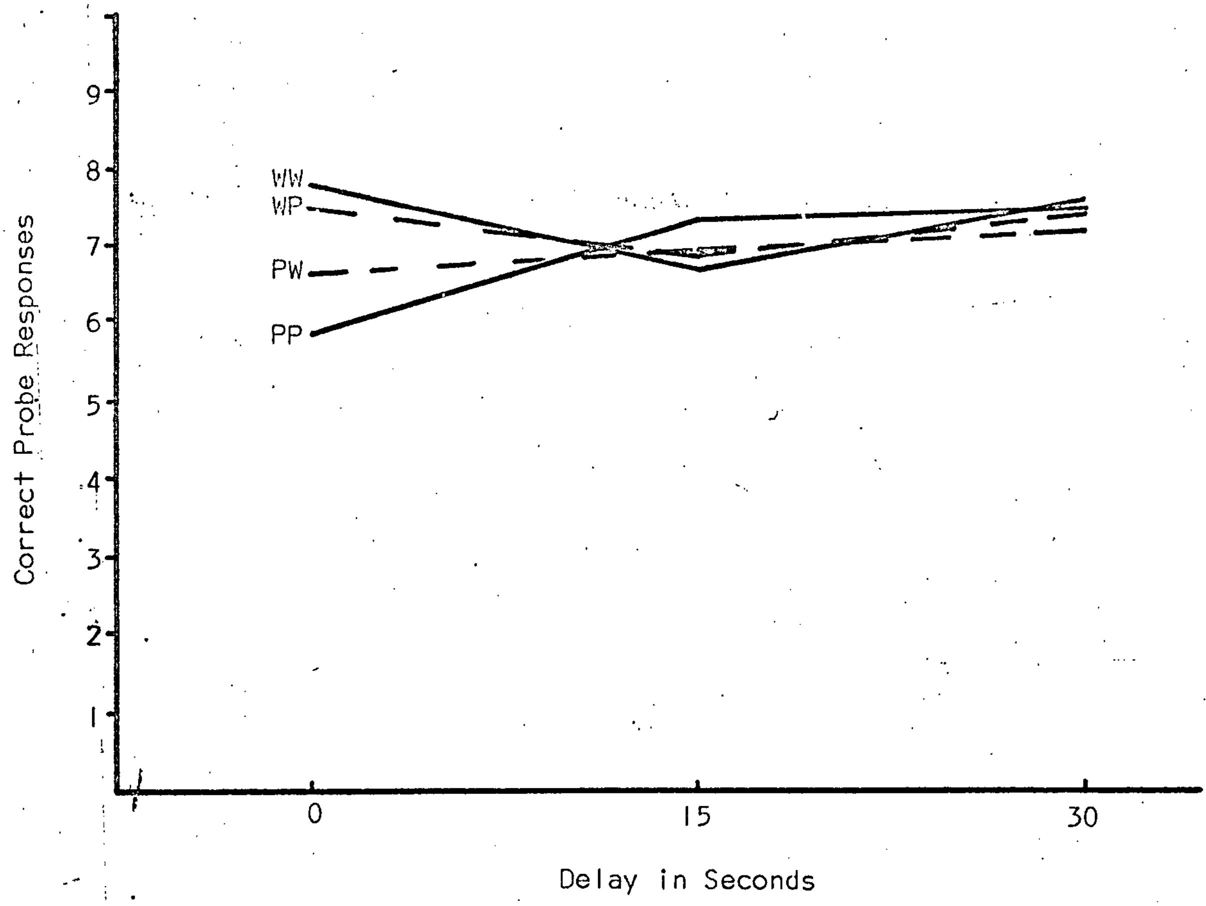

FIG. 1. Mean Number of Probe Responses out of a Maximum of Nine for EXP. 1.

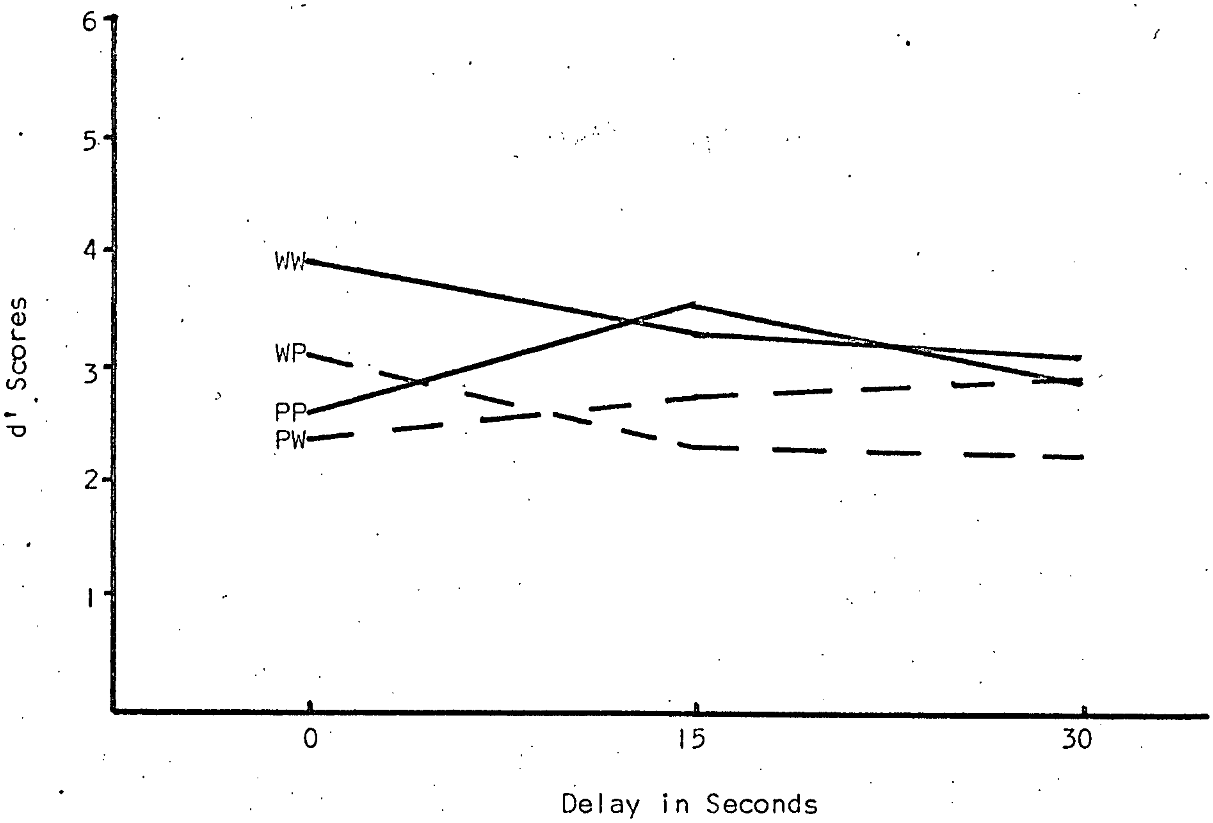

FIG. 2. d' Scores for EXP. I out of a Maximum of Six.

both analyses agree that study-presentation effects appear only in the zero delay condition, followed by a significant convergence of study-presentation effects over delay.

Since discrepancies between the two response measures can be attributed to the correction factor for guessing in the d' scores, a comparison of the response pattern (Fig. 1 & 2), F ratios (Appendix, Tables 1 & 4), and false alarm rates, should point out differential guessing rates for some of the experimental conditions. High agreement between the response measures should indicate experimental conditions in which Ss felt fairly confident about what they have learned, whereas discrepancies will designate conditions in which Ss did not feel as confident about differentiating between probe and distractor items in the recognition sequence. An inspection of Fig. 1 and 2 suggest that little guessing occurred for WW and PP groups, especially at zero delay. The different response patterns for the mixed presentation groups, especially after longer delays, in contrast, suggest two independent factors which seem to encourage guessing i.e. mixed-presentation and delay. This is further substantiated by the different significant F ratios of both analyses. Even though latency scores did not support the claim for increasing retrieval problems in PW and WP, discrepancies between probe responses and d' scores suggest that the higher guessing rate in these groups could be due to increasing errors if words have to be recognized as pictures and vice versa. On the other hand, it seems not too surprising to find longer interference associated with increased guessing. An additional factor contributing to increased guessing during delay conditions can be attributed to the experimental design. That is, delay was used as a within-S variable. Therefore, a particular response set to find an equal number of old responses in each recognition sequence might have developed in Ss, leading to higher guessing rates in these conditions.

Overall word-picture presentation effects are at this stage still fairly ambiguous. The study-presentation effects of the first analysis will have to be attributed to guessing errors inherent in the raw data, in light of the different significant main effects found in both analyses. Even the study x test-presentation interaction of the d' scores has to be qualified by a strong study-presentation x delay interaction. Since zero delay responses are the most accurate indicators of STS, the consistent work-picture difference, at least for the learning stage, presents fairly strong support for the predominantly verbal-acoustic coding mechanism of STS. Even this finding has to be qualified by subsequent clarification of possible differential learning rates for pictures and words.

Delay effects in contrast are more consistent, yet, even more puzzling for the picture study groups. As predicted, verbal interference damages the recognition level of verbal material. While interference effects could be expected to be lower for the visual store, an increase in recognition level certainly seems contradictory to previous results and would not be expected on the basis of any current theoretical framework. It is important to note though that interference effects for mixed-presentation groups are always consistent with their respective same modality group, which provides some evidence against cross-modality encoding in the learning phase.

In order to investigate further the nature of the differential interference effects for words and pictures, responses in the recognition sequence will be analyzed in more detail. The recognition task itself lasted 45 seconds, thereby constituting an additional delay component for five out of six recognition items in each sequence. That is, the temporal arrangement of the recognition task could be a factor determining the unexpected interference effects.

Probe responses were, therefore, converted into percentages of correct responding per position in the sequence. While the data are analyzed in conjunction with the results from EXP. III (Fig. 3) and are discussed in more detail at that stage, it suffices to mention here that apart from random fluctuations within conditions, only one consistent pattern emerged. Probe responses for the first position at zero delay are almost errorless, i.e. 85% and 90% for PP and WW respectively, and are followed by a significant drop to a constant recognition level for the remaining positions. Surprisingly though, the word-picture difference still remains even for the small difference in the first position when analyzed in conjunction with all positions of the sequence. In any case, the critical finding here is the significant drop from the first position to the rest of the sequence. Probe position percentages were also computed for WP and PW groups (Table 7) but were excluded from further analysis since mixed presentation groups were eliminated from further investigation.

In spite of several limitations of the percentage data, i.e. percentages are based on only one or two data points per probe position and are not corrected for guessing, a new interpretation of the experimental task, at least for the zero delay conditions, becomes plausible at this stage. The previous word-picture differences at zero delay, collapsed over all recognition positions, clearly support the verbal superiority in STM experiments. The small modality difference, i.e. 85% and 90%, and temporal consideration of the first position response are more in line with previous research investigating verbal-visual differences using very short temporal parameters. In a partial recall experiment of a 4 x 4 matrix of letters, substitution errors, for instance, were found to be predominantly visual (Rudov, 1966). With a similar approach Turvey (1967) found also no acoustic confusion effects. In addition, Posner et al. (1969) presented convincing evidence for equal visual or name matching under given conditions. Unrelated as these experiments might seem, they do show that similar as well as different coding abilities of visual and verbal material can be obtained depending on given temporal parameters. Neisser (1967) concludes from his research that words or drawings do not differ as long as the "iconic store" has not been encoded verbally.

Furthermore, research in tachistoscopic recognition leaves little doubt that visual impressions are briefly available for further processing even after the termination of the visual stimulus. The duration of this sensory display depends largely on the duration and intensity of the visual display as well as the type of post exposure field (Sperling, 1960, 1963). While some theorists are not as outspoken about the effects of the sensory memory in a wide range of experimental situations due to the lack of sufficient empirical validation (Atkinson & Shiffrin, 1968), Neisser (1967, p. 20) claims that under ideal conditions "the icon remains legible as long as five seconds." Whether the experimental task at hand qualifies as an "ideal condition" is, of course, questionable. Certainly, the stimulus is presented relatively long, the white outlines on a dark background seem of adequate intensity, and most of all, there is no masking effect before the first recognition slide. But, on the other hand, eye movements and physical scanning of the display definitely complicate the analogy. More important, however, is the significant drop in recognition level following the first recognition slide. Though masking effects have only been investigated with tachistoscopic stimulus presentations, the experimental task and the results strongly resemble a masking effect of the sensory store during the first recognition slide. In effect, it is conceivable that data in the zero delay condition are based on responses from two distinct memories. The first position response is mediated by the sensory store, subsequent responses are based on STS.

Since it is critical to the interpretation of zero delay conditions to establish whether the recognition sequence is in fact mediated by different memory systems it becomes necessary to investigate further this proposition. There are two separate experimental manipulations available to determine sensory memory involvement in this particular task: an immediate free recall task and a recognition sequence with an auditory presentation of the first probe. It can be expected that both approaches in conjunction will provide an adequate assessment of the underlying question.

EXPERIMENT II

Introduction

The following experiment was included to determine to what extent an immediate free recall task can be used to investigate sensory memory effects in this experimental situation. Assuming that the stimulus presentation in this experiment falls within Neisser's (1967, p. 20) definition of an "ideal visual display," after all, duration and intensity are sufficient and there is no masking effect, it can be expected that sensory traces will be available to S for a short period of time after termination of the matrix display. Since six items can easily be called out within several seconds, it can be expected that recall scores for word and picture presentation are equally high, assuming, of course, as in EXP. I similar scanning rates in both modalities. The assessment of the expected results is, however, further complicated by the necessary verbal coding of pictures for this response task.

METHOD

Subjects and Design

Twenty-eight Ss from the same subject pool as in EXP. I volunteered for EXP. II. Fourteen Ss were randomly assigned to either word or picture group. The male-female ratio was kept constant across all groups. The four sets of learning material were consecutively alternated in blocks of four within each modality.

Material

All four sets of learning matrices from EXP. I were used in this experiment in their verbal and pictorial forms.

Apparatus

A Carousel 850 projector was activated by an automatic timer for a 1.2 second display of each matrix.

Procedure

Ss were individually tested and randomly assigned to either word or picture study condition. The general procedure and instructions were similar to EXP. I, except modified for an immediate free recall task. That is, learning matrices were presented for 1.2 seconds, followed by S's oral recall. To keep the temporal considerations fairly constant with respect to EXP. I, a 60 second intertrial interval was employed in this task. Aural responses were checked off on a scoring sheet, and a liberal scoring method for the picture condition was used, since objects like ship, doll, oven could equally be labelled boat, girl, stove respectively.

RESULTS & DISCUSSION

Recall scores were collapsed over the four sets of learning lists for word and picture groups. The mean recall scores were 36.67 and 36.57 for pictures and words respectively (Table 9). The lack of word-picture differences of the recall data as well as E's observation that most items were recalled within several seconds after the termination of the stimulus display, fall in line with predictions made from considerations of sensory memory effects. However, the different task demands in the two experiments cannot be ignored as potential confounding variables. Picture recall requires verbal coding, whereas picture recognition does not necessarily demand a similar process. Yet, if labelling pictures and verbalizing words leads to equal recall, differential learning rates in the recognition task should be minimal, assuming similar learning strategies for both response tasks. However, this latter assumption seems also questionable. It is, for instance, necessary to scan over the whole stimulus display to maximize recognition scores, whereas debriefing sessions in the recall experiment suggested that it is more advantageous for S to concentrate on a few items and subsequently be able to recall these, than to look at all six items and forget half of them. However, a clarification of this point has to wait for additional evidence.

Still, the complementary evidence from the recall data and the response pattern of the percentage data for zero delay conditions, do support the idea that word-picture differences of the zero delay sequence can be interpreted with reference to sensory memory effects. Hence, the first position response seems mediated by SM processes, while subsequent positions reflect recognition scores from STS. This STS recognition level is, however, not a true estimate of short-term storage since it is modified by the visual masking effect in SM.

With this new interpretation of the zero delay sequence in mind, even the increase of recognition scores for picture groups over delay also appears in a new light. If the low recognition level at zero delay can be, at least partly, attributed to the masking effect of the initial sensory trace, the difference between zero and 15 seconds delay for picture groups subsequently does not necessarily reflect an increase per se, but merely points to a relative difference due to differential interference effects under the two conditions. That is, the visual masking effect for picture storage at zero delay is more detrimental to recognition than 15 seconds of counting backwards. There is, of course, no masking effect for the 15 second delay condition, since the SM trace only lasts for a brief duration and transfer from SM to verbal STS is complete by then. While the WW group also suffers from visual masking, it is unclear to what extent the zero delay recognition level is due to a superior learning rate or a smaller masking effect. In any case, it seems safe to state that verbal recognition suffers more from counting backwards for 15 seconds than from the masking effect at zero delay.

A summary of findings at this point still presents an ambiguous picture. There are no modality differences at zero delay for a recall task. Yet in a recognition task performance on words is superior to that on pictures. At the same time, this difference cannot be attributed to differential short-term storage because of the masking effect and possible differences in learning rates. Without a valid reference point at zero delay for STS, interference effects can also not be accurately evaluated. Before continuing to investigate SM implications with an auditory first probe presentation, the next step, therefore, will be to replace the interference task with a rehearsal interval, in order to assess interference effects with respect to rehearsal conditions.

EXPERIMENT III

Introduction

Experimental evidence has quite consistently shown the facilitative effects of rehearsal in STM experiments utilizing verbal material (Hellyer, 1962; Crawford et al., 1969). But rehearsal effects on the visual STS have not been convincingly demonstrated. Posner (1967) found no improvement of the visual location response after a 20 second rehearsal period. Milner (1968), in contrast, obtained a lower recognition level for nonsense figures, light flashes, and clicks using both a rehearsal period and an interference task. Stimuli of this type can, of course, not be readily verbalized and are, therefore, well suited for the investigation of non-verbal rehearsal processes. Since cross-modality encoding has been shown to play a negligible role in this experimental task, word and picture groups can, therefore, be expected to reflect a differential rehearsal effect, as well as provide a valid reference point to assess the interference data from EXP. I relative to rehearsal conditions. In order to reduce guessing errors in the data, mixed presentation groups and the 30 second delay condition were eliminated from further investigation. Thus, rehearsal effects will be investigated in WW and PP groups at 0, 7.5 and 15 seconds of delay.

The specific predictions under these experimental conditions are the following. Zero delay responses from WW and PP groups in EXP. I should be replicated. Rehearsal effects should lead to a higher recognition level for WW, either with respect to the interference condition or even with respect to the zero delay condition. Rehearsal effects for PP group cannot be predicted, but a comparison of the recognition level after interference or rehearsal activity should lead to a tentative statement about the fruitfulness of the concept of a visual short-term rehearsal mechanism.

METHOD

Subjects and Design

Forty Ss from the same subject pool participated in EXP. III. Ss were tested in groups and randomly assigned to WW and PP groups. The three recognition intervals, 0, 7.5, and 15 seconds, were randomly assigned to the nine trials in blocks of threes, and were constant across groups.

Material

Only one set of the four learning lists in EXP. I was randomly selected for the group presentation.

Apparatus

As in EXP. I a Carousel 850 projector was activated by an automatic timer. Instead of the response button, Ss received a response sheet to mark down their choices.

Procedure

Ss were tested in groups of ten. Two sessions each were required to fill both groups. Procedures and instructions were identical to EXP. I except for two changes: one, Ss were encouraged to rehearse the learning material during delay; two, scoring sheets were provided and Ss were instructed to answer with "O" (for old) if the recognition item was from the previous matrix, and "N" (for new) if the item had not been presented before.

RESULTS & DISCUSSION

Recognition scores were again tabulated as in EXP. I. Fig. 4 and 5 reveal highly congruent response patterns for correct probe responses and d' scores, indicating that a reduction in guessing errors has been achieved in this design. A comparison of response means (Tables 5 and 6) with EXP. I shows that similar zero delay differences have been obtained again and recognition scores tend to increase in both modalities.

A 2 x 3 analysis of variance for both response measures was performed with factors: (a) presentation (word vs. picture); (b) three delay conditions as a repeated measure. The analysis of probe responses (Appendix, Table 8) reveals a significant superiority of word over picture recognition ($F=18.61$; $df=1, 38$; $p<.01$), as well as a significant increase over delay ($F=8.40$, $df=2, 76$; $p<.01$). The delay effect, however, has to be further qualified by a presentation x delay interaction ($F=5.37$; $df=2, 76$; $p<.01$). A Newman-Keuls test clarifies the nature of this interaction (Appendix, Table 10). That is, word recognition is consistently superior to picture recognition. But there is no increase during rehearsal for WW, while the increase for PP occurs only between 0 and 7.5 seconds.

An analysis of d' scores (Appendix, Table 11) shows an equally strong presentation effect ($F=16.07$, $df=1, 38$; $p<.01$) and improved recognition over rehearsal periods ($F=5.03$; $df=2, 76$; $p<.01$). As opposed to the previous analysis, the interaction is not significant. But, similar to the probe responses, a Newman-Keuls test for the delay effect shows an increase due to rehearsal only between 7.5 and 15 seconds (Appendix,

TABLE 5

Mean Number of d'Scores for WW and PP Groups Under Interference (Experiment I), Rehearsal (Experiment III), and Rehearsal plus Responding to an Initial Auditory Probe (Experiment IV)

		Delay in Seconds			
		0	7.5	15	30
WW	Experiment I	3.97	-	3.37	3.17
	Experiment III	3.73	3.51	4.33	-
	Experiment IV	2.51	3.46	3.14	-
PP	Experiment I	2.42	-	2.79	2.95
	Experiment III	2.46	2.75	3.05	-
	Experiment IV	2.19	2.71	2.94	-

TABLE 6

Mean Number of Correct Probe Responses for WW and PP Groups under Interference (Experiment I), Rehearsal (Experiment III), and Rehearsal plus Responding to an Initial Auditory Probe (Experiment IV)

		Delay in Seconds			
		0	7.5	15	30
WW	Experiment I	7.75	-	6.70	7.60
	Experiment III	7.55	7.25	7.05	-
	Experiment IV	6.25	6.95	6.75	-
PP	Experiment I	5.90	-	7.40	7.45
	Experiment III	5.30	6.35	6.90	-
	Experiment IV	5.60	6.80	7.05	-

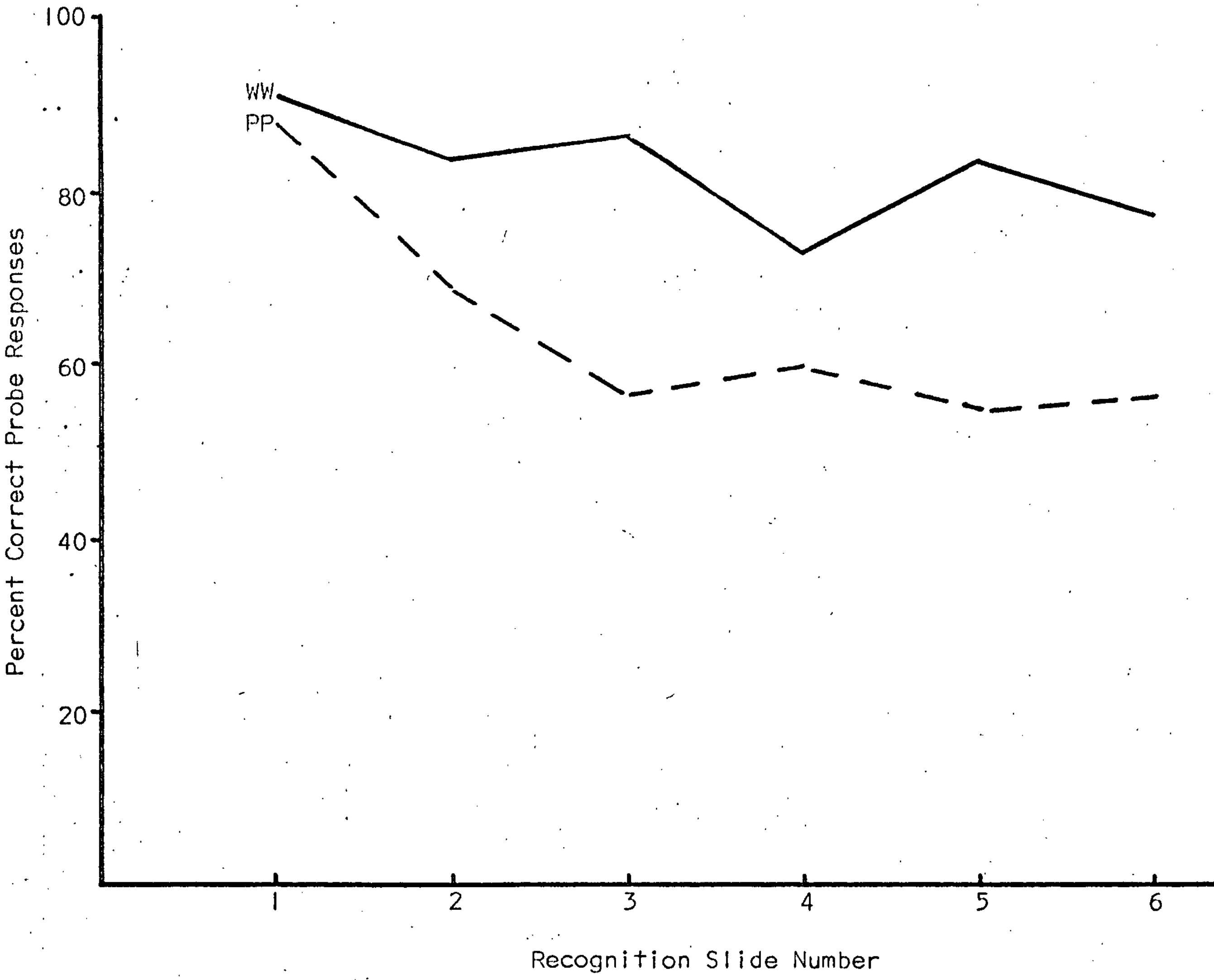

FIG. 3. Percent Correct Probe Responses for PP and WW on Zero Delay Recognition Trials Collapsed Over EXP. I and III.

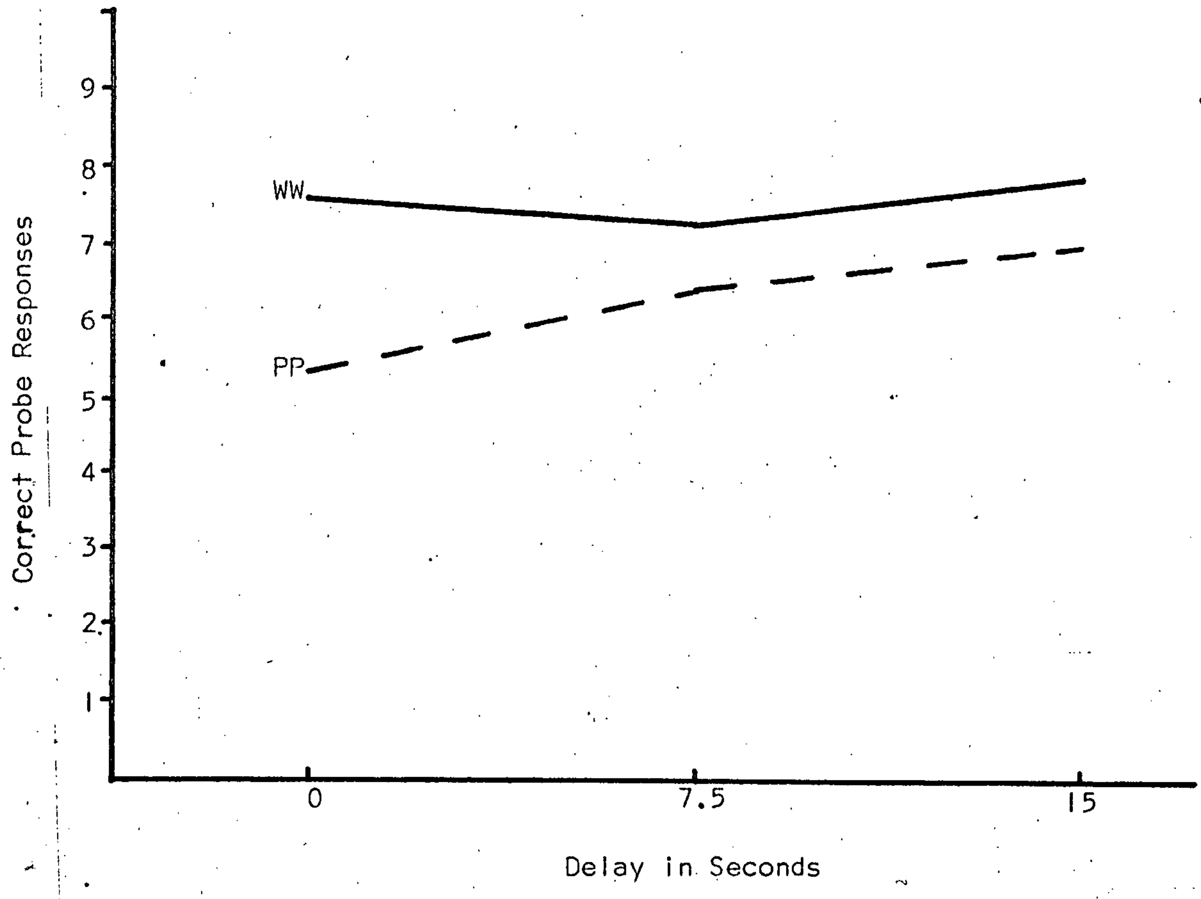

FIG. 4. Number of Correct Probe Responses out of Maximum of Nine for EXP. III.

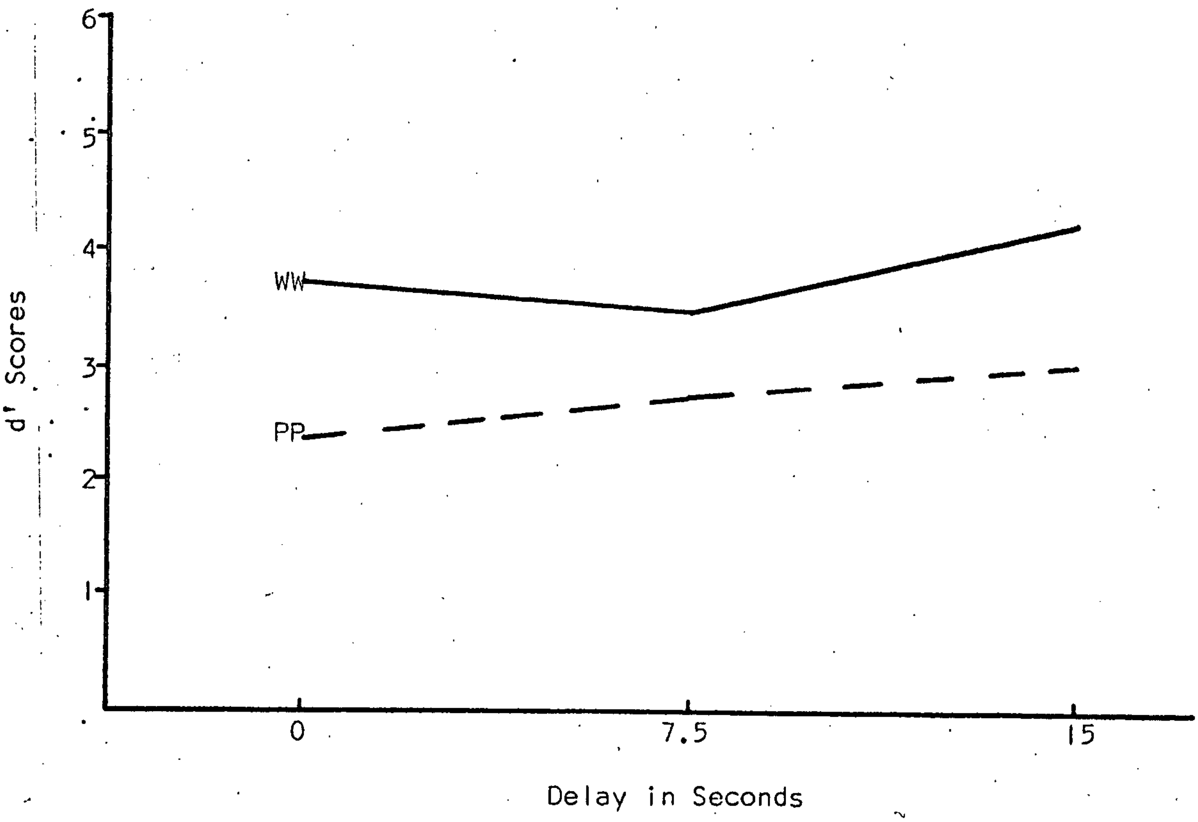

FIG. 5. d' Scores for EXP. III out of a Maximum of Six.

Table 12).

An analysis of probe positions again revealed a similar pattern as in EXP. I (Table 7). Since there were only minor differences between zero delay conditions of EXP. I and III, i.e. group testing, and only one set of material was used, a 2 x 2 x 6 analysis of variance (Appendix, Table 13) was performed for zero delay responses. The factors are: (a) Experiment (EXP. I vs. EXP. III); (b) presentation (WW vs. PP); (c) six positions of the zero delay sequence as a repeated measure. Results clearly show there is no difference between the two experiments ($F=.17$; $df=1, 76$; $p>.05$). Word-picture effects are highly significant ($F=24.95$; $df=1, 76$; $p<.01$) with WW recognition superior to PP. Most important, however, is the position effect ($F=4.88$; $df=5, 380$; $p<.01$). A Newman-Keuls test (Appendix, Table 14) further clarifies this position effect. Recognition for the first position is significantly higher than the remaining five positions, with no significant differences among them (Fig. 3).

The overall results of the experiment reflect, in effect, high agreement with the predictions. Zero delay responses have been replicated. Rehearsal leads to a significant increase in recognition, and, because of the rehearsal effect, a significant main effect for word-picture presentation emerges. But, a closer inspection of the results still leaves an ambiguous picture.

The probe position analysis, for instance, favours a SM interpretation for the zero delay recognition sequence. The significant drop after the first recognition response in word and picture groups appears to be a typical masking effect causing the consistently lower recognition level for the remaining positions. Yet, if SM involvement is postulated for the zero delay condition, the increase during rehearsal should occur already between 0 and 7.5 seconds and not between 7.5 and 15 seconds, since SM traces can be expected to have dissipated by then. Indeed, the percentage data for probe positions for the 7.5 second condition only reveal random fluctuations, with only 65% correct for the first probe position (Table 8). In contrast, the presentation x delay interaction of the probe analysis places the increase between 0 and 7.5 seconds for PP group. But because the analysis is based on uncorrected raw data no valid inferences can be drawn from it.

Word-picture differences are equally ambiguous. While there is a consistent superiority of word over picture condition which can be attributed to differential rehearsal capacities in the two modalities for the 7.5 and 15 second condition, there is no valid reference point for short-term storage, since the data at zero delay are confounded by the initial masking effect. Although presentation differences are consistent across all positions at zero delay, it must be remembered that word-picture superiority is only 5% for the first position versus 22% for the remaining five positions. An interpretation of presentation effects in terms of learning rate differences appears, therefore, on weak grounds. At the same time, however, the statistical analysis did not reflect a differential masking effect for words and pictures. To complicate the results, a separate analysis using only the first two positions at zero delay was also performed. This analysis revealed no modality difference, only a significant position effect (Appendix, Table 15). In effect then, while modality effects are highly significant, the underlying processes are by no means clear.

Rehearsal effects, in contrast, render a more satisfactory interpretation. Though there is still no assessment of absolute increases due to rehearsal, because there is no reference point for STS, a comparison with EXP. I confirms the effectiveness of verbal rehearsal in STM experiments. The parallel increase for PP group, however, differs only slightly from EXP. I. That is, between zero and 15 seconds, picture recognition increases 1.45 and 1.60 mean items during interference and rehearsal respectively. The results perhaps suggest that whatever has been operationally defined as interference or rehearsal seems quite irrelevant to the underlying processes. Atkinson & Shiffrin's (1968) tentative hypothesis about the lack of a visual rehearsal mechanism, therefore, seems to be confirmed again, in spite of two unanswered problems, i.e. differential learning rates and the specific temporal locus of the increase during rehearsal.

With all the limitations of the results in mind, there are still two important findings to report. A comparison of the 15 second delay conditions for WW and PP in EXP. I and III clearly suggest the effectiveness of the verbal rehearsal mechanism and the lack of a similar facilitative process in the visual STS in this particular experimental task. To what extent rehearsal and interference activities modify the initial STS of both modalities cannot be adequately assessed in the present experimental situation. Since the initial STS suffers from the presentation of the first visual probe, it can be expected that by removing the masking stimulus a more accurate recognition level of the STS can be obtained. The next experiment is designed to investigate this proposition.

EXPERIMENT IV

Introduction

If the first recognition response is indeed mediated by SM effects as suggested by the position data and results from free recall, replacing the visual with an auditory presentation of the first probe in an identical design to EXP. III should further clarify this proposition. While it is not clear what additional complications an auditory presentation might introduce, there is no doubt that at least the visual masking effect will be eliminated. By introducing this change into the basic design of EXP. III two separate predictions can be made. Since there is no masking stimulus after the matrix display, the probe position analysis at zero delay should not show a significant break in response level between position one and the remaining five positions. At the same time, since responses do not suffer from masking during SM, an overall higher recognition level for zero delay can be expected. It follows from this prediction that rehearsal effects should be smaller than in EXP. III.

METHOD

Subjects and Design

Forty Ss from the same subject pool participated in this experiment. There were again two groups, i.e. WW and PP, with delay conditions as in EXP. III.

Material and Apparatus

The same set of study and test material was used as in EXP. III, and presented with the same apparatus.

Procedure

Four groups of five Ss each were randomly assigned to PP and WW conditions. Procedure and instructions were identical to EXP. III except for one modification: Ss were told that the first recognition item in each sequence would be presented auditorily.

RESULTS & DISCUSSION

Recognition responses were again analyzed with respect to: (1) correct probe responses; (2) d' scores; (3) probe position percentages. As can be seen in Tables 5 and 6 response patterns differ from EXP. III, yet, not in the predicted direction. The analyses of variance for both response measures (Appendix, Tables 16 and 18) show that word-picture differences have disappeared ($F=.32$; $df=1, 38$; $p>.05$ for probe responses; $F=2.29$; $df=1, 38$; $p>.05$ for d' scores). But there is still a significant delay effect ($F=9.54$; $df=2,76$; $p<.01$ for probe responses; $F=5.20$; $df=2, 76$; $p<.01$ for d' scores). A Newman-Keuls test in both cases places the increase between 0 and 7.5 seconds in contrast to EXP. III (Appendix, Tables 17 and 19).

The analyses of probe positions (Appendix, Table 20) further substantiates the lack of word-picture differences at zero delay ($F=1.54$; $df=1, 38$; $p>.05$). A significant position effect appears again ($F=3.53$; $df=5, 190$; $p<.01$), but contrary to EXP. I and III, a Newman-Keuls test (Appendix, Table 21) shows that there is no loss of recognition after the first probe response. Instead there seems to be a fairly linear decline throughout the sequence with the only significant difference being between position one and six.

TABLE 7

Per Cent Correct Probe Responses for WW and PP Groups in the Zero Delay Recognition Sequence for Experiments I, III, IV, and Mixed Presentation Groups in Experiment I

		Position					
		1	2	3	4	5	6
WW	Experiment I	90.00	82.50	87.50	65.00	87.50	75.00
	Experiment III	95.00	85.00	85.00	80.00	80.00	80.00
	Experiment IV	85.00	67.50	85.00	65.00	60.00	50.00
PP	Experiment I	85.00	70.00	62.50	55.00	57.50	67.50
	Experiment III	90.00	67.50	50.00	65.00	52.50	45.00
	Experiment IV	80.00	70.50	62.50	60.00	52.50	50.00
Experiment I	WP	100.00	95.00	85.00	45.00	82.50	87.50
	PW	80.00	70.00	82.00	65.00	82.50	57.50

TABLE 8

Per Cent Correct Probe Responses at 7.5 Seconds for Experiments III and IV

		Position					
		1	2	3	4	5	6
WW	Experiment III	82.50	85.00	90.00	50.00	75.00	90.00
	Experiment IV	82.50	77.50	95.00	45.00	80.00	75.00
PP	Experiment III	65.00	57.50	100.00	50.00	90.00	55.00
	Experiment IV	92.50	67.50	90.00	60.00	82.50	45.00

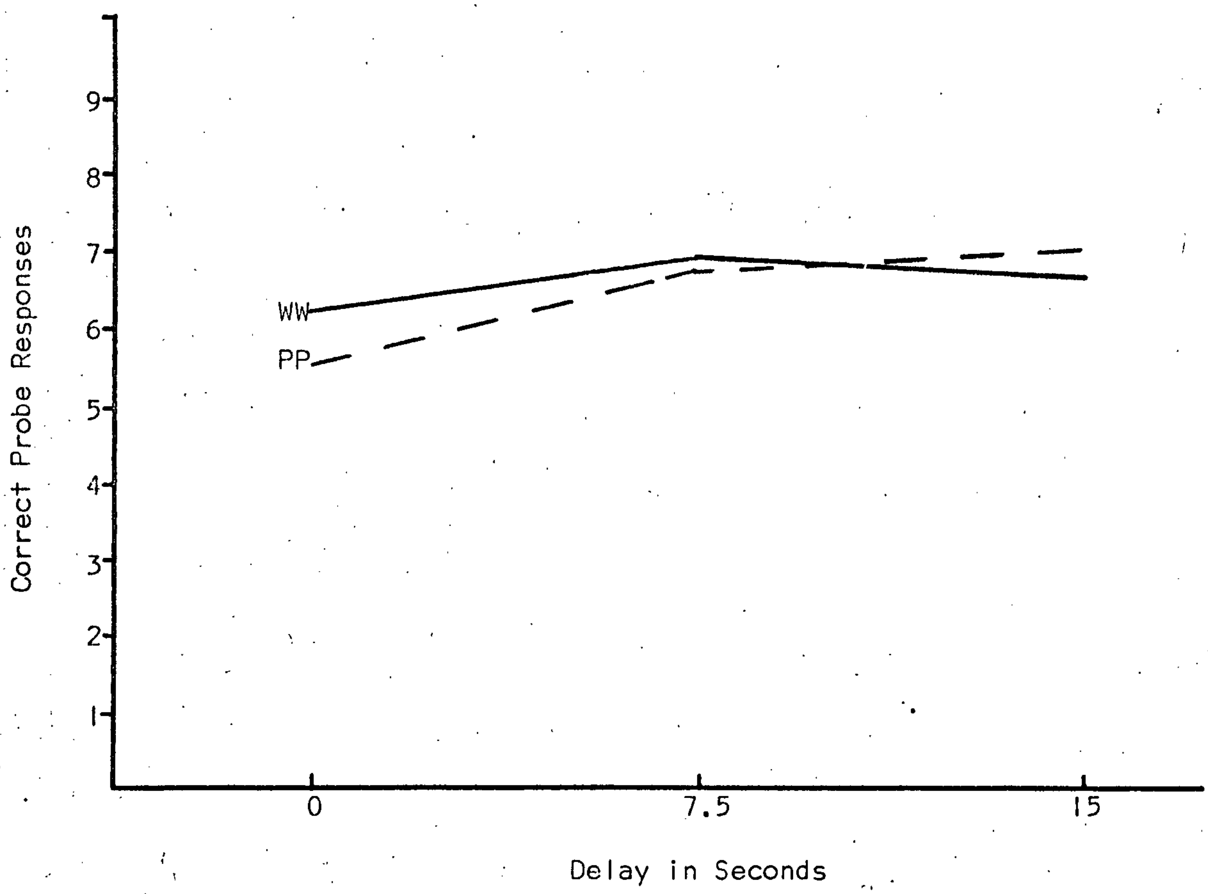

FIG. 6. Correct Probe Responses for EXP. IV.

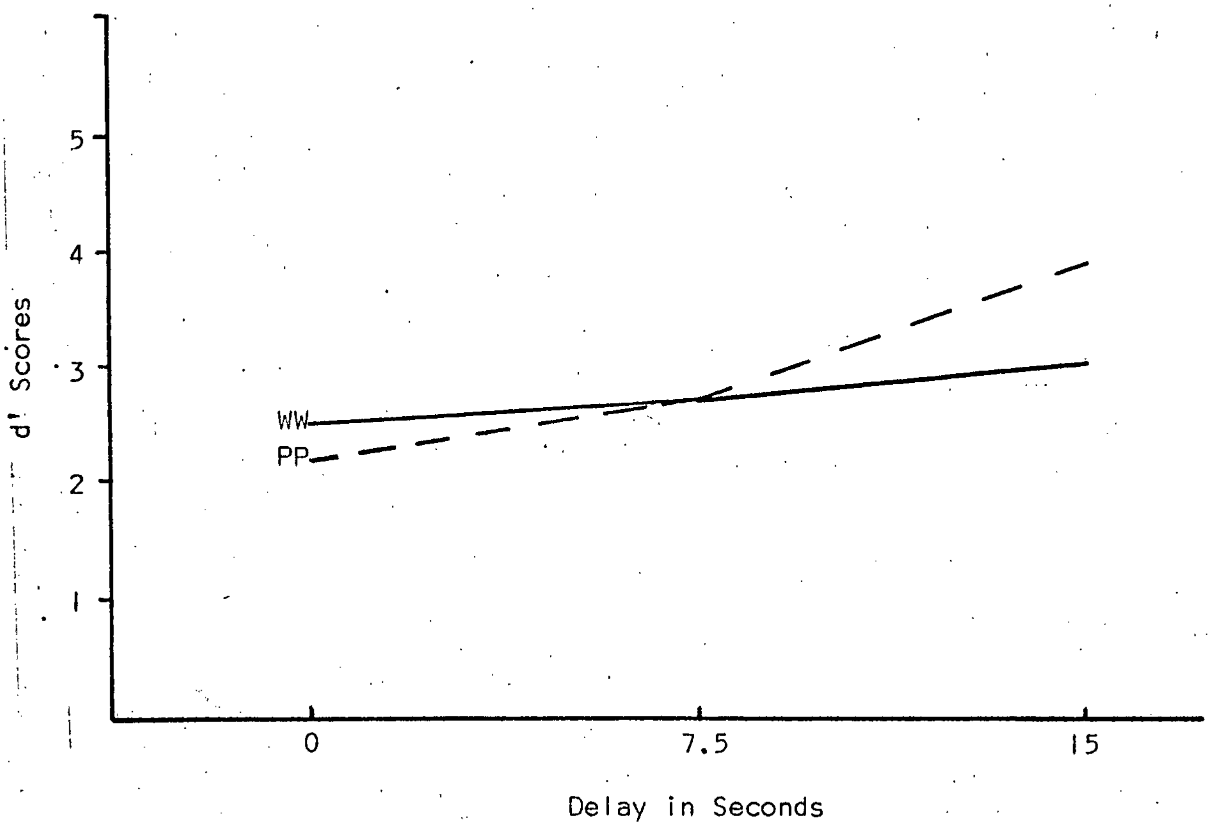

FIG. 7. d' Scores for EXP. IV.

Though the results are hardly in agreement with predictions made from a SM interpretation, several interesting implications emerge again. As predicted, the drop in recognition level after the first probe at zero delay did not occur. But, while this could be attributed to the absence of a masking stimulus, the overall response level does not increase because of the absence of the masking effect. Moreover, recognition level for WW group has decreased to the extent of eliminating the previously consistent word-picture effect. In spite of the decrease of WW recognition, first position responses are comparable to the previous results, i.e. 85 and 80 percent for WW and PP versus 90 - 85 and 95 - 90 percent for EXP. I and III respectively. The importance of differential learning rates contributing to modality differences seems, therefore, even less acceptable at this stage.

It seems fairly clear then, that by removing the hypothesized visual masking effect an even stronger damaging effect on STS has been simultaneously introduced. Interestingly enough, the effect seems to be modality specific. Returning to the previously mentioned memory model of Atkinson and Shiffrin (1968) a plausible explanation for underlying processes becomes available. As the matrix of words, for instance, is presented the S starts a continuous rehearsal cycle, while at the same time waiting, i.e., giving attention, for the auditory probe. As the auditory probe enters the STS, items in the store can be knocked out of STS or can be lost in the search process involved in retrieval. With increased rehearsal more items can be expected to enter LTS. Subsequently, recognition scores are lowest for the zero delay condition, since little reorganization and rehearsal has occurred when the auditory probe is added to STS. At the same time transfer to LTS is minimal at this stage. As rehearsal continues, recognition will improve because of increased transfer to LTS and better reorganization of STS, but will always suffer from the auditory presentation, thereby leading to lower performance with respect to EXP. III. The picture conditions cannot be as easily explained, mainly because of zero delay responses. It seems unsatisfactory to claim that by coincidence responding to a visual or auditory first probe leads to the same recognition level, and only the nature of the decrease is different in both cases. It seems also unsatisfactory to claim that pictures have been encoded verbally and, therefore, suffer to the same extent as words, in light of the data arguing against cross modality encoding. The most parsimonious, yet probably equally unsatisfactory, explanation could be in considering the diversion of attention which is demanded from S at the presentation of the first probe. That is, if attention is diverted during the transfer process from SM to STS, e.g., zero delay responses, less information will enter STS. If the attention is diverted after the transfer process more information can be expected to be stored in STS. The rehearsal effect in EXP. III and IV for picture groups are quite in line with this descriptive analysis. Since pictures are stored visually, the auditory presentation of the first probe will enter the auditory-verbal STS and, therefore, have no damaging effect on the visual store.

Far fetched as these interpretations might be, they do fit into the Atkinson and Shiffrin (1968) memory model. For the word condition, further support can be found in Neisser's (1967) "echoic memory" system and Crowder's (1970) "precategorical acoustic storage." While both theorists avoid the term auditory sensory memory, their investigations do center around experimental conditions which can be described as such. Crowder's particular experimental manipulations, for instance, include recall of strings of items presented either with a prefix or suffix. Summarizing the results of this type of research he concludes that the suffix is believed to remove the advantage auditory presentation has (i.e., precategorical acoustic storage traces) over visual presentation. That is, an additional auditory input damages the acoustic storage traces of the initially stored material. While the analogy to this particular task certainly has to be stretched, it is encouraging to find similar effects under a wide variety of experimental manipulations.

Still, the experiment failed in its original purpose. There is still no valid reference point for STS modality effects and, considering the experimental task at hand, attempting to isolate further this effect seems rather futile at this stage. Interference and rehearsal effects can, subsequently, only be assessed with respect to each other.

The remaining problem then centers around the free recall data of EXP. II. Since the original data were used as support for SM involvement in the zero delay recognition sequence, and since SM effects for this condition are still ambiguous, it becomes critical to investigate further recall responses under interference and rehearsal conditions in order to throw some light on the nature of word-picture effects obtained in EXP. II.

EXPERIMENT V

Introduction

The present experiment is, therefore, designed to investigate possible differential encoding, storage, and retrieval processes with respect to the two task variables. Differential coding and/or storage processes for words and pictures have been established in the recognition task employing interference and rehearsal activities. With the use of the same interpolated activities, it can be expected that recall scores will reveal a similar pattern. That is, there will be an increase and decrease due to rehearsal and interference respectively for word-recall and no difference between interference and rehearsal for pictures, if pictures and words are coded differently. Since the response task in the picture condition demands verbal labelling, it could also be expected that modality specific coding differences become negligible. In this case word-picture recall after rehearsal and interference would be undifferentiated. Retrieval problems are, of course, generally increased in a recall task but cannot be assessed until storage differences are known. The persistent question of differential learning rates for words and pictures will also be involved again in this task but can only be considered in conjunction with the results.

METHOD

Subjects and Design

Ten Ss from the same subject pool were assigned to each of the four groups in a factorial design with two levels of presentation (word vs. picture) and two levels of interpolated activity (Interference vs. Rehearsal). Recall was always tested after a 15-sec. retention interval.

Material and Apparatus

The same study material and apparatus were used as in EXP. II.

Procedure

The general procedure was identical to EXP. II. The same recall instructions were given again, but modified to explain interference or rehearsal conditions.

RESULTS & DISCUSSION

The mean recall scores for the four groups can be seen in conjunction with the data from EXP. II (Table 9). It should be mentioned here that four randomly selected Ss were excluded from the data of EXP. II to simplify the later analyses. Noteworthy at this point is the lack of word-picture differences under any experimental condition (Fig. 8), which is quite opposite to results for the recognition task.

Three separate analyses of variance were performed with the six independent groups. An analysis of presentation and interpolated activity effects after 15 seconds of delay (Appendix, Table 22) leaves no doubt about equal recall for pictures and words under both conditions ($F=2.24$; $df=1, 36$; $p>.05$). The decrease in performance due to interference in turn is highly significant ($F=63.99$; $df=1, 36$; $p<.01$). The analysis investigating recall at zero and 15 seconds of rehearsal for both presentations (Appendix, Table 23) again reveals no word-picture difference ($F=1.73$; $df=1, 36$; $p>.05$). There is a small main effect for rehearsal ($F=5.53$; $df=1, 36$; $p<.05$), but contrary to recognition scores rehearsal leads to a small decrease in performance. A similar analysis for interference effects (Appendix, Table 24) was performed which again negates any word-

TABLE 9

Mean Recall Scores for Zero Delay (Experiment II) and 15 Seconds of Rehearsal or Interference (Experiment V) out of a Maximum of 54 Items

	Delay in Seconds		
	0	15	
		Interference	Rehearsal
Word	37.60(36.67)*	23.20	36.00
Picture	37.60(36.57)*	23.00	32.10

*Indicates mean recall for all 14 Ss in Experiment II.

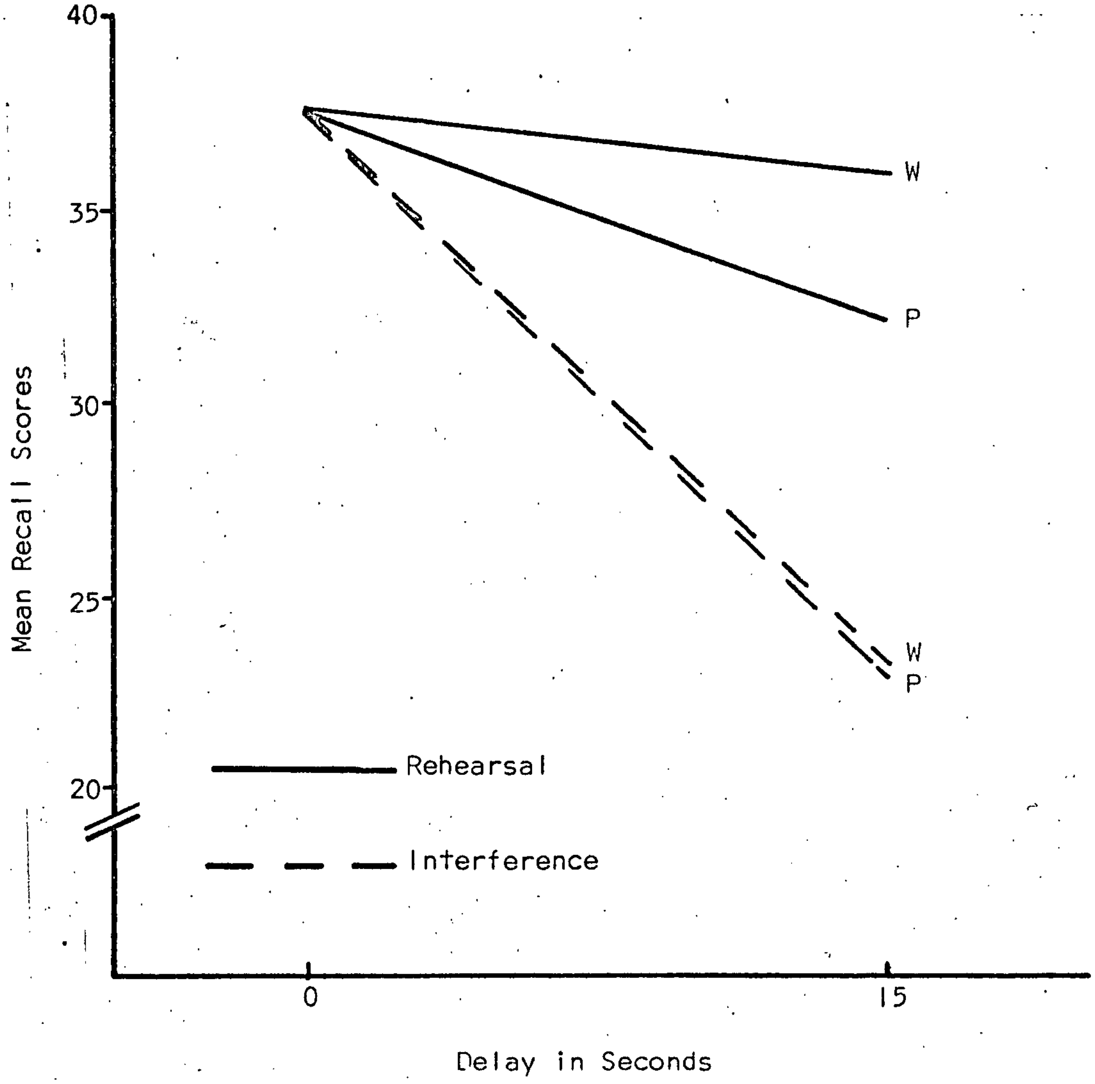

FIG. 8. Mean Recall Scores for Zero Delay (EXP. II) and Rehearsal and Interference Groups in EXP. V out of a Maximum of 54 Items.

picture differences in recall (F=.001; df=1, 36; p>.05) while supporting the previous damaging effects of interference (F=102.99; df=1, 36; p<.01).

The consistent lack of a significant word-picture difference leaves little doubt that recall of words and pictures does not differ under any of the experimental manipulations. Possible reasons for this will be discussed with reference to the interpolated activities effects. The small increase after 15 seconds of rehearsal remains well within predictions, especially with respect to the large decrease due to verbal interference. With respect to rehearsal effects in the recognition task, the difference can be explained in terms of greater retrieval problems in the recall task. Furthermore, the recognition task never reflected a valid reference point for zero delay, thereby, leaving the relative increase due to rehearsal on questionable grounds. Interference effects, in contrast, are highly significant and quite in agreement with expected results.

If presentation effects are considered in light of rehearsal and interference effects it becomes quite apparent that, contrary to the recognition task, the learning material for words and pictures has been verbally coded. This is especially evident in the undifferentiated rehearsal and interference effects in both modalities. As opposed to recognition scores rehearsal and interference have the same effect on word and picture storage. The different interpolated activity effects for words and pictures during recognition have been interpreted in terms of differential verbal and visual coding. Since in the recall task no differential interpolated activity effects become apparent it will have to be assumed that words and pictures have been encoded verbally. If words and pictures are recalled equally well, it could be assumed that learning rates are also similar. Yet, if reading words and labelling pictures proceed at an equal rate, differential learning rates for the recognition task can be practically ignored, if not assumed to favour picture superiority. But learning rates also have to be considered with respect to different study strategies in the two response tasks, as discussed in EXP. II, which makes inferences from learning rates in recall to learning rates in recognition almost worthless. Furthermore, since the different presentation effects in recall and recognition are shown to be underlying different short-term storage mechanisms, results in EXP. II which were used in support of SM involvement because of word-picture equality, have to be rejected as such.

In effect, the response task becomes a critical variable in this experimental condition. It leads to differential learning strategies to maximize performance in each task, which at the same time will influence learning rates in each presentation condition. Subsequently, because of the different task requirements, i.e. pictures have to be labelled in recall, differential storage system for words and pictures are only obtained in recognition, but not in a recall task.

GENERAL DISCUSSION

Before the data can be properly evaluated and their implications considered in a theoretical framework it becomes necessary to clarify several questions in order to establish the meaningfulness of the results. That is, to what extent do the operationally defined conditions reflect their postulated underlying processes. First of all, in showing differential coding mechanisms for words and pictures, does the experimental task in fact qualify as an adequate research tool to investigate verbal and visual coding differences of the STS? The argument supporting this claim is the following. If the given experimental task is used to replicate results of well established variables, e.g. interference and rehearsal effects on verbal recognition, the experimental task can be considered as a valid research approach for STM experiments. Whether it can be generalized that the research tool for words, is equally suitable for pictures, is of course, an open question, yet, in the light of the results seems perhaps to be answered positively.

Assuming this positive answer can be accepted, it must be established how confidently cross modality encoding can be rejected as a confounding variable in word-picture differences. EXP. I has convincingly demonstrated that differential interference effects for mixed presentation groups were always in line of same presentation groups (Tables 1 and 2). These results imply strongly that the stimulus material in all groups had been coded in the form of the study material. Similarly, if pictures were encoded verbally, the results of the picture group in EXP. III should have shown some increase due to verbal rehearsal (Tables 5 and 6). In addition, the interpretation of results in EXP. IV shows the auditory probe to be an effective interference condition for verbal storage. If pictures were coded verbally in this experiment, a lower recognition level would have to be expected with respect to EXP. III. More evidence against cross modality encoding can be found in a comparison of recognition and recall differences. Interpolated activity effects remained constant for word and picture recall (Table 9). The reason for this lies in the necessary verbal labelling of picture stimuli in a recall task. In contrast, interpolated activities exerted a differential effect on word and picture conditions in the recognition task (Tables 5 and 6). Therefore, the learning material in the different presentation groups must have been stored in separate, verbal-visual storage mechanisms, otherwise, interpolated activity effects should have been similar for word and picture recall. In effect, the data strongly suggest that the operationally defined condition which was designed to investigate visual short-term mechanisms has achieved this aim, but only in the recognition experiment.

Another confounding factor underlying presentation differences is possible differential learning rates for word and picture matrices. While this problem has been mentioned throughout the discussion of the experiments, a summary of the arguments presents the following picture. Learning rate differences had been shown to be negligible in pilot work using pictures and words as a within-S variable. Subjective reports from Ss in turn indicated personal preferences, but no consistent trend in either direction. Considering the first recognition response at zero delay as the most accurate estimate of learning rate, all three recognition experiments show consistent word over picture superiority. But, the difference is consistently only five percent, which in conjunction with the other five probes results in a significant word-picture difference in EXP. I and III, yet not in EXP. IV. Furthermore, a separate analysis of the first two probe positions in EXP. I and III reveals no word-picture differences. In addition, learning rates for words and pictures seem to be equal in a recall task, in spite of the necessary labelling of pictures. But, because of differential learning strategies to maximize performance in the two response tasks, any inferences from recall experiments seem inappropriate. In effect, the information about differential learning rates is ambiguous. In light of the small, if not inconsistent, differences, however, it seems safe to assume that it is not the critical variable underlying word-picture differences.

With these arguments in mind, the interpretation of verbal and visual coding differences becomes more acceptable. Differential short-term coding for words and pictures can be postulated in light of their relative difference in recognition scores after 15 seconds of interference or rehearsal (Tables 5 and 6). That is, the presentation of words leads to verbal encoding and subsequent storage in the verbal STS. The amount of stored information after a 15 second retention interval can be effectively manipulated by counting backwards or rehearsing. To what extent the intervening activities change the initial verbal STS can, however, not be assessed because the experiment failed to obtain a pure STS recognition level at zero delay. In any case, the significant difference between word recognition after the two interpolated activities underlines the importance of the verbal rehearsal mechanism in STS, as well as provides evidence for the damaging effects of verbal interference on verbal STS.

In contrast, the lack of interpolated activity effects for the picture condition suggests, first of all, that pictures have not been coded verbally, otherwise one could expect similar interpolated activity effects; secondly, whatever has been operationally defined as an interference or rehearsal condition does not affect the storage of picture stimuli differentially. Therefore, verbal storage can hardly be involved under these conditions and results will have to be interpreted as reflecting a separate, non-verbal STS. The lack of an adequate reference point for picture recognition at zero delay, in conjunction with the absence of a differential interpolated activity effect, introduces even further complications in assessing the relative effectiveness of the visual STS over retention intervals.

Since there is no valid reference point for verbal and visual STS at the zero delay condition, no statement can be made about the superiority of words or pictures in an immediate recognition sequence. Word recognition is significantly superior to picture recognition after 15 seconds of rehearsal (EXP. III), but, recognition scores for the two modalities are undifferentiated after verbal interference (EXP. I). Whether this undifferentiated response level after a 15 second retention interval for words and pictures in EXP. I and pictures in EXP. III is the result of similar STS processes or different STS processes converging to a similar recognition level is, of course, a justified question, which, at the same time, seems unanswerable at this point.

Further support for separate verbal and visual storage systems can be obtained from the complimentary evidence of the recall data. Since verbal labelling is demanded for words and pictures in free recall, no differences emerge due to interpolated activities because words and pictures are stored in the same STS. If the same interpolated activities in a recognition task produce word-picture differences, it is safe to assume that words and pictures, under these conditions, were stored in different short-term systems.

In effect, the presentation of verbal material in a recall or recognition task always leads to verbal coding. Subsequently verbal interference and rehearsal will influence the response level of the verbal store after 15 seconds as predicted. When pictures are required to be coded verbally, as in a free recall task, the verbal storage of the picture stimuli will be affected during the interpolated activities in the same way. Picture storage in a recognition task, in contrast, is not affected differentially by the interpolated activities, and, therefore, is postulated to be stored in a separate, visual STS.

Rehearsal effects are quite consistent throughout the experiments. The increase of word recognition due to rehearsal was significant in EXP. III as well as in EXP. IV, though the overall response level was lower due to the auditory first probe in the latter experiment. However, since rehearsal effect can only be accurately assessed with respect to interference effects, the data from EXP. IV cannot be considered because there is no comparable reference point. Additional support for the rehearsal effect can be found in EXP. V where recall scores show a highly significant increase over delay periods. Since recall scores do have a valid reference point at zero delay, the small decrease between zero and 15 seconds retention, though in contrast to recognition scores, still supports the facilitative effects of the verbal rehearsal mechanism with reference to the interference effect.

The relative increase in picture recall after rehearsal has already been attributed to verbal coding of picture material in this experimental condition. Rehearsal effects on the visual store can, therefore, only be assessed in the recognition task. Since the apparent increase, with respect to zero delay, during rehearsal in EXP. III and IV does not differ from the increase during interference (EXP. I), a comparable visual rehearsal mechanism seems, therefore, ineffective under the given experimental conditions.

The data from the recognition and recall experiments, therefore, support previous findings of the facilitative effects of the verbal rehearsal mechanism in STM experiments, as well as provide additional evidence against the existence or effectiveness of a similar facilitative mechanism in the visual STS.

The effects of verbal interference have also shown a consistent pattern throughout the experiments. Since interference data will have to be evaluated again with respect to rehearsal conditions, interference effects will merely be a complementary aspect of the previously discussed rehearsal effects. That is, verbal interference has a damaging effect on verbal storage in both response tasks, while the visual store in the recognition task is unaffected by counting backwards.

However, it seems apparent that counting backwards was not the only interference activity involved in this experiment. Though not defined as such, responding to the initial visual or auditory probe following stimulus termination exerted a more damaging effect on STS than some of the operationally defined interference conditions. The word condition seemed especially sensitive to the various types of interferences, which makes it possible to rank order the different types of interferences across the three recognition experiments (Tables 5 and 6). Responding to an auditory probe immediately after stimulus presentation results in the strongest damaging effect of the verbal STS (EXP. IV). Counting backwards for 15 seconds is less damaging to the verbal store, yet is equal to responding to an auditory probe after a 15 second rehearsal period (EXP. I vs. EXP. IV). The least damaging of the interference effects on verbal storage is responding to a visual probe at zero delay (EXP. I and III). Fifteen seconds of rehearsal lead, of course, to the highest recognition level.

The picture conditions seem to be less influenced by these particular task demands. In fact, there are only two distinct recognition levels, one at zero and the other at 15 seconds delay. An immediate recognition response leads to equally strong interference effect whether the probe is presented visually or auditorily (EXP. I and III vs. EXP. IV). On the other hand, counting backwards, rehearsing, or rehearsing plus auditory probe results in an equally high recognition level (EXP. I, III &

IV).

With this new interpretation of the various interfering task demands in hand, a re-evaluation of the data leads to several, interesting implications. It seems fairly clear that any type of verbal facilitation or interference has little effect on the visual store, once pictures are encoded visually. The response level for picture conditions after a 15 second retention interval in EXP. I, III and IV leaves little doubt about this assumption. More difficult to explain is the equally damaging effect in the zero delay conditions due to responding to a visual or auditory probe. Why the visual STS at this particular temporal location, i.e. during the transfer process of information from SM to STS, suffers equally in either presentation modality of the first probe, has been tentatively answered in terms of the damaging effects on STS by diverting attention during the transfer process. But, even this answer seems highly unsatisfactory in light of differential responses in the word condition under the same circumstances.

In general, the word condition leads to more provocative speculations. The verbal-auditory as well as the visual task demands, seem to exert consistently damaging effects on the verbal STS. It is important to notice though, that every one of the auditory-verbal task demands, i.e., responding to an immediate auditory probe, counting backwards, and rehearsing plus responding to an auditory probe, are more damaging to the verbal store than are the visual task demands, i.e., responding to an immediate visual probe. No claim can be made at this stage about consistent storage specific interference effects. That is, it might be speculated that verbal-auditory interference is more detrimental to verbal storage and visual interference is more damaging to the visual store. Some examples for STS specific interference effects can be extracted from the experiments. For instance, responding to a visual probe at zero delay is more damaging for pictures than words (EXP. I and III), whereas for the word condition, a lower recognition level is obtained by responding to an auditory first probe than to a visually presented first probe (EXP. IV vs. EXP. I and III). However, there are also data which show that counting backwards results in a lower recognition score for pictures than does responding to a visual probe at zero delay for words (EXP. I).

On the other hand, it might seem more reasonable to classify interfering conditions with respect to their temporal occurrance during the response task. That is, one could consider responding immediately, as one type of interfering activity, diverting attention during the retention interval as another type. However, for this kind of analysis the data are incomplete since there is no visual interference task during the retention interval. Even with the available interference conditions, verbal interference plus responding to an auditory probe is missing from the data. As a result of this, verbal and visual STS specific and task demand specific interference effects cannot be comprehensively assessed. Some aspects of the data, however, do point towards a possible trend of specific interference conditions for the verbal and visual STS.

A comparison of recall and recognition data has to start with an evaluation of the different response demands in each task, which in turn have led to an unexpected series of task specific adjustments. Learning strategies have been shown to differ in the two response tasks. Though the evidence is largely based on subjective reports, the task specific learning strategies appear by no means counterintuitive. After all, why should S in a recall task look at all items in the matrix only to forget some of them if he can obtain a higher recall score by concentrating on a few of the items. Subsequently, learning rates for the two tasks can be expected to differ also. Learning rates within each task for words and pictures, however, appear to be fairly constant, if zero delay responses can be used as an adequate indicator. There is no word-picture difference in the recall experiment at this stage, and word-picture differences in the recognition experiments are small, yet ambiguous in their interpretation across experiments. At the same time, verbal labelling of pictures is required in the recall task, whereas little cross modality encoding has been evidenced in the recognition task. Hence, if learning rates for words and pictures are the same with cross modality encoding, i.e., recall, learning rates without cross modality encoding, i.e., recognition, should be even faster for pictures than words. However, this might be a rather inappropriate extention of the argument in light of the different learning strategies across the two response tasks. In summary, it seems fairly clear that Ss use different strategies to maximize their response scores in the two tasks. It seems less clear whether pictures and words are learned at a different rate within each strategy. However, there is ample evidence that words and pictures are stored differently in the two types of experiments because of response demands.

In spite of these limitations of the data a comparison of recall and recognition results contributes critical evidence for the existence of a visual STS. If the response task demands verbal labelling of pictures, the stimulus information will be stored verbally. Subsequently there is no difference between word and picture recall under rehearsal and interference conditions. If Ss are prevented from labelling pictures verbally, as in the recognition task, they will be stored in a separate STS, and will show different effects with respect to word recognition under the two interpolated activities. In effect, the negative outcome of the recall experiments can be used as complimentary evidence for the existence of a visual STS in the recognition task. It should be noted though at this stage that the interpolated activities were introduced as a within-S variable in the recognition experiments, and as a between-S variable in the recall task. To what extent this procedural difference could be confounding the data is, of course, unknown.

Throughout the discussion of the presentation, interpolated activity, and response task effects, several persistent problems have been, at times, ignored and will be discussed now in more detail. The most critical of these is the failure of the series of experiments to obtain a recognition level for the immediate STS in words and pictures. Subsequently, no statement can be made about the relative efficiency of the verbal and visual short-term storage. Furthermore, because of this failure, interpolated activity effects could be assessed only with respect to each other, and the absolute amount of change which occurs in STS due to rehearsal and interference is still unknown. At this stage it seems clear, that underlying this failure was the specific recognition task selected. The damaging effect on STS due to responding to the initial probe in the zero delay condition unexpectedly introduced an interference factor which could not be resolved in the given experimental situation; and though the nature of this damaging effect has not been satisfactorily answered, its persistency strongly evidences the importance of the underlying phenomena. That is, responding during the time of the postulated transfer process of information from SM to STS has been shown to be a critical interference paradigm.

Since responding immediately after stimulus presentation leads to a decrease of recognition for the remainder of the sequence, the 7.5 second delay condition in EXP. III should be the next closest indicator of the pure STS estimate, at least for the picture group. After all, the transfer process from SM to STS should be completed by then, and it has been shown that verbal rehearsal does not facilitate the visual store. If restricting the discussion to d' scores only, the data present again a contradictory picture. In EXP. III there is no increase in picture or word recognition between zero and 7.5 seconds of rehearsal, followed by a significant increase for the 15 second condition. In EXP. IV, the increase occurs between zero and 7.5 seconds instead. But the only difference in the experimental situation is the replacement of the visual with an auditory first probe. Yet, how this experimental manipulation is related to the changing locus of the increase in recognition scores is by no means evident, and trying to explain it with unwieldy speculations seems equally futile.

It should be added here that, since d' scores in EXP. III suggested an increase for PP between zero and 7.5 seconds, further post hoc analyses were applied in an attempt to evaluate statistically this proposition. However, a homogeneity of variance and a sign test did not change the statistical interpretation. Moreover, it became apparent, that the d' score in itself might not be the most accurate assessment of the data, since the transformation of the raw data to a normal curve was based on a relatively small N.

A further data point which invites speculations is the consistent response level for the 15 second delay conditions for pictures and words in EXP. I and IV respectively. Though the data points are highly similar, they are clearly reflecting two different processes, i.e., counting backwards for EXP. I and rehearsal plus an auditory probe in EXP. IV. The picture conditions give data points of 7.40, 6.90 and 7.05 for counting backwards, rehearsal and rehearsal plus auditory probe. These data have been interpreted in terms of the visual STS being unaffected by the given interpolated activities. However, looking at all five data points, the differences are extremely small, and it becomes reasonable to wonder whether the data points are indeed mediated by the different postulated processes, or whether the data points are indicative of one single underlying process. That is, under the given experimental conditions, this is the absolute minimum recognition level which will be always obtained, regardless of experimental manipulations. The only argument against this latter interpretation is the even lower response level for pictures at 7.5 seconds of rehearsal in EXP. III. Hence, the question whether the same or different processes are underlying this common recognition level can be satisfactorily answered in the two word conditions, is less clear in the three picture conditions, and becomes very meaningful in a word-picture comparison, yet again is contradicted by the even lower recognition level for the picture condition at 7.5 seconds of rehearsal[2].

The remaining problem centers around the involvement of specific memory sub-systems in their contribution to overall recognition scores. As previously postulated the immediate recognition response after stimulus presentation seems to be mediated by SM involvement. This SM effect apparently holds for visual and auditory presentations of the initial probe. Since the recognition sequence lasted 45 seconds, and under delay conditions Ss were still responding after 60 or 75 seconds following stimulus presentation, it also becomes reasonable to ask whether responses under these conditions can be considered as reflecting short-term storage. Previous evidence (among others, Atkinson & Shiffrin, 1968) strongly suggest that short-term traces do not last for more than 15 to 30 seconds. In effect then, most of the recognition responses in these experiments have been obtained outside of the normal confines of STM. On the other hand, all of the experimental manipulations, i.e., interference and rehearsal, have been confined within the temporal limits of STM duration. With respect to the previously discussed Atkinson and Shiffrin model, the following processes are postulated to occur. The stimulus information enters the SM and is immediately transferred to STS. In the recall experiments this information is either reproduced immediately, rehearsed, or interfered with. Subsequent recall scores reflect rather adequately the underlying processes in STS. In the recognition task, however, most of the data points are obtained beyond the accepted duration of STS processes. Hence, most of the data points can be expected to reflect STS or LTS processes. Yet, since LTS capacity depends on the ability of STS to transfer information into LTS, and since all experimental manipulations occurred during STS temporal limits, the obtained recognition scores, whether they rely on STS or LTS are still indicative of STS functions as determined by the experimental variables. For example, recognition scores in the word condition after verbal rehearsal are relatively high, but not only because verbal-auditory traces in STS have been continuously regenerated and are, therefore, relatively strong, but also because of the continuous transfer process to LTS, which made a high response level at 60 seconds after stimulus presentation still possible. In effect then, while some of the recognition response might not have been mediated purely by STS, they still reflect to what extent STS was able to function under the experimental conditions.

SUMMARY

In spite of problems in the design and various contradictory results within a given and across the three response measures for the series of experiments, several worthwhile findings can still be reported. The recognition experiments have shown that words and pictures will be stored differentially if cross modality encoding can be experimentally reduced. Subsequently, the verbal STS will suffer from verbal interference and will be facilitated by rehearsal. The postulated visual STS seems to be unaffected under similar experimental conditions. In addition, responding to a recognition item immediately after stimulus presentation exerts a damaging effect on the verbal and visual STS. Here again, the damaging effect seems modality specific for the verbal STS, i.e., an auditory probe is more damaging than a visual probe, while the visual STS suffers to the same extent under both conditions. At the same time, verbal and visual coding strategies seem to be task specific. In the recall experiments, for instance, where pictures must be labelled for the response task, word and picture study groups do not differ for immediate recall nor after rehearsal or verbal interference. That is, when pictures are coded verbally, recall scores reflect similar response patterns for word and picture presentations at zero delay and after both interpolated activities. The series of experiments, however, failed to obtain any evidence about verbal or visual STS superiority. The reasons for this failure are the following: the equal recall scores for word and picture study groups at zero delay had to be interpreted in terms of verbal coding in both groups; in contrast, the differential recognition scores for WW and PP at zero delay had to be evaluated with respect to the damaging effects of responding to the initial recognition item.

With reference to the original question asked in the introduction, i.e., if verbal coding is not demanded for pictorial material, does a non-verbal short-term mechanism exist with similar properties as the verbal STS, the answer seems to support Atkinson and Shiffrin's (1968) tentative hypothesis. The experiments have confirmed previous findings of the damaging effect of verbal interference and facilitative effects of the rehearsal activity in the verbal STS. The lack of a differential effect of the interpolated activities in the picture conditions in conjunction with the relatively high recognition level after a fifteen second retention interval, on the other hand, indicate that there is a visual STS. In light of the ineffectiveness of the rehearsal condition the data further suggest that the postulated visual STS lacks a corresponding rehearsal mechanism, or at least show that the visual rehearsal mechanism is ineffective in facilitating recognition scores in this particular experimental situation.

FOOTNOTES

[1]The term "trace" is here used as in the Atkinson and Shiffrin model, i.e., as an internal representation of the to-be-remembered material.

[2]Subsequent research has shown that counting backwards plus responding to an auditory first probe leads to no increase in recognition scores from zero to fifteen seconds of delay. These data suggest that the various postulated interference conditions seem to exert an additive damaging effect on the verbal STS.

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APPENDIX I

INSTRUCTIONS

This is an experiment in STM. In each trial you will be presented with a matrix of six words which you are to remember for a subsequent recognition task. Each trial will start with the presentation of the six words for 1.2 seconds. Now, 1.2 seconds is a very short duration to learn six words. Therefore, you will have to scan over the whole display as rapidly as possible, in order to know all of the words. Make sure, that you don't miss any one of the words during the short presentation time, because some of the words will reappear in the subsequent recognition task. The recognition task itself will consist of six slides, with one word each, presented at a rate of one slide every 7.5 seconds. Some of these words in the recognition sequence will be from the previously presented matrix, and some of them will be new, unrelated words. Your task will be, as the recognition slide appears, to decide whether the word had been in the previous matrix or not. If you think the word is from the previous matrix, press the button "OLD." If you think the word had not been in the matrix, press "NEW." Since I am interested in reaction time, you should press the choice button as fast as possible. In addition, on several trials, the recognition task will not be immediately following the presentation of the matrix, instead a three digit number will appear, and you are to count backwards by threes from this number till I initiate the recognition sequence. To summarize. There will be nine trials. Each trial will start with a 1.2 second presentation of six words, followed either by the first recognition slide, or by a number, in which case you count backwards till I initiate the recognition sequence.

Your task is to make sure you see every word in the matrix, and to respond as fast as possible in the recognition task by pressing the appropriate button. Are there any questions?

APPENDIX II

TABLE 1

ANOVA for Correct Probe Responses in

Experiment I.

Source of Variance	SS	df	MS	F	p
Between Subjects	153.50	79			
A (Study Presentation)	6.34	1	6.34	3.33	-
B (Recognition Presentation)	.70	1	.70	.36	-
AB	1.71	1	1.71	.90	-
Subjects within Groups	144.75	76	1.90		
Within Subjects	270.00	160			
C (Delay)	6.01	2	3.00	2.08	-
AC	33.97	2	16.89	11.79	<.01
BC	7.06	2	3.53	2.45	-
ABC	3.56	2	1.78	1.23	-
C x Subjects within Groups	219.40	152	1.44		
Total	423.50	239			

TABLE 2

Analysis of Simple Effects for AC Interaction With Probe Responses (Experiment I)

	C_1	C_2	C_3
A_1 (Word)	7.62	6.82	7.27
A_2 (Picture)	6.25	7.17	7.32

Source	df	MS	F	p
C for A_1	2	6.43	4.47	.05
A_2	2	13.56	9.41	.01
A for C_1	1	37.81	26.26	.01
C_2	1	2.45	1.70	-
C_3	1	0.05	0.03	
Error Within	152	1.44		

TABLE 3

Newman Keuls Test for Delay Effects Using Correct Probe Responses in Experiment I

		2	3
$S\bar{x}q$	.95	.7512	.9014
$S\bar{x}q$	.99	.9927	1.1268

Order		1	2	3
Treatments in Order of C for A_1		b	c	a
C for A_1		6.82	7.27	7.62
		b	c	a
	b	–	.80*	.35
	c	–	–	.45
	a	–	–	–
C for A_2		a	b	c
	a	–	.92*	1.07*
	b	–	–	.15
	c	–	–	–

TABLE 4

ANOVA for d' Scores in Experiment I

Source of Variance	SS	df	MS	F	p
Between Subjects	185.61	79			
A (Study Presentation)	1.74	1	1.74	.82	-
B (Recognition Presentation)	4.60	1	4.60	2.23	-
AB	22.48	1	22.48	10.89	.01
Subjects within Groups	156.79	76	2.06		
Within Subjects	235.22	160			
C (Delay)	2.20	2	1.10	.81	-
AC	22.87	2	11.43	8.42	.01
BC	1.10	2	.55	.40	-
ABC	2.54	2	1.27	.94	-
C x Subjects within Groups	206.48	152	1.35		
Total	420.84	239			

TABLE 5

Analysis of Simple Effects for AB Interaction with d' Scores

	B_1 (Word Recognition)	B_2 (Picture Recognition)
A_1 (Word Study)	3.50	2.61
A_2 (Picture Study)	2.72	3.06

Source	df	MS	F	p
B for A_1	1	23.7185	11.49	.01
A_2	1	3.3701	1.63	-
A for B_1	1	18.3691	8.90	.01
B_2	1	5.8565	2.84	-
Error Between	76	2.0630		

TABLE 6

Analysis of Simple Effects for AC Interaction
with d' Scores

	C_1	C_2	C_3
A_1 (Word Study)	3.57	2.87	2.73
A_2 (Picture Study)	2.53	3.19	2.94

Source	df	MS	F	p
C for A_1	2	8.0759	5.94	.01
A_2	2	4.4652	3.29	.05
A for C_1	1	21.6736	15.95	.01
C_2	1	2.0865	1.54	-
C_3	1	.8569	.63	-
Error Within	152	1.3584		

TABLE 7

Newman Keuls Test for Simple Delay Effects with d' Scores in Experiment I

	2	3
$S\bar{x}q$ .95	.5160	.6192
$S\bar{x}q$ .99	.6818	.7740

		1	2	3
Order		1	2	3
Treatments in Order of C for A_1		c	b	a
C for A_1		2.73	2.87	3.57
		c	b	a
	c	-	.7022**	.8367**
	b	-	-	.1345
Treatments in Order of C for A_2		a	c	b
C for A_2		2.5337	2.9450	3.1955
		a	c	b
	a	-	.6618*	.4113
	c	-	-	.2505

TABLE 8

ANOVA for Correct Probe Responses in Experiment III

Source of Variance	SS	df	MS	F	p
Between Subjects	170.53	39			
A (WW vs. PP)	56.03	1	56.03	18.61	<.01
Subjects within Groups	114.50	38	3.01		
Within Subjects	113.34	80			
B (Delay)	18.32	2	9.16	8.40	<.01
AB	11.72	2	5.86	5.37	<.01
B x Subjects within Groups	83.30	76	1.09		
Total	283.87	119			

TABLE 9

Analysis of Simple Effects for AB (Presentation x Delay) Interaction with Probe Responses (Experiment III)

	B_1	B_2	B_3
A_1 (Word)	7.55	7.25	7.85
A_2 (Picture)	5.30	6.35	6.90

Source	df	MS	F	p
B for A_1	2	1.80	1.68	
A_2	2	13.22	12.35	.01
A for B_1	1	50.62	47.31	.01
B_2	1	8.10	7.57	.01
B_3	1	9.03	8.43	.01
Error Within	76	1.07		

	2	3
$S_{\bar{x}}q$ .95 =	.6545	.7864
$S_{\bar{x}}q$ .99 =	.8696	.9899

B for A_2	1	2	3
1	-	1.05**	1.60**
2	-	-	.55

TABLE 10

Newman Keuls Test Using Probe Responses for Delay Conditions (Experiment III)

		Delay		
		C_1	C_2	C_3
		6.42	6.80	7.37
		2	3	
$S\bar{x}q$	.95	.4666	.5606	
$S\bar{x}q$	.99	.6200	.7057	

	1	2	3
1	-	.3750*	.9500**
2	-	-	.5750*

TABLE 11

ANOVA for d' Scores in Experiment III

Source of Variance	SS	df	MS	F	p
Between Subjects	123.25	39			
A (WW vs. PP)	36.64	1	36.64	16.07	<.01
Subjects within Groups	86.61	38	2.27		
Within Subjects	77.91	80			
B (Delay)	8.90	2	4.45	5.03	<.01
AB	1.78	2	.89	1.01	
B x Subjects within Groups	67.22	76	.88		
Total	201.16	119			

TABLE 12

Newman Keuls Test Using d' Scores
for Delay Conditions (Experiment III)

		C_1	C_2	C_3
		3.09	3.13	3.69

		2	3
$S\bar{x}q$	.95	.4208	.5056
$S\bar{x}q$	.99	.5591	.6320

	1	2	3
1	-	.0422	.5977*
2	-	-	.5555*

TABLE 13

ANOVA for Per Cent Correct Responding to Probe Positions at Zero Delay for Experiments I and III

Source of Variance	SS	df	MS	F	p
Between Subjects	1,875.83	79			
A (Experiment I vs. Experiment III)	3.33	1	3.33	.17	-
B (WW vs. PP)	460.20	1	460.20	24.95	<.01
AB	10.22	1	10.22	.55	-
Subjects within Groups	1,402.08	76	18.44		
Within Subjects	5,216.67	400			
C (Position)	305.87	5	61.17	4.98	<.01
AC	84.80	5	16.96	1.38	
BC	119.18	5	23.83	1.94	
ABC	42.89	5	8.57	.69	
C x Subjects within Groups	4,662.92	380	12.27		
Total	7,092.50	479			

TABLE 14

Analysis for Simple Position Effects for Zero Delay Conditions for WW and PP Groups in Experiments I and III

Order	1	2	3	4	5	6
Treatment in Order of Positions	c	a	d	b	e	f
	66.25	66.87	71.25	71.87	76.25	90.00

Truncated Range	2	3	4	5	6
$S\bar{x}q$ .95	10.844	12.958	14.211	15.111	15.777
$S\bar{x}q$ .99	14.250	16.168	17.226	18.009	18.635

	c	a	d	b	e	f
c	-	0.625	5.000	5.625	10.000	23.750**
a	-	-	4.375	5.000	9.375	23.125**
d	-	-	-	0.625	5.000	18.750**
b	-	-	-	-	4.375	18.125**
e	-	-	-	-	-	13.750**

TABLE 15

ANOVA for Per Cent Correct Responding at Zero Delay for Positions One and Two (Experiments I and III)

Source of Variance	SS	df	MS	F	p
Between Subjects	1,069.39	79			
A (Experiment I vs. Experiment III)	2.50	1	2.50	.18	-
B (W vs. P)	40.00	1	40.00	2.95	ns
AB	.63	1	.63	.04	-
Subjects within Groups	1,026.25	76	13.50		
Within Subjects	725.00	80			
C (Position I vs. Position 2)	75.63	1	75.63	9.03	<.01
AC	2.50	1	2.50	.29	-
BC	10.00	1	10.00	1.19	-
ABC	.62	1	.62	.07	-
C x Subjects within Groups	636.25	76	8.37		
Total	1,794.38	159			

TABLE 16

ANOVA for Correct Probe Responses in Experiment IV

Source of Variance	SS	df	MS	F	p
Between Subjects	119	39			
A (W vs. P)	1	1	1	.32	-
Subjects within Groups	118	38	3.10		
Within Subjects	129	80			
B (Delay)	25	2	12.50	9.54	<.01
AB	4	2	2.00	1.52	-
B x Subjects within Groups	100	76	1.31		
Total	258	119			

TABLE 17

Newman-Keuls for Delay Effect with Probe Responses
(Experiment IV)

	Delay		
	0	7.5	15
$\bar{X}$ Correct	5.9250	6.8750	6.900

	2	3
$S_{\bar{x}}q$ .95	.5116	.6147
$S_{\bar{x}}q$ .99	.6798	.7738

	1	2	3
1	–	.9500**	.9750**
2	–	–	.0250
3	–	–	–

TABLE 18

ANOVA for d' Scores (Experiment IV)

Source of Variance	SS	df	MS	F	p
Between Subjects	93.55	39			
A (W vs. P)	5.33	1	5.33	2.29	-
Subjects within Groups	88.21	38	2.32		
Within Subjects	114.64	80			
B (Delay)	13.61	2	8.60	5.20	<.01
AB	1.59	2	.79	.60	-
B x Subjects within Groups	99.42	76	1.30		
Total	208.19	119			

TABLE 19

Newman-Keuls for Delay Effect with d' Scores
(Experiment IV)

	Delay		
	0	7.5	15
$\bar{X}$ d' scores	2.35	3.08	3.54

	2	3
$S\bar{x}q$ .95	.5116	.6147
$S\bar{x}q$ .99	.6798	.7738

	1	2	3
1	-	.73**	1.19**
2	-	-	.45
3	-	-	-

TABLE 20

ANOVA for Correct Per Cent Responding to Probe Positions at Zero Delay (Experiment IV)

Source of Variance	SS	df	MS	F	p
Between Subjects	601.57	39			
A (W vs. P)	23.44	1	23.44	1.54	-
Subjects within Groups	578.13	38	15.21		
Within Subjects	3,337.50	200			
B (Position)	280.96	5	56.19	3.53	<.01
AB	38.44	5	12.37	.77	-
B x Subjects within Groups	3,018.12	190	15.88		
Total	3,939.07	239			

TABLE 21

Analysis for Simple Position Effects for Zero Delay Conditions for WW and PP in Experiment IV

Order	1	2	3	4	5	6
Treatment in Order of Positions	a	b	c	e	d	f
	50.00	58.20	62.50	68.70	73.80	82.50
Truncated Range	2	3	4	5	6	
$S_{\bar{x}}q$ .95	17.451	20.853	22.869	24.318	25.389	
$S_{\bar{x}}q$ .99	22.932	25.956	27.720	28.980	29.988	

	a	b	c	e	d	f
a	-	8.2	12.5	18.7	23.8	32.5**
b	-	-	4.3	10.5	15.6	24.3
c	-	-	-	6.2	11.3	20.0
e	-	-	-	-	5.1	14.8
d	-	-	-	-	-	8.7
f	-	-	-	-	-	-

TABLE 22

ANOVA for Recall Scores in Experiment V

Source of Variance	SS	df	MS	F	p
A (W vs. P)	42.03	1	42.03	2.24	-
B (Int. vs. Rel.)	1,199.03	1	1,199.03	63.99	<.01
AB	34.22	1	34.22	1.82	-
Subjects within Groups	674.50	36	18.73		
Total	1,994.78	39			

TABLE 23

ANOVA for Word Picture Effects During Rehearsal in Free Recall

Source of Variance	SS	df	MS	F	p
A (W vs. P)	39.03	1	39.03	1.71	-
B (Rehearsal)	126.03	1	126.03	5.53	<.05
AB	38.02	1	38.02	1.67	-
Subjects within Groups	819.70	36	22.76		
Total	1,021.78	39			

TABLE 24

ANOVA for Word-Picture Effects After Interference in Free Recall

Source of Variance	SS	df	MS	F	p
A (W vs. P)	.10	1	.10	.0048	-
B (Interference)	2,102.10	1	2,102.10	102.99	.01
AB	.50	1	.50	.0244	-
Subjects within Groups	735.00	36	20.41		
Total	2,837.1	39			