REACTION TIME MEASURES OF PICTORIAL AND VERBAL ENCODING

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Thesis submitted to the Department of Psychology, Memorial University of Newfoundland, in partial fulfillment of the requirements for the degree of Master of Science, August 1973.

ACKNOWLEDGEMENTS

I would like to express my appreciation to the following people for their help in the preparation of this thesis. Thanks are due to Dr. P. Jones and Dr. R.L. Taylor of my committee for their comments on earlier drafts. Special thanks go to Dr. E.J. Rowe who supervised the research and who was always available and willing to help in any way he could.

ABSTRACT

The relative availability of verbal and pictorial memory representations for pictures and words was examined in a visual matching task with reaction time (RT) as the dependent variable. Unfilled retention intervals of .5, 2, or 8 seconds were employed to estimate the effect of temporal parameters upon such memory representations. In Experiment I, Ss were unaware of the format (picture or word) of the first or second stimulus, while Experiment II included blocks of trials in which the format of the second stimulus was known. The results from both experiments suggest that visual and verbal memory codes are in general equally available for pictures, while the verbal code is more available for words. Thus, verbal labelling of pictures is easier than image generation for words. In addition, the visual code for pictures seems to decrease in availability more rapidly than the verbal code with increasing delay of the second stimulus, a result which might be due to a higher tendency to use verbal rather than visual rehearsal in short-term memory.

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INTRODUCTION

A consistent finding in a wide variety of memory tasks is that pictures are more easily remembered than words. The first section of this thesis will review some of the research demonstrating this effect in free recall, recognition memory, verbal discrimination learning (VDL), and paired associate learning (PAL). Theoretical discussion of improved picture memory will center on Paivio's (1971) two-process explanation which stresses the differential availability of verbal and imaginal memory codes for pictures and words. Some experiments utilizing successive matching tasks will be discussed in terms of the information that they provide concerning the relative availability of imaginal and verbal memory codes and temporal factors affecting the availability of such codes. The present experiments attempted to explore the availability of imaginal and verbal memory codes over time through the use of a successive visual matching task involving pictures and words and different unfilled retention intervals. The rationale for these experiments and some general predictions concerning the speed of various matches in this task will conclude the introduction.

A number of experiments using free recall as the memory task have demonstrated that objects or pictures of objects are recalled better than their corresponding verbal labels. Lieberman and Culpepper (1965) showed improved recall for both objects and their pictures as compared to their word labels with both simultaneous and serial presentation of the stimuli. Superior recall for pictures of objects as compared to the objects' names was replicated by Paivio, Rogers, and Smythe (1968). Memory for pictures as compared to word labels is enhanced not only when free recall is immediate and expected, as in the above studies, but also when recall is delayed (1 day) and incidental (Sampson, 1969, 1970). Additional support for improved free recall of pictures regardless of instructional set was provided by Paivio and Csapo (1972) in a series of experiments involving several orienting tasks and standard free recall with incidental or intentional learning instructions. Paivio and Csapo (1969) demonstrated improved free recall of pictures with a slow presentation rate (2 items per sec.) but not with a fast presentation rate (5.3 items per sec.) suggesting that presentation rate may be an important factor in obtaining the effect. Ducharme and Fraisse (1965) obtained better recall for pictures than their word labels with adults but the opposite with 7 and 8 year old children indicating that there may be developmental limitations to improved free recall with pictures. However, this apparent exception to the rule of picture superiority in free recall has been questioned by the results of Cole, Frankel, and Sharp (1969) who found that objects and pictures were consistently easier to remember than words by children in all grades one through nine. Thus, in general, the available evidence supports the contention that, with free recall, objects and pictures are better remembered than their word labels.

With recognition memory the evidence also supports improved retention of pictures in comparison to their word labels. Several investigators (e.g. Nickerson, 1965; Standing, Conezio, & Háber, 1970) have demonstrated the existence of an extremely large capacity memory store for recognizing pictures. The Ss of Standing et al. (1970) performed with 90.5% accuracy in choosing the old item from a pair of photographs after having inspected 2560 photographs for 10 sec. each, over a period of several days. In recognition memory experiments involving direct comparisons of pictures and words, recognition performance for pictures is still superior. Shepard (1967), in an experiment which employed 600 stimuli, found 98%, 90%, and 88% accuracy in the recognition of old as compared to new stimuli for pictures, sentences, and words respectively. Snodgrass, Volvovitz, and Wolfish (1972) demonstrated improved recognition of pictures as compared to words, however, a picture and its word label presented simultaneously did not result in higher recognition than presentation of a picture alone, suggesting that Ss either implicitly label pictures as they are presented or that they attend to the pictorial material alone when exposed to both a picture and a word. Jenkins, Neale, and Deno (1967) used a recognition task in which Ss viewed successively presented stimuli and then were asked to indicate whether the test stimuli were old or new. The stimuli for study and test phases were either all pictures or all words depending upon the particular experimental condition. The four conditions were (see) picture- (recognize) picture (PP), picture-word (PW), word-word (WW), and word-picture (WP). The PP condition resulted in highest recognition followed by PW and WW conditions, which were equivalent, and finally the WP condition. Thus, the superiority of pictures over words in recognition memory was replicated. Enhanced recognition memory for pictures is observable with primary and pre-school children (Corsini, Jacobus, & Leonard, 1969; Davies, 1969) indicating that the effect generalizes over several age ranges.

The beneficial effect of pictures over words is also evident in VDL. Rowe and Paivio (1971) demonstrated significantly better discrimination of pictures than words; a result which was replicated by Rowe (1972) and extended to show that it held regardless of response type (verbal or non-verbal), presentation paradigm, or age of the Ss.

Enhanced picture memory is present in a number of studies involving PAL. One of a series of experiments by Epstein, Rock, and Zuckerman (1960) demonstrated that picture pairs were more easily learned than word pairs. Yarmey and Barker (1971) reported higher recall of picture pairs than word pairs on both immediate and delayed (1 week) tests suggesting that the effect is relatively stable over time. Wicker (1970) used colour photographs, line drawings, and words and found enhanced recall for pictorial stimuli as compared to verbal. A series of experiments by Wollen and Lowry (1971) demonstrated increased recall of paired associates when pictures containing both stimulus and response terms accompanied the noun-noun pairs. Thus, the picture-word effect has been clearly demonstrated in PAL.

Despite the consistent superiority of pictures over words in the above tasks, one memory task in which pictures are not, in general, better recalled than their word labels is serial recall. Although some investigators (e.g. Herman, Broussard, & Todd, 1951) have demonstrated improved serial learning with pictures, this finding is atypical. Paivio and Csapo (1968) reported that with fast presentation rates (5.3 items per sec.), word recall was better than picture recall in sequential memory tasks (memory span and serial learning), however, there were no differences with non-sequential tasks. Since the fast rate was sufficiently rapid to prevent implicit labelling of pictures and word recall exceeded picture recall in sequential tasks at fast rates, the argument is made that the verbal code is necessary for serial recall. Therefore, the apparent inferiority of pictures in serial verbal recall may be explained by the verbal code being less available with pictures presented at a fast rate thus resulting in decreased recall.

This interpretation was supported in an experiment by del Castillo and Gumenik (1972) which employed familiar and unfamiliar forms as stimuli and the same presentation rates as Paivio and Csapo (1969). It was assumed that familiar forms would more readily evoke verbal encoding and hence they should be more affected by the presentation rate than the unfamiliar forms. This prediction was confirmed and a further experiment demonstrated that providing Ss with additional experience with the unfamiliar figures through the use of multiple test trials resulted in equivalent recall for familiar and unfamiliar figures at the slow presentation rate. It was argued that the additional experience resulted in development of a usable verbal code for unfamiliar forms. The combined evidence suggests that lower serial recall for pictures or forms as compared to words may depend on the use of fast presentation rates which serve to decrease the availability of the verbal code.

In summary, the sum of the evidence clearly indicates that pictures are remembered better than words in most, if not all, nonsequential memory tasks. Other evidence suggests that this difference may be reversed for sequential tasks such as immediate memory span and serial learning, although this reversal may be restricted to rapid presentation rates which inhibit or prevent implicit verbal labelling of pictures.

The observed superiority of pictures over words in the tasks mentioned above has been explained by Paivio (1971) in terms of a dual coding or two-process theory of memory. Briefly, the theory contends that easily-named pictures and objects readily arouse both a concrete memory representation (an image) and, to a lesser extent, a verbal label. With concrete (high imagery) and abstract (low imagery) words the verbal code is equally available; however, the imaginal code is more available for concrete words. It is further assumed that the verbal code for easily-named pictures is more readily available than the imaginal code for concrete words. These assumptions are based primarily on reaction-time (RT) data reported by Fraisse (1964) who demonstrated that words can be read faster than pictures can be named, and Paivio (1966) who showed that the latency of image arousal is faster for concrete than abstract words. These RT data suggest that image arousal to words requires more time than verbal coding of words or easily-labelled pictures. Thus, the combination of imaginal and verbal codes make pictures easiest to retrieve followed by concrete and abstract words in that order. The verbal and imaginal memory systems are assumed to be independent and can be used in combination to allow for additive effects of the two types of codes.

Evidence for the independence of verbal and visual codes comes from experiments by Bahrick and Boucher (1968) and Bahrick and Bahrick (1972), who demonstrated that verbal recall and recognition performance was uncorrelated with visual recognition performance. Nelson and Brooks (1973) found that phonetic similarity depressed PAL when the stimuli were presented as words but not when they were presented as pictures unless Ss were required to overtly name the picture stimuli. From these data, the argument is made that pictorial representations can function as memory codes independently of their corresponding verbal representations.

Support for the additivity assumption may be drawn from a series of experiments by Paivio and Csapo (1972) who found that repeating a picture as a word or a word as a picture in a standard free recall list resulted in increased recall as compared to simply repeating a picture or a word in their original form. Their results further suggested that the imaginal code has a two-fold superiority over the verbal code since the single presentation of a picture doubled the probability of recall as compared to the single presentation of a word. In addition, repeated presentations of a word resulted in recall equivalent to a single presentation of a picture. The results from a number of experiments involving several different types of memory tasks are interpretable within the framework of two-process theory (e.g. Paivio & Csapo, 1969; Paivio, Rogers, & Smythe, 1968; Rowe & Paivio, 1972).

A further memory task which provides information concerning relative visual (imaginal) and verbal code availability over time involves the successive matching of pictures or forms and their word labels with RT as the dependent variable. For example, Tversky (1969), using schematic faces with well-learned nonsense names, varied the frequency of occurrence of the second to-be-matched (test) stimulus as a picture or a word for a given session. Thus, in a single session, the test stimulus might be a picture 79% of the time and a word 21% of the time, in which case a picture would be the "expected" stimulus. For half of the sessions the expected stimulus was a word, for the other half a picture. The interstimulus interval (ISI) was constant at 1 sec. Same-different RTs were significantly faster when the second stimulus was in the expected form regardless of the form of the first (memory) stimulus. For expected stimuli and with both same and different responses, the fastest RTs were obtained with picture-picture comparisons. From the results, Tversky argued that Ss can encode a given stimulus as either a picture or a word depending upon their expectation of the form in which the test stimulus will be presented. In terms of the relative availability of pictorial and verbal codes, the results suggest that Ss can generate a pictorial code for words and a verbal code for pictures and efficiently maintain these generated codes for at least 1 sec. However, the pictorial code for pictures appeared to be easiest to maintain since picture-picture expected comparisons were the most rapid.

Cohen (1969) investigated pattern to pattern and description to pattern comparisons while manipulating ISI and the level of complexity of coloured geometric patterns which varied in the number of relevant stimulus attributes. With high complexity patterns (which are presumably closest to pictures) and same responses, the pattern to pattern matching condition was superior to the description to pattern condition at both the short (1 sec.) and long (5 sec.) delays suggesting that the visual code was more available than the verbal code with these particular stimuli for at least 5 sec.

Additional information on relative code availability as inferred from matching speed is available from an experiment by Wingfield (1968) in which Ss heard the name of a common or rare object followed 5 sec. later by a picture of the same or a different object. Another condition involved picture-picture comparisons. Subjects were required to make same-different judgements. Thus, there were conditions roughly analogous to the word-picture and picture-picture or pattern-pattern conditions of other experiments, although it is important to note that the name was presented aurally rather than visually. It is, however, interesting that picture-picture comparisons were significantly faster than word-picture, reaffirming the contention that the visual code can be efficiently maintained for 5 sec.

To summarize, the experiments using successive matching tasks indicate that the visual code is more available than the corresponding verbal code for delays up to 5 sec. Thus, Tversky (1969), Cohen (1972), and Wingfield (1968) all demonstrated faster matches with pictures and patterns than with word labels or descriptions. Tversky's results also suggest that code availability may be manipulated by varying the frequency of occurrence of the test stimulus as a picture or a word.

An important aspect of the Cohen (1972) and Wingfield (1968) experiments was the fact that Ss were always aware of the format in which the test stimulus would occur. The results of Tversky (1969) showed conclusively that knowledge of the form in which the test stimulus occurs is a critical factor, in that Ss encode the memory stimulus in a manner which will be congruent with what they expect the test stimulus to be. Thus, the results of these RT experiments reflect coding capabilities rather than preferences since Ss were aware of the form in which the to-be-matched stimulus would occur. The initial experiment of the present investigation was concerned with the question of the relative availability of the pictorial and verbal codes for pictures and words in a situation where it is impossible to predict which code will be the most advantageous to maintain. Tversky's results indicate that Ss are able to maintain one code or the other; the present experiments sought to discover whether both verbal and visual codes might be maintained together with equal efficiency over time. Thus, in Experiment I half of the stimuli were words, half pictures. Subjects never knew in advance whether the test stimulus would be a picture or a word and thus there was no advantage in single (verbal or visual) encoding of the memory stimulus. In fact, it would be most advantageous to maintain both a verbal and an imaginal code for the memory stimulus if possible and thus be prepared for any type of comparison. Experiment II investigated the case where Ss were forewarned of the test stimulus format and hence were provided with the opportunity to concentrate on the maintenance of a single code alone. The matching task in both experiments required Ss to decide whether or not two successively presented stimuli had the same name and to indicate their decision by a key press response. The stimuli for a single trial could be easily labelled pictures, words, or one of each. Comparison speed was the dependent variable of primary interest. The rationale for estimating code availabilities centered around the supposition that if the imaginal (pictorial) code for a picture is more readily available than the verbal code for the same picture, at a given delay, then matching speed should be facilitated by the re-presentation of the same picture as opposed to the presentation of the name of that picture. Similarly, if the verbal code for a word is predominant, RTs should be faster if the word is re-presented than if the corresponding picture is presented.

The above logic resembles that used by Posner and his associates (Posner, Boies, Eichelman, & Taylor, 1969; Posner & Keele, 1967) in their investigations. Posner and Keele (1967) compared matches of physically identical letters (e.g. AA) with matches of letter pairs which had the same name only (e.g. Aa) over delays of 0, .5, and 1.5 sec. The underlying assumption was that if physically identical matches are faster than name matches, then a visual code which maintained the physical properties of the memory stimulus is present at the time the match is made. If no difference in a physical versus a name match exists, then visual information has not been preserved. Posner and Keele (1967) found no significant difference between physical and name matches with a 1.5 sec. delay, a finding replicated by Posner et al. (1969) after a 2 sec. delay. These findings led Posner (1970) to suggest that the visual code may be highly susceptible to decay and that it exhibits little evidence of consolidation. These results obtained with letter matches may not apply to pictorial stimuli since the use of letters might encourage verbal rather than visual coding. However, the use of pictures might result in maintenance of the visual (imaginal) code for periods longer than 2 sec. This suggestion was explored in the present investigation by inclusion of delay intervals of .5, 2, and 8 sec. between the to-be-matched items.

EXPERIMENT I

Method

Subjects. The Ss were 12 undergraduate volunteers (6 males) from Memorial University paid $2.00 per session for participation in the experiment. All Ss were right-handed.

Apparatus. The stimuli were projected onto a plain white screen by a Gerbrands Model G1171 projection tachistoscope. The tachistoscope included two projectors and a half-silvered mirror which focused the slide from each projector on identical areas of the screen. The on and off duration of each slide was controlled by the logic unit of the projection tachistoscope. Two keys, 15.24 cm. apart, were used by the Ss for responding. A Hunter Timer, Model 1520, digital display, indicated the RT in msec.

Experimental Design. The experiment involved an 8x3x12 factorial design with 8 different stimulus comparison types, 3 different delay intervals, and 12 Ss. The different comparison types are summarized in Table 1.

Lists. The experimental stimuli consisted of 90, 35 mm. black and white positive slides. One-half of the slides were pictures (line drawings) which were easily-labelled (e.g. tree, church, boy); the other half were the word labels of the pictures. The pictures were chosen on the basis of labelling consistency as indicated by the University of Western Ontario norms (Paivio & Csapo, unpublished). The pictures were labelled with at least 80% accuracy by a normative sample of Western undergraduates. For 28 of the

TABLE 1

Types of Comparisons - Experiment I

Stimulus 1	Stimulus 2	Abbreviation	Correct Answer
	Matches		
Picture	Picture (Same)	PP	Same
Picture	Word (label of Stimulus 1)	PW	Same
Word	Word (Same)	WW	Same
Word	Picture (label of which is Stimulus 1)	WP	Same
	Mismatches		
Picture	Picture (Different)	P$\overline{P}$	Different
Picture	Word (not the label of Stimulus 1)	P$\overline{W}$	Different
Word	Word (Different)	W$\overline{W}$	Different
Word	Picture (label of which is not Stimulus 1)	W$\overline{P}$	Different

word labels of the pictures the Thorndike-Lorge frequency was A or AA. The mean frequency of the remaining 17 labels was 26 per million.

Each of three testing sessions consisted of five blocks of 24 trials for a total of 120 trials per session. The sequences of comparison type, delay interval (.5, 2, or 8 sec.), and the actual stimuli chosen were randomized within blocks with the following restrictions. First, each block contained an equal number of each comparison type and delay interval. This meant that there were also an equal number of same and different responses (12 each) within each block and hence within and across sessions. Secondly, the same interval or type of comparison occurred no more than twice in succession and the same response (same or different) no more than three times in succession. Restrictions on the random selection procedure over all three sessions included the requirement that each item occurred equally often as a picture and a word and that each item was used in each of the eight types of comparisons and three delay intervals. In addition each item occurred as both the first and second stimulus in the comparisons requiring a different response. Finally, at least 10 trials intervened between successive occurrences of the same item as either a word or a picture.

The random sequencing of conditions coupled with the above constraints resulted in each item being used either five or six times in the first two sessions and a minimum of four times in the final session. Only four items occurred four times in Session 3, the rest five or six. The frequency of presentation of an item as a picture or a word within a given session reached maximum inequality when an item was presented four times as a picture (or word) and twice as a word (or picture). This inequality was entirely unpredictable.

Procedure. At the beginning of the first session, each S was provided with pretraining in labelling the pictures to ensure that the labels used were identical to the word slides. Each picture was projected for 5 sec. and the S was required to label it. If the spontaneously produced label corresponded to the experimentally defined 'correct' label, the E said "correct," and proceeded to the next slide. If the produced label did not correspond to the word slide, the S was provided with the 'correct' label which he repeated aloud. This procedure was continued until all slides were correctly labelled. Pretraining occurred in the first session only.

Subjects were tested individually at the same time on three successive days. The first session lasted approximately 50 minutes, the second and third 40 minutes each. Upon completion of the pretraining in the first session, instructions were given concerning the nature of the experimental task. The S was informed that a slide of a picture or a word would be shown followed after a variable interval of time by another slide which could also be a picture or word, the task being to decide whether or not the two slides had the same name or referred to the same thing. Several examples of correct same and different responses were given. If the two stimuli represented identical objects, the S was to press the "same" reaction key, if not he was to press the "different" key. The instructions stressed rapid but accurate responding. Care was taken to ensure that the instructions were clearly understood, and they were repeated at the beginning of the second and third sessions. The first block of 24 trials in each session was considered as practice and excluded from any analysis. Subjects were told that half of the slides would be pictures and half words. For half of the Ss ~~the~~ right-hand key served as the "same" key and for the other half the left key was the "same".

The Ss were seated 22 m. from the screen at a table on which was placed two keys and a digital display which indicated the RT, defined as the time between the onset of the second stimulus for a trial and the key press. The RTs on the display were videotaped since there was insufficient time to record them manually.

The sequence of events for a trial was controlled by the logic unit of the projection tachistoscope. The first slide was shown for 1 sec. and was followed by one of the three delay intervals during which the screen was dark. At the end of this interval the second slide came on activating the RT counter. The S's key press terminated the exposure of the slide and stopped the counter. The inter-trial interval (time between the offset of the second slide and the onset of the first slide of the next trial) was constant at 10 sec. The click of the advancing slide trays warned the S that the first slide of the next trial would be shown in 2 sec. The room was dark except when a slide was exposed on the screen.

Results

Median RTs were calculated for each type of comparison at each of the delay intervals for each S. The means of these medians and the percentage of errors for each condition are presented in Table 2. Incorrect responses were excluded in the calculation of medians. The mean error rate over all Ss and all types of comparisons was 2.3%.

Same Responses. A 2x2x3x12 analysis of variance was performed on the median RTs with stimulus 1 (picture or word), stimulus 2 (picture or word), delay interval (.5, 2, or 8 sec.), and Ss (12) as the respective factors. The analysis of variance summary table for this and all subsequent analyses are given in Appendix A. The significant factors in the analysis were delay interval, $F(2,22)=36.67$, $p<.001$, Stimulus 1 x Stimulus 2, $F(1,11)=9.03$, $p<.05$, and the Stimulus 1 x Interval interaction, $F(2,22)=3.89$, $p<.05$.

The interval main effect is attributable to increasing RTs with increasing delays. The mean RTs were 460, 511, and 544 msec. for the .5, 2, and 8 sec. delays respectively. The Stimulus 1 (S1) x Stimulus 2 (S2) interaction is attributable to the fact that, with a picture as the first stimulus, matches were slightly faster when the second stimulus was a picture rather than a word (501 vs. 515 msec.) whereas the difference was reversed with a word as the first stimulus (527 vs. 478 msec.). Newman-Keuls tests among the four means yielded a significant difference between WP and WW means only.

The result of primary interest involved the S1 x Delay

TABLE 2

Mean RTs in msec. for each of the comparison types at each delay interval in Experiment I. The error percentages are given in parentheses.

Comparison Type	Delay 0.5	2.0	8.0	$\overline{X}$
		Same Responses		
PP	437 (2.5)	507 (1.4)	558 (1.9)	501 (1.9)
WW	439 (0.7)	478 (0.9)	516 (2.5)	478 (1.4)
PW	466 (2.3)	533 (3.0)	545 (3.2)	515 (2.9)
WP	498 (3.2)	525 (3.2)	557 (3.9)	527 (3.5)
$\overline{X}$	460 (2.2)	511 (2.1)	544 (2.9)	505 (2.4)
		Different Responses		
P$\overline{P}$	506 (3.7)	564 (0.7)	575 (1.4)	548 (1.9)
W$\overline{W}$	524 (0.7)	547 (0.9)	565 (2.5)	545 (1.4)
P$\overline{W}$	510 (2.3)	565 (3.0)	548 (3.2)	541 (2.9)
W$\overline{P}$	524 (3.2)	550 (3.2)	595 (3.9)	556 (3.5)
$\overline{X}$	516 (2.7)	557 (1.6)	571 (2.3)	548 (2.2)

Interval interaction. The source of this interaction is apparent from Figure 1 which presents the mean RTs over the three delays as a function of whether the initial stimulus was a picture or a word. Matching time for pairs of stimuli which involved an initial presentation of a picture (i.e. the PP and PW matches) increased more rapidly between the .5 and 2 sec. delays than did RTs for matches involving an initial presentation of a word (the WW and WP matches), resulting in the crossover depicted in Figure 1. The increase in RT from .5 to 2 sec. was significant for both picture-first (P1) and word-first (W1) matches. Numerically faster RTs occurred with P1 than W1 matches at the .5 sec. delay while W1 matches tended to be faster at the 2 and 8 sec. intervals. However, the differences were not significant at any of the delays (Newman-Keuls test).

<u>Different Responses</u>. Different responses will be discussed as an adjunct to the same response results. Less emphasis will be placed on their interpretation due to the fact that mismatches probably involve different and more complex processes than matches (cf. Bindra, William, & Wise, 1965; Kreuger, 1973; Seymour, 1969). A 2x2x3x12 analysis of variance was executed on the median RTs with S1, S2, delay, and Ss as the factors. The significant effects were interval, $\underline{F}$ (2,22)=26.55, $\underline{p}$<.01 and the S1 x Interval interaction, $\underline{F}$ (2,22)=3.89, $\underline{p}$<.05. The interval main effect was again due to increasing RTs with longer delays (mean RTs = 516, 555, and 571 msec. for the .5, 2, and 8 sec. delays respectively).

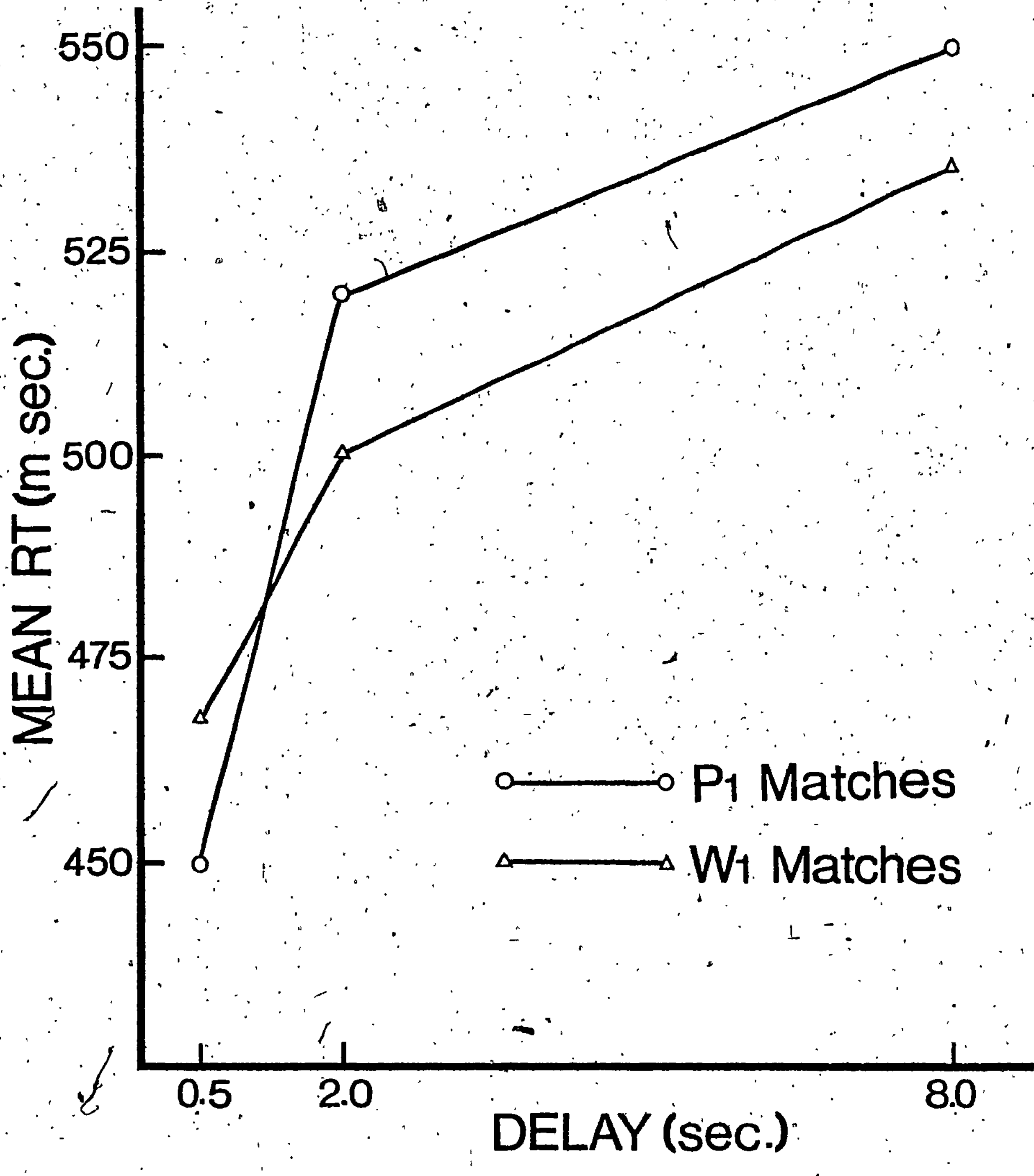

FIG. 1. Mean RTs for Experiment I same matches involving a picture as the first stimulus (P1 matches) and for matches involving a word as the first stimulus (W1 matches) plotted as a function of the three delay intervals.

The source of the S1 x Interval interaction can be derived from Figure 2 which shows mean RTs plotted over delays as a function of the first stimulus being a picture or a word. The interaction has the same form as that noted with same responses for the .5 and 2 sec. delays in that mismatches involving an initial presentation of a picture were numerically faster at .5 sec. while W1 mismatches tended to be faster at the 2 sec. delay. Newman-Keuls comparisons indicated that the increase from .5 to 2 sec. was significant for both P1 and W1 mismatches. However, the two types of mismatches did not differ significantly from each other at either delay. There was an additional reversal at the 8 sec. delay with P1 mismatches resulting in more rapid RTs than W1 mismatches at this interval although again the difference between the two types of mismatches was not significant according to the Newman-Keuls test.

Discussion

The S1 x S2 interaction with same responses reflected the fact that PP matches were not significantly different from PW, while WW matches were significantly faster than WP. Thus, it seems that both the visual and verbal code for a picture are about equally available, while the verbal code is more readily available than the visual code with words. However, the results are largely uninformative regarding the relative availability of visual and verbal memory codes as a function of delay. The significant S1 x Interval interaction, which emerged from both the same and different responses,

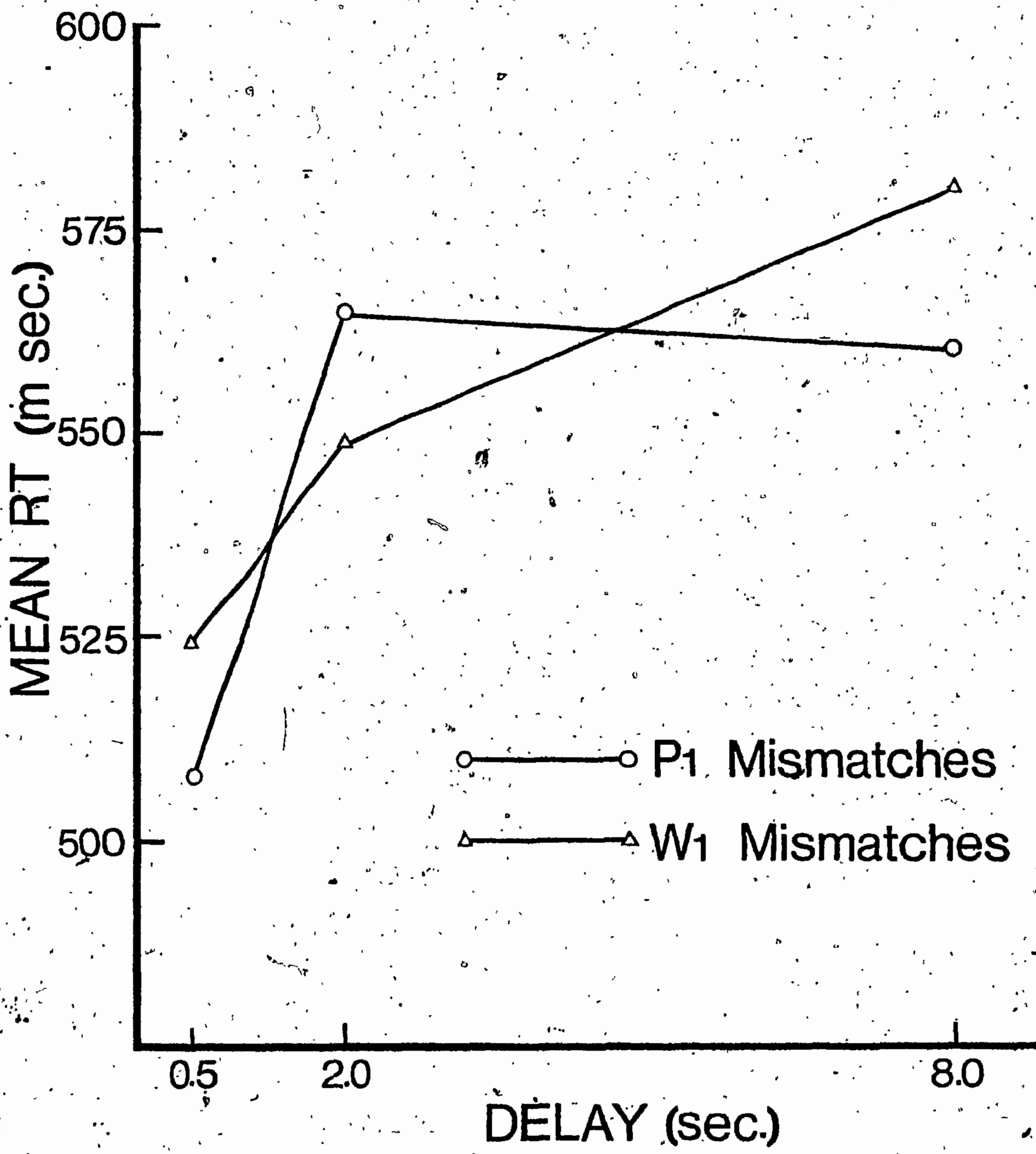

FIG. 2. Mean RTs for P1 and W1 matches for Experiment I different responses as a function of the three delay intervals.

took a form suggesting that availability of the representation which mediated matches and mismatches for a picture as the first stimulus decreased more rapidly than the corresponding representation for a word, at least between .5 and 2 sec. delay. On the assumption that the dominant form of representation is visual for a picture and verbal for a word, a tentative interpretation would assign a more rapidly decreasing availability to the visual than to the verbal code (cf. Posner, et al., 1969). However, it is difficult to draw any firm conclusions on the issue in the absence of significant differences between the various match types at a given delay.

Experiment II introduced two procedural changes designed to provide a clearer indication of how the two codes change in relative availability in the first few sec. following stimulus presentation. In Experiment I, Ss were pretrained in labelling the pictures to ensure that labels used by the Ss corresponded to the word slides. This procedure may have primed the use of the verbal code, i.e., there may have been a carry-over to the actual experimental sessions in that Ss concentrated on labelling the pictures as they did in pretraining. This labelling would favor the verbal memory representation and might act to reduce any advantage enjoyed by the visual code, especially since Ss were not pretrained in imaging to the words. The second experiment attempted to correct for this possible deficit by including pretraining in imaging.

In addition, the second experiment used a manipulation similar to Posner et al. (1969, Exp. III), who attempted to encourage maintenance of the visual code in a successive letter matching task through the use of "pure" lists where the first and second letters were always uppercase and thus visual information was a reliable cue. Performance under "pure" list conditions was compared with performance under "mixed" list conditions in which the first letter was once again uppercase but the second letter could be either upper or lower case, thus eliminating visual information as a reliable cue. This technique resulted in more efficient maintenance of physical (visual) information in pure lists over the delays (0, .5, or 1 sec.) examined.

Thus with sufficient encouragement, Ss may be able to adequately maintain a visual code for several seconds when they are required to match visually presented letters (cf. Kroll et al., 1970). The second experiment attempted to replicate this type of result with pictures and words by informing Ss of the format (picture or word) of the second stimulus, thus providing them with ample opportunity to capitalize on the maintenance of visual or verbal memory representations.

EXPERIMENT II

Method

Subjects. The Ss were nine undergraduates (4 males) paid $2.00 per session and selected from the same pool as Experiment I. All Ss were right-handed.

Experimental Design. The experiment involved a 2x2x2x3x9 factorial design with type of block (mixed or pure), stimulus 1 (picture or word), stimulus 2 (picture or word), delay interval (.5, 2, or 8 sec.), and Ss as factors. Separate analyses were carried out for same and different responses. The different comparison types for the pure blocks are summarized in Table 3.

Procedure. The Ss participated in four different sessions. The initial session lasted approximately 30 min.; the other sessions 45 min. The initial session involved pre-training in labelling pictures in a manner similar to Experiment I. Each of the 45 pictures were exposed for 5 sec. each, and Ss were required to label each picture in order to ensure correspondence of their labels with the word slides. After the slides were viewed and labelled once, the procedure was repeated. No 'incorrect' labels were given the second time through.

Subjects were then shown each word and asked to try to visualize the corresponding picture as shown in the series of slides previously viewed. The Ss verbally indicated their success in imaging the pictures. Inability to image the corresponding picture for a given word resulted in the

TABLE 3

Types of Comparisons - Experiment II*

Stimulus 1	Stimulus 2	Correct Answer
	Pure Word Blocks	
Word	Word (Same)	Same
Picture	Word (label of Stimulus 1)	Same
Word	Word (Different)	Different
Picture	Word (not the label of Stimulus 1)	Different
	Pure Picture Blocks	
Picture	Picture (Same)	Same
Word	Picture (label of which is Stimulus 1)	Same
Picture	Picture (Different)	Different
Word	Picture (label of which is not Stimulus 1)	Different

*Comparisons in mixed blocks were of the same type as in Experiment I (see Table 1).

immediate re-exposure of the appropriate picture slide. As with the picture slides and labelling, the whole procedure was repeated with the word slides and imaging. Thus, the Ss saw each word and picture slide twice for 5 sec. each and were required to label the pictures and image to the words.

Subjects were given task instructions similar to Experiment I, but including information concerning the nature of the three different types of blocks. In the pretraining session, Ss completed eight practice trials for each of the three block types. Thus, each S was given a total of 24 practice comparisons, 8 comparisons (4 same-4 different) with a pure word block, 8 with a pure picture block, and 8 with a mixed block. The stimuli used in the practice trials never occurred in the same pairings in the actual experimental sessions. The purpose of the practice trials was to familiarize the Ss with the apparatus, the three different types of blocks, and the experimental procedure.

The actual experimental sessions consisted of a total of 120 comparison trials each. For 40 consecutive trials the second slide was always a picture (pure picture block), for another 40 the second slide was invariably a word (pure word block), and for a third block of 40 trials the second slide could be either a picture or a word (mixed block). Subjects were fully informed of the type of block with which they were dealing. The order of presentation of the blocks was counterbalanced over sessions and Ss. The first eight trials of each block were considered to be practice and were excluded from the analyses. Thus, with each block, there were 32 trials per session for scoring purposes with 16 same and different responses per block. Within the pure blocks, there were 8 of each of the 4 possible comparison types per session, while with mixed blocks there were 4 of each of the 8 possible comparison types. Within all blocks there were 10 instances of one of the delays and 11 instances of the other two for each session. Delays were balanced so that over the three sessions there was equal representation of each delay with each comparison type in each type of block.

In Experiment II, Ss were informed of incorrect responses by the onset of a "WRONG" light. The trial formation procedure was identical to Experiment I with mixed blocks, but modified for pure blocks such that although there were not an equal number of pictures and words in a pure picture or pure word block alone, combined across the two blocks there were an equal number of each. Other previous restrictions on the trial formation procedure were enforced. The apparatus and all other procedural details were identical to Experiment I.

Results

Median RTs were computed for each type of comparison at each delay for each S. The medians were calculated separately for each block type. The mean of these medians and the percentage errors are presented in Table 4. The incorrect responses were excluded from the calculations. The mean error rate over all Ss and all types of comparisons was 4%.

Same Responses. A 2x2x2x3x9 analysis of variance was executed on the medians, the respective factors being type of block (mixed or pure), S1, S2, delay interval, and Ss. Pure block responses were faster than mixed block responses, $F\ (1,8)=53.42$, $p<.001$, with RTs of 477 vs. 537 msec. respectively. The S1 main effect, $F\ (1,8)=19.39$, $p<.01$, reflected faster matches overall when a picture rather than a word was the initial stimulus (mean RTs=498 vs. 516 msec.) while the main effect of S2, $F\ (1,8)=13.55$, $p<.01$, indicated that matches were faster with a word (491 msec.) than with a picture (523 msec.) as the second stimulus. The effect of delay interval, $F\ (2,16)=16.90$, $p<.001$, mirrored the previous finding of increased RTs with longer delays (see Table 4).

The significant interaction of S1 x Delay Interval, $F\ (2,16)=5.52$, $p<.05$, as well as the S1 and S2 main effects were qualified by the triple interaction of S1 x S2 x Delay Interval, $F\ (2,16)=4.42$, $p<.05$. This interaction is depicted in Figure 3 which plots P1 and W1 matches over the three delays as a function of whether the test stimulus was a word

TABLE 4

Mean RTs in msec. for each of the Comparison Types at each Delay for each Type of Block in Experiment II. The error percentages are given in parentheses.

Comparison Type	Same Responses 0.5	2.0	8.0	$\overline{X}$	Different Responses 0.5	2.0	8.0	$\overline{X}$
				Mixed Blocks				
PP	454 (0.0)	576 (6.0)	587 (0.0)	539 (2.0)	563 (0.0)	567 (3.0)	611 (3.0)	580 (2.0)
WW	494 (3.0)	554 (3.0)	556 (3.0)	535 (3.0)	550 (0.0)	597 (6.0)	558 (0.0)	568 (2.0)
PW	463 (3.0)	527 (9.0)	537 (3.0)	509 (5.0)	543 (9.0)	596 (6.0)	589 (0.0)	576 (5.0)
WP	552 (13.0)	566 (6.0)	577 (0.0)	565 (6.0)	561 (6.0)	592 (6.0)	569 (6.0)	574 (6.0)
$\overline{X}$	491 (4.0)	556 (6.0)	564 (1.0)	537 (4.0)	554 (4.0)	588 (5.0)	582 (2.0)	575 (4.0)
				Pure Blocks				
PP	401 (0.0)	522 (6.0)	538 (4.0)	487 (3.0)	518 (4.0)	570 (8.0)	546 (4.0)	545 (6.0)
WW	412 (0.0)	465 (3.0)	507 (4.0)	461 (2.0)	511 (6.0)	531 (3.0)	514 (4.0)	519 (4.0)
PW	428 (1.0)	451 (8.0)	493 (10.0)	458 (7.0)	507 (4.0)	549 (4.0)	536 (3.0)	531 (4.0)
WP	456 (7.0)	494 (3.0)	557 (7.0)	502 (6.0)	534 (1.0)	562 (6.0)	572 (3.0)	556 (3.0)
$\overline{X}$	424 (2.0)	483 (5.0)	524 (6.0)	477 (4.0)	518 (4.0)	553 (5.0)	542 (4.0)	538 (4.0)

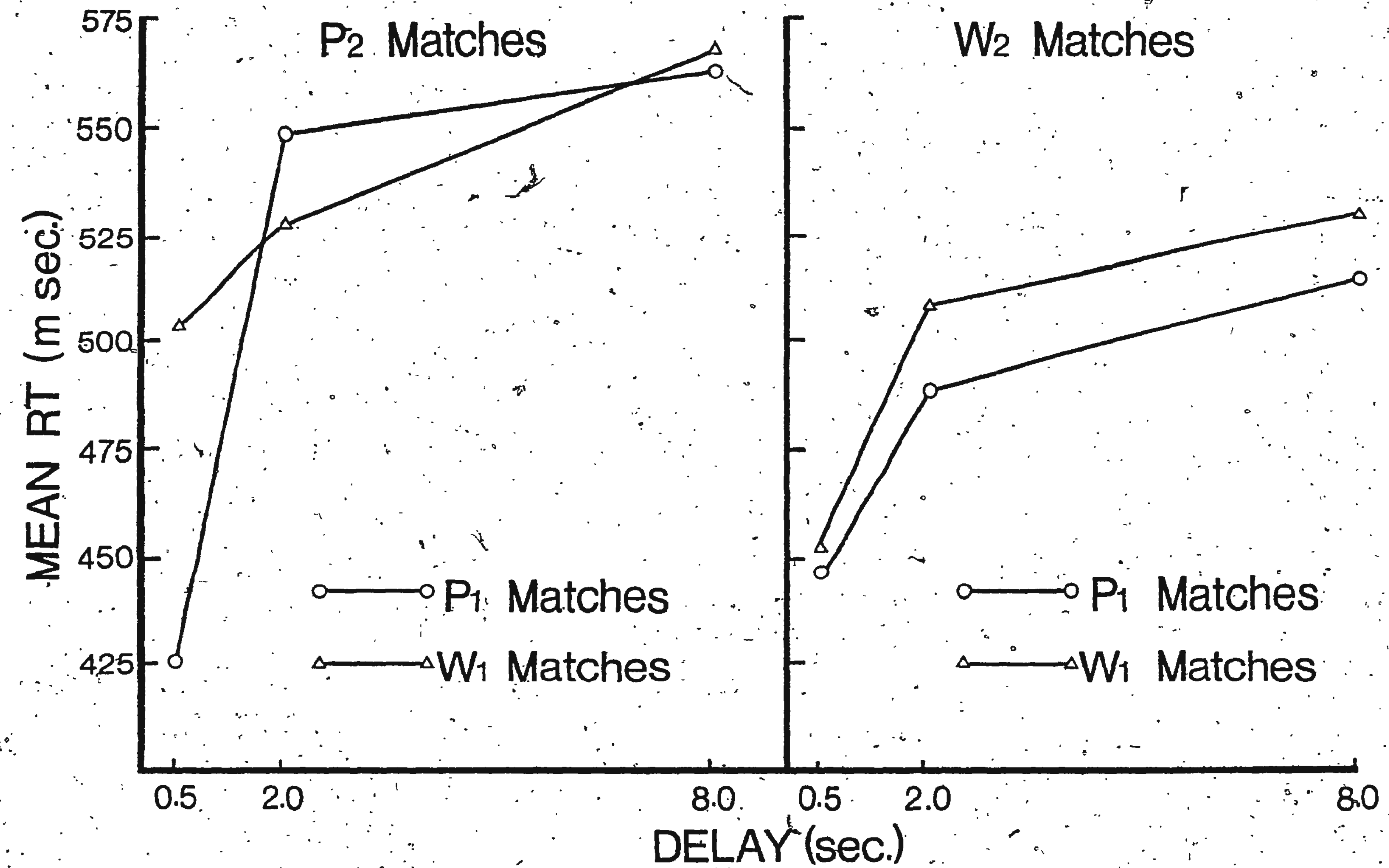

FIG. 3. Mean RTs for P1 and W1 matches for Experiment II same responses plotted as a function of test stimulus (picture or word; P2 or W2) and of the three delay intervals.

or a picture. The interaction is due to the fact that with a word as the second stimulus, P1 and W1 matches increased at roughly the same rate over the three delays, but with a picture as the second stimulus, P1 matches increased much more rapidly than W1 matches from the .5 to 2 sec. interval. Two separate analyses of variance on P2 and W2 matches with blocks, S1, delay, and Ss as factors yielded a significant S1 x Delay Interval interaction for the P2 analysis only, $F(2,16)=7.49$, $p<.01$, suggesting that differential rates of increase were confined to these matches. Multiple comparisons by the Newman-Keuls test indicated that while PP matches at the 2 sec. delay were significantly longer than PP matches at the .5 sec. delay, the same comparison was not significant for WP matches. With the 8 sec. delay both PP and WP matches resulted in significantly longer RTs than corresponding matches at .5 or 2 sec. In contrast, with a word as the second stimulus, the curves for PW and WW matches were similar over all delays, as suggested by the lack of a S1 x Interval interaction. Thus PW matches at .5 sec. were significantly faster than PW matches at 2 and 8 sec., which did not differ from each other (Newman-Keuls test). An identical pattern existed for WW comparisons over the three delays.

The S1 x Delay Interval interaction noted above suggests that the memory representation of a picture as the first stimulus disappears more rapidly than the corresponding representation of a word. The main difference between this finding and the analogous result of Experiment I is that the interaction was here restricted to the case where a picture served as the second stimulus. The reason for this is not entirely clear. It does not seem attributable to the use of pure blocks trials, since there were no interactions involving type of block in the initial overall analysis. Thus the results hold for both pure and mixed blocks. It might be noted in passing that the interaction shown in the left panel of Figure 3 seems entirely due to the longer time required for a WP than a PP match at the .5 sec. delay.

The effects of the different pretraining procedure can be seen by comparing the mixed block results alone with those of Experiment I. The main differences between the two sets of data are that PW matches tend to be more rapid in the second experiment, whereas WP matches were slowest of all in both experiments. Thus pretraining in labelling the pictures seems to have resulted in numerically faster RTs for PW over other types of matches, whereas pretraining in imaging to the words had little effect. In general, the addition of these changes to the procedures of Experiment I did little to clarify the nature of the result of that experiment. Specifically, comparisons among the different match types were still largely inconclusive concerning relative availabilities. Apparently the RT method as used in the two experiments does not provide a sensitive test of such questions.

Different Responses. A 2x2x2x3x9 analysis of variance with block type (mixed or pure), S1, S2, delay, and Ss as factors was carried out on the median RTs. The only significant effects were type of block and delay interval. Thus, longer RTs were obtained in mixed as compared to pure blocks, F (1,8)=32.41, p<.001 and RTs increased with longer delays, F (2,16)=4.50, p<.05. Different responses were, in general, slower than same responses for both mixed and pure blocks.

GENERAL DISCUSSION

Although the results of both experiments are for the most part inconclusive, they do reveal certain trends concerning the relative availability of visual and verbal codes for pictures and words. Discussion of relative code availabilities is predicted on the assumption that if one code is more available than another at a given delay, then comparison time will be more rapid if the second stimulus is in the form of the more available code. In Experiment I, an S1 x S2 interaction resulted from the fact that overall RT for PP versus PW matches did not differ, whereas WW matches were significantly faster than WP. This suggested equal availability of both codes for pictures but greater availability of the verbal code for words. The same pattern of results failed to emerge in the second experiment, where S1 and S2 were significant main effects, but did not interact. Nonetheless, considering each of the 12 PP-PW and WW-WP comparisons separately (Table 4), we see that in 11 cases WW comparisons were faster than WP ($p<.01$ by a sign test) while PP exceeded PW in only 3 cases ($p=.15$ by a sign test). There is, therefore, some justification for drawing a similar conclusion as arrived at for Experiment I - namely, that the verbal code is more readily available for words while both are about equally available in the case of pictures.

If we apply this type of analysis to PW versus WP comparisons across the two experiments, we find that PW is faster than WP in 15 of the 18 comparisons ($p<.01$). Even in pure blocks all six PW comparisons were faster than WP. Thus the availability of the alternate code for a picture appears to be higher than the alternate code for a word. These results are convergent with labelling latency data discussed by Paivio (1971) and offer added support for this particular aspect of dual coding theory.

These tentative conclusions regarding relative code availabilities for pictures versus words must also be viewed in the light of the apparent influence of the delay factor. Even though individual comparisons between different match types at given delays were, with one exception, nonsignificant, the occurrence of a significant S1 x Delay interaction with both same and different responses in Experiment I, and with same responses when S2 was a picture in Experiment II, deserves some comment. All three interactions were contributed to by a more rapid increase in the speed of comparisons which involved pictures rather than words as first stimuli across delays, especially between .5 and 2 sec. This suggests that visual memory representations as primed by the present experimental situation decreased in availability faster than verbal representations, as has been reported by other investigators (Posner, 1970; Posner, et al., 1969; Posner & Keele, 1967).

Furthermore, there is some indication from the form of the interactions that the visual code for pictures is used as the basis for comparisons with the second stimulus after .5 sec. and that the verbal code is used at longer delays.

Such a conclusion seems reasonable in the light of recent evidence on differences between visual and verbal rehearsal processes, which suggests that there may be no counterpart to the well-known auditory-verbal rehearsal loop in visual short-term memory (Shaffer & Shiffrin, 1972; Shiffrin, 1973). While others have presented evidence to the contrary (see Dale, 1973), there is reason to suppose that visual rehearsal is perhaps more difficult or at least less prevalent in the maintenance of information over relatively short time intervals. This could explain why Ss in the present experiments showed a tendency to rely on the verbal code for pictures as the basis for comparison over delays of 2 seconds or more. It could also provide a reason why the verbal code for words seems to have been preferred, even in pure blocks when it was known that the second stimulus would always be a picture.

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APPENDIX A - TABLE 1

Summary Table for Analysis of Variance on Median RTs for Same Responses - Experiment I

Source	df	MS	F
Stimulus 1 (S1)	1	997.51	1.09
S1 x Subjects (Subjs.)	11	917.03	
Stimulus 2 (S2)	1	11218.30	3.51
S2 x Subjs.	11	3195.60	
Delay Interval (I)	2	86727.40	36.67***
I x Subjs.	22	2364.83	
S1 x S2	1	35815.50	9.03*
S1 x S2 x Subjs.	11	3965.27	
S1 x I	2	4442.78	3.89*
S1 x I x Subjs.	22	1142.69	
S2 x I	2	898.59	0.80
S2 x I x Subjs.	22	1130.01	
S1 x S2 x I	2	3062.44	2.35
S1 x S2 x I x Subjs.	22	1301.68	
Subjs.	11	38568.10	

***$p < .001$
*$p < .05$

APPENDIX A - TABLE 2

Summary Table for Analysis of Variance on Median RTs for Different Responses - Experiment I

Source	df	MS	F
Stimulus 1 (S1)	1	1332.25	0.96
S1 x Subjects (Subjs.)	11	1381.45	
Stimulus 2 (S2)	1	2898.03	2.18
S2 x Subjs.	11	1332.38	
Delay Interval (I)	2	38877.70	26.55***
I x Subjs.	22	1464.16	
S1 x S2	1	144.00	0.06
S1 x S2 x Subjs.	11	2334.51	
S1 x I	2	4471.91	3.89*
S1 x I x Subjs.	22	1149.53	
S2 x I	2	3366.16	2.65
S2 x I x Subjs.	22	1268.56	
S1 x S2 x I	2	0.09	0.00
S1 x S2 x I x Subjs.	22	1335.17	
Subjs.	11	37065.00	

***$p < .001$
*$p < .05$

APPENDIX A — TABLE 3

Summary Table for Analysis of Variance on Median RTs for Same Responses - Experiment II

Source	df	MS	F
Blocks (B)	1	193441.00	53.42***
B x Subjects (Subjs.)	8	3620.95	
Stimulus 1 (S1)	1	17031.10	19.39**
S1 x Subjs.	8	878.52	
Stimulus 2 (S2)	1	57558.60	13.55**
S2 x Subjs.	8	4247.73	
Delay Interval (I)	2	143327.00	16.90***
I x Subjs.	16	8480.86	
B x S1	1	3816.94	1.76
B x S1 x Subjs.	8	2172.06	
B x S2	1	362.94	0.25
B x S2 x Subjs.	8	1464.20	
B x I	2	5398.44	2.82
B x I x Subjs.	16	1911.94	
S1 x S2	1	504.19	0.53
S1 x S2 x Subjs.	8	950.26	
S1 x I	2	8366.94	5.52*
S1 x I x Subjs.	16	1516.90	
S2 x I	2	3565.06	2.00
S2 x I x Subjs.	16	1780.64	
B x S1 x S2	1	416.63	0.15
B x S1 x S2 x Subjs.	8	2823.96	
B x S1 x I	2	3664.34	2.69
B x S1 x I x Subjs.	16	1362.75	
B x S2 x I	2	1488.22	0.48
B x S2 x I x Subjs.	16	3130.81	
S1 x S2 x I	2	14094.90	4.42*
S1 x S2 x I x Subjs.	16	3188.06	
B x S1 x S2 x I	2	446.91	0.28
B x S1 x S2 x I x Subjs.	16	1569.94	
Subjs.	8	58635.60	

***$p < .001$
**$p < .01$
*$p < .05$

APPENDIX A - TABLE 4

Summary Table for Analysis of Variance on Median RTs for Picture-Second (P2) Same Responses - Experiment II

Source	df	MS	F
Blocks (B)	1	88522.80	28.96***
B x Subjects (Subjs.)	8	3056.87	
Stimulus (Sl)	1	11697.90	52.16***
Sl x Subjs.	8	224.27	
Delay Interval (I)	2	95447.60	14.53***
I x Subjs.	16	6570.56	
B x Sl	1	855.75	0.23
B x Sl x Subjs.	8	3688.89	
B x I	2	3740.66	1.10
B x I x Subjs.	16	3386.79	
Sl x I	2	22090.70	7.49**
Sl x I x Subjs.	16	2947.43	
B x Sl x I	2	2937.03	1.70
B x Sl x I x Subjs.	16	1725.70	
Subjs.	8	38701.40	

***$p < .001$

**$p < .01$

APPENDIX A - TABLE 5

Summary Table for Analysis of Variance on Median RTs for Word-Second (W2) Same Responses - Experiment II

Source	df	MS	F
Blocks (B)	1	105281.00	51.90***
B x Subjects (Subjs.)	8	2028.56	
Stimulus 1 (S1)	1	5837.37	3.64
S1 x Subjs.	8	1604.73	
Delay Interval (I)	2	51444.80	13.94***
I x Subjs.	16	3691.08	
B x S1	1	3377.94	2.58
B x S1 x Subjs.	8	1306.77	
B x I	2	3146.03	1.90
B x I x Subjs.	16	1655.70	
S1 x I	2	371.31	0.21
S1 x I x Subjs.	16	1757.31	
B x S1 x I	2	1174.53	0.97
B x S1 x I x Subjs.	16	1209.50	
Subjs.	8	24182.00	

***$p < .001$

APPENDIX A - TABLE 6

Summary Table for Analysis of Variance on Median RTs for Different Responses - Experiment II

Source	df	MS	F
Blocks (B)	1	74816.50	32.41***
B x Subjects (Subjs.)	8	2308.63	
Stimulus 1 (S1)	1	778.24	0.50
S1 x Subjs.	8	1558.48	
Stimulus 2 (S2)	1	12451.80	2.58
S2 x Subjs.	8	4834.22	
Delay Interval (I)	2	23472.60	4.50*
I x Subjs.	16	5214.13	
B x S1	1	633.94	0.29
B x S1 x Subjs.	8	2168.48	
B x S2	1	5766.06	3.35
B x S2 x Subjs.	8	1721.53	
B x I	2	107.47	0.07
B x I x Subjs.	16	1439.94	
S1 x S2	1	2103.13	1.53
S1 x S2 x Subjs.	8	1376.32	
S1 x I	2	2700.71	1.43
S1 x I x Subjs.	16	1892.58	
S2 x I	2	1888.67	1.45
S2 x I x Subjs.	16	1296.16	
B x S1 x S2	1	1525.25	0.51
B x S1 x S2 x Subjs.	8	2971.98	
B x S1 x I	2	4644.28	2.21
B x S1 x I x Subjs.	16	2105.84	
B x S2 x I	2	1923.22	0.61
B x S2 x I x Subjs.	16	3164.06	
S1 x S2 x I	2	355.25	0.38
S1 x S2 x I x Subjs.	16	940.69	
B x S1 x S2 x I	2	1486.16	0.83
B x S1 x S2 x I x Subjs.	16	1783.31	
Subjs.	8	88749.60	

$^{***}p<.001$

$^{*}p<.01$